INDIANA BRIDGE INSPECTION MANUAL

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List of Acronyms

Part 1: Administration

Chapter 1
NBIS  National Bridge Inspection Standards

Chapter 2
ASNT  American Society for Nondestructive Testing
FHWA  Federal Highway Administration
INDOT  Indiana Department of Transportation
NBI  National Bridge Inventory
NICET  National Institute for Certification in Engineering Technologies
NDT  Nondestructive Testing
OSHA  Occupational Safety and Health Administration
U.S.  United States

Chapter 3
PDT  Partially-Destructive Testing
SI&A  Structure Inventory and Appraisal

Chapter 4
MUTCD  Manual on Uniform Traffic Control Devices
USCG  United States Coast Guard

Chapter 7
BRAGI  Bridge Reporting for Appraisal and Greater Inventory
CEMP  Comprehensive Emergency Management Plan
Part 2: QA/QC

Chapter 1
QA     Quality Assurance
QAO    Quality Assurance Officer
QC     Quality Control
QCO    Quality Control Officer
QCODR  Quality Control Officer for Data Review
QCORR  Quality Control Officer for Report Review

Chapter 2
PDF    Portable Document Format

Part 3: Load Rating

Chapter 1
AASHTO American Association of State Highway and Transportation Officials

Chapter 4
AS     Allowable Stress
CFR    Code of Federal Regulations
LF     Load Factor
LRFR   Load and Resistance Factor Rating

Chapter 5
EI     Engineering Intern
PE     Professional Engineer

Chapter 7
ASD    Allowable Stress Design
LFD    Load Factor Design
LRFD   Load and Resistance Factor Design
NHS    National Highway System
Chapter 10
INMUTCD Indiana Manual of Uniform Traffic Control Devices

Chapter 11
IDOR Indiana Department of Revenue

Part 4: Bridge Inspection

Chapter 1
BIRM Bridge Inspector's Reference Manual

Chapter 3
ADT Average Daily Traffic

Chapter 4
PTFE Polytetrafluoroethylene

Chapter 7
HEC Hydraulic Engineering Center
STRAHNET Strategic Highway Network

Chapter 10
AREMA American Railway Engineering and Maintenance-of-Way Association

Part 5: Movable Bridges

Chapter 3
AD Active Differential

Chapter 4
AC Alternating Current
DC Direct Current
GFCI Ground Fault Circuit Interrupter
I/O Input/Output
NEC National Electric Code
NEMA National Electrical Manufacturers Association
### Acronyms

**Part 6: NDT & PDT Testing**

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<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>PLC</td>
<td>Programmable Logic Controller</td>
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<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
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<tr>
<td>RGS</td>
<td>Rigid Galvanized Steel</td>
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**Part 6: NDT and PDT Testing**

**Chapter 1**

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<tbody>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
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<td>AWS</td>
<td>American Welding Society</td>
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<td>HWDC</td>
<td>Half-Wave Direct Current</td>
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**Chapter 19**

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<td>CSP</td>
<td>Continuous Seismic-Reflection Profiling</td>
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CHAPTER 1 INTRODUCTION

There are approximately 18,600 fixed roadway bridges and three movable roadway bridges carrying traffic in the state of Indiana, all with the potential to cause damage and injuries if they fail. Bridge inspectors fill the vital role of assessing the condition of these structures to ensure public safety.

Congress created the National Bridge Inspection Standards (NBIS) in 1971 after the collapse of the Silver Bridge in Point Pleasant, West Virginia over the Ohio River in 1967. The NBIS are federal guidelines pertaining to bridge inspection frequency, inspector qualifications, report formats, inspection and rating procedures, and the maintenance of a state bridge inventory. These standards were created in an effort to make bridge inspections thorough and consistent nationwide. The NBIS are minimum standards, and states may elaborate on these guidelines to clarify them or to make them more stringent. The NBIS led to the National Bridge Inspection Program which mandated that all states maintain an up-to-date inventory of all bridges over 20 feet in span and inspect them at regular intervals using the NBIS criteria. Any bridge not inspected and inventoried in compliance with NBIS may be ineligible for federal bridge replacement funding.
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It is important for the safety of the driving public that qualified personnel inspect Indiana’s bridges and small structures. The Bridge Inspector is required to render judgment on a daily basis pertaining to the safety and integrity of the structures inspected.

The individuals involved in the State Bridge Inspection Program have critical input on many issues, including the allocation of scarce rehabilitation funds and the decision to close major bridges. It is important that the Inspector is highly trained and proficient; he/she must understand the mechanics, behavior trends, and economics of a wide range of bridge types.

Indiana’s State Bridge Inspection Program operates under the directives of the Federal Highway Administration (FHWA) and the Indiana Department of Transportation (INDOT). The mission of the program is as noted below:

1. Ensure public safety.
2. Provide for the efficient use of resources in maintaining the serviceability of Indiana’s bridges and small structures.
3. Comply with all federal and state laws, rules, and policies.
4. The State is given the responsibility to accurately inventory and inspect all highway bridges on public roads. The State shall inspect the bridges on its highways and delegates this responsibility to the counties to accurately inventory and inspect their bridges on public roads.
5. The failure of a county to perform these responsibilities may cause a loss of funding. The State shall have the authority to take the appropriate action to assure bridge safety. These assurances will include that the bridge has been inspected at the proper frequency, that if necessary the bridge is posted, and that the posting is done in a timely manner. The State shall have the authority to close unsafe bridges.
SECTION 2.2 INSPECTION PROGRAM

The State Bridge Inspection Program is federally mandated and has been in effect since 1971. The program policies are based on the National Bridge Inspection Standards (NBIS). Bridge inspection reports and records are kept by INDOT in its Central Database and the required bridge data is forwarded to the FHWA on an annual basis.

NBIS define a bridge as a structure, including supports, erected over a depression or an obstruction, such as water, highway, or railway. It has a track or passage way for carrying traffic or other moving loads, and has an opening measured along the center of the roadway of more than twenty feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes. It may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening.

This manual will address all bridges meeting this definition, as well as small structures spanning between 4 and 20 feet. Refer to Figures 1:2-1 and 1:2-2 for the defining bridge measurements.
Figure 1:2-1: Bridge and Small Structure Measurements

* IF GREATER THAN 20 FEET
NBIS *112 = Y
Figure 1:2-2: Additional Bridge and Small Structure Measurements
SECTION 2.3 ORGANIZATION

The State Program Manager (SPM) is charged with administering the State Bridge Inspection Program. The INDOT Bridge Inspection Engineers (BIE), State/Toll Road/County/Local Bridge Inspection Consultants report to the State Program Manager. Inspection Team Leaders report to the appropriate INDOT Bridge Inspection Engineer, the Toll Road Operating Engineer, or Bridge Inspection Consultant. Inspection Team Members report to their Inspection Team Leaders.

The organization of the State Bridge Inspection Program is shown in Figure 1:2-3 and described in detail later in this section. The review and quality assurance/quality control procedure is discussed in Part 2, Quality Assurance/Quality Control.

Figure 1:2-3: State Bridge Inspection Program Organization
SECTION 2.4 QUALIFICATIONS AND RESPONSIBILITIES

Subsection 2.4.1 State Program Manager (SPM)

The SPM is responsible for setting all bridge inspection policies and procedures, and for all bridge inspections and related reporting in the state.

The SPM must meet the following minimum qualifications:

1. Capable of overseeing the INDOT Bridge Inspection Engineers (BIE), all Bridge Inspection Consultants (BIC)
2. Sound background in bridge inspection
3. Specialized knowledge and skills in bridge design, construction, soils, construction materials, and emergency repair techniques
4. Successful completion of the Safety Inspection of In-Service Bridges (FHWA-NHI-130055) course
5. Successful completion of the Fracture Critical Inspection Techniques for Steel Bridges (FHWA-NHI-130078) course
6. Registered Professional Engineer (PE) in the state of Indiana

As a part of the responsibilities of this position, the SPM shall:

- Oversee the INDOT BIE, all Inspection Consultants
- Manage the statewide bridge inspection and inventory programs.
- Ensure all bridges in the state are inspected at a frequency and by a method consistent with the NBIS and state law.
- Ensure that bridge inspection data is uploaded to the Central Database within mandated time frames.
- Ensure load ratings are completed in accordance with all federal requirements.
- Oversee quality assurance and quality control of all bridge inspection programs.
- Coordinate with federal, state, toll road, county, and local governmental agencies.
- Formulate and monitor in-depth inspection programs for bridges with fracture critical members, underwater components, or unique or special features requiring additional attention during inspection to assure the safety of such structures.
- Conduct annual inspections of state border bridges in company with respective states’ personnel and district offices to determine required actions and lead the effort to accomplish Indiana’s portion of any required actions.
- Notify FHWA of all critical findings.
Manage the state bridge posting and restriction program.

Ensure load-posted bridges receive interim inspections as required by federal and state laws, rules, and policy.

Ensure proper signage is in place for bridges that require load posting or other restrictions.

Ensure a system is in place that will notify INDOT BIE and BIC of required inspections and their due dates.

Ensure a system is in place to upload all approved inspection data to the Central Database.

Formulate and administer programs and policies.

Develop, implement, and evaluate inspection and preservation policies, standards, procedures, and programs.

Analyze federal and state legislation, administrative rules, and national and industry standards for incorporation in programs and policies.

Recommend the revision of legislation and participate in new legislation development.

Lead prompt, decisive, and effective responses to emergencies such as floods, earthquakes, and major bridge damage.

Train bridge inspection personnel.

Develop, monitor, and update training programs for state and consultant inspectors.

Arrange or conduct inspection training programs and refresher programs throughout the state.

Provide training on proper access, equipment operation, and safety procedures.

Review and approve Inspection Team Leader and Inspection Team Member qualifications. The SPM will have the final say on all questions of qualifications.

Maintain a list of all qualified Inspection Team Leaders and Inspection Team Members in Indiana. The list will identify training required to keep the qualifications up to date.

Evaluate Inspection Team Leaders and Inspection Team Members and require additional training as necessary.

Advise on technical issues concerning problems or deficiencies discovered during inspections.

Act as an Inspection Team Leader as needed.
Monitor inspections and develop a good, general knowledge of all bridges in the state and their inspection records.

Review all inspection reports for complex bridges performed on Indiana bridges.

Manage state bridge inspection personnel and consultants to meet the needs of the State Bridge Inspection Program.

Manage state-owned underbridge access equipment to assist in the inspection of bridges statewide.
Subsection 2.4.2  Bridge Inspection Area Engineer (BIAE)

The BIAE is responsible for assisting the SPM as directed, for setting all bridge inspection policies and procedures, and for all bridge inspections and related reporting in the state.

The BIAE will meet the following minimum qualifications:

1. Capable of overseeing the INDOT BIE
2. Sound background in bridge inspection
3. Specialized knowledge and skills in bridge design, construction, soils, construction materials, and emergency repair techniques
4. Successful completion of FHWA-NHI-130055
5. Successful completion of FHWA-NHI-130078
6. Registered PE in the state of Indiana

As a part of the responsibilities of this position, the BIAE shall:

- Oversee INDOT BIE
- Assist the SPM in managing the state bridge posting and restriction program.
- Ensure load-posted bridges receive interim inspections as required by federal and state laws, rules, and policy.
- Ensure proper signage is in place for bridges that require load posting or other restrictions.
- Ensure a system is in place that will notify INDOT BIE and BIC of required inspections and their due dates.
- Ensure a system is in place to upload all approved inspection data to the Central Database.
- Assist in the formulation and administration of programs and policies.
- Develop, implement, and evaluate inspection and preservation policies, standards, procedures, and programs.
- Analyze federal and state legislation, administrative rules, and national and industry standards for incorporation in programs and policies.
- Recommend the revision of legislation and participate in new legislation development.
- Lead prompt, decisive, and effective responses to emergencies such as floods, earthquakes, and major bridge damage.
- Train bridge inspection personnel.
• Develop, monitor, and update training programs for state and consultant inspectors.

• Arrange or conduct inspection training programs and refresher programs throughout the state.

• Provide training on proper access, equipment operation, and safety procedures.

• Assist in maintaining a list of all qualified Inspection Team Leaders and Inspection Team Members in Indiana. The list will identify training required to keep the qualifications up to date.

• Assist in the evaluation of Inspection Team Leaders and Inspection Team Members and require additional training as necessary.

• Advise on technical issues concerning problems or deficiencies discovered during inspections.

• Act as an Inspection Team Leader as needed.

• Monitor inspections and develop a good, general knowledge of all bridges in the state and their inspection records.

• Review all inspection reports for complex bridges performed on Indiana bridges.
Subsection 2.4.3  INDOT Bridge Inspection Engineer (BIE)

The INDOT BIE is responsible for the inspection and reporting for all assigned state-owned bridges.

The INDOT BIE must meet the following minimum qualifications:

1. Successful completion of FHWA-NHI-130055
2. Qualified as a Bridge Inspection Team Leader in the state of Indiana
3. Registered PE in the state of Indiana with appropriate training and experience
4. Capable of overseeing Inspection Team Leaders and Inspection Team Members
5. Successful completion of FHWA-NHI-130078 (required to inspect complex bridges)
6. Demonstrate a strong background in such areas as structural engineering, structural behavior trends, and bridge rehabilitation techniques
7. Demonstrate management abilities
8. Demonstrate thorough familiarity with NBIS, this manual, and applicable INDOT guidelines
9. Good eye sight and the ability to walk and climb over uneven surfaces and be comfortable working at heights, near water, in confined spaces, and close to live traffic

As a part of the responsibilities of this position, the INDOT BIE shall:

- Coordinate inspections to ensure that all inspections are completed in compliance with this manual.
- Oversee Inspection Team Leaders and Inspection Team Members.
- Ensure that all assigned state-owned bridge inspection results are approved and uploaded to the Central Database within 30 days of the date of the inspection and within seven days for all closures and emergency inspections. Notify the SPM of all bridge closures.
- Notify the SPM of all critical findings in accordance with section 7.2.
- Act as an Inspection Team Leader as needed.
Subsection 2.4.4  Bridge Inspection Consultant (BIC)

The BIC is the individual in a prequalified consulting firm who is responsible for all contracted inspections.

The BIC must meet the following minimum qualifications:

1. Registered PE in the state of Indiana with appropriate training and experience.
2. Qualified as an Inspection Team Leader in the state of Indiana.
3. Successful completion of FHWA-NHI-130055
4. Successful completion of FHWA-NHI-130078 (required to inspect complex bridges).
5. Capable of overseeing ATL and ATM.

The BIC shall:

- Oversee ATL and ATM.
- Accept responsibility for all contracted inspections.
- Inspect or ensure that qualified inspectors inspect all bridges and small structures included in their contracts in compliance with this manual.
- Ensure that all inspection results are approved and uploaded to the Central Database within 60 days of the completion of the inspection and within seven days for all closures and emergency inspections.
- Ensure that all quality control and quality assurance procedures are met for all team leaders.
- Fulfill requests for information from the SPM in an efficient and timely manner.
- Recommend load posting, restrictions, or bridge closings and ensure the related signage is in compliance with the applicable requirements.
- Notify the SPM of all critical findings in accordance with section 7.2.
- Assist the hiring agency in maintaining a perpetual inventory of all bridges and small structures in the Central Database. For toll road, county, or local agencies, provide the agency with a report for each bridge.
- For toll road, county, or local agencies, recommend a bridge repair and construction program to the agency.
- Forward a list of qualified ATL, ATM, and Load Rating Team Members in the firm to the SPM yearly before December 31st. The list shall include the following:
  a) Proof of PE Registration in the State of Indiana for all professional engineer team leaders, state assigned inspection numbers for all team leaders and team members. This requirement applies to inspector and load rating teams.
b) Certificates of training for FHWA-NHI-130055 for team leaders.

c) Certificates of training for the FHWA-NHI-130078 Fracture Critical Inspection Techniques for steel bridges for team leaders performing fracture critical and complex bridge inspections.

d) Certificates of training for the underwater bridge inspection class and diver training listed in section 2.4.10
Subsection 2.4.5 Inspection Team Leader (ATL)

The ATL is the person responsible for the field inspection work. Preferably, the inspection team should consist of two persons: an ATL and an Inspection Team Member (ATM).

The ATL must meet the following requirements to be considered qualified:

1. Be responsible for field work and be on site during the inspection
2. Demonstrate a strong background in such areas as structural engineering, structural behavior trends, and bridge rehabilitation techniques
3. Demonstrate management abilities
4. Thorough familiarity with all NBIS, this manual, and applicable INDOT guidelines
5. Good eye sight, the ability to walk and climb over uneven surfaces, and the ability to work at heights, near water, in confined spaces, and close to live traffic
6. Meet one of the following:
   a. Successful completion of FHWA-NHI-130055
      AND
      Registered PE in the state of Indiana
   b. Successful completion of FHWA-NHI-130055
      AND
      Bachelor degree in Engineering from a college or university accredited by the Accreditation Board for Engineering and Technology or a substantially equivalent organization
      AND
      Successful completion of the National Council of Examiners for Engineering and Surveying Fundamentals of Engineering exam
      AND
      Two years of bridge inspection experience in a responsible capacity under the direction and supervision of a qualified ATL
   c. Successful completion of FHWA-NHI-130055
      AND
      Five years of Bridge Inspection Experience in a responsible capacity under the direction and supervision of a qualified ATL
   d. Successful completion of FHWA-NHI-130055
      AND
      Certified Level III or IV NICET Bridge Inspector
e. Successful completion of FHWA-NHI-130055
   AND
   Associate’s degree in Engineering or Engineering Technology from a college or university accredited by the Accreditation Board for Engineering and Technology or by a substantially equivalent organization
   AND
   Four years of bridge inspection experience in a responsible capacity, as determined by the SPM, under the direction and supervision of a qualified ATL

A request for Inspection Team Leader status shall be submitted on the Record of Qualifications form. Appendix B contains a blank copy of this form. Each Inspection Team Leader is assigned an Inspection Team Leader Number by the SPM.

To remain qualified, all Inspection Team Leaders:

- Must successfully complete Bridge Inspection Refresher Training (FHWA-NHI-130053) or FHWA-NHI-130055 at least once every 10 years.
- Must have conducted a bridge inspection, where he/she has fully participated in the field inspection work and signed his/her name on the report in the last five years. Inspection Team Leaders who do not meet this requirement must successfully complete FHWA-NHI-130053 to become re-qualified.

The Inspection Team Leader who does not meet the ongoing qualifications outlined may conduct field inspections during an emergency such as a flood, post-earthquake, or after a collision. He/she must be instructed by, and under the supervision of, a qualified Inspection Team Leader. The inspections should be limited and should not involve changing any NBI data without having their data reviewed by a qualified Inspection Team Leader.
Subsection 2.4.6 Complex Bridge Inspection Team Leader (ATL-C)

Inspection Team Leaders for the inspection of a complex bridge must meet the following requirements:

1. Qualified Inspection Team Leader
2. Successful completion of FHWA-NHI-130078 within the last 5 years
3. Provide precertification documentation to the SPM showing familiarity with the type of complex bridge to be inspected, understanding of how the bridge functions, and where possible defects might occur; must be current on issues with the type of bridges being inspected. This type of inspection will require design level three criteria.
4. Licensed PE in the state of Indiana.

Subsection 2.4.7 Fracture Critical Inspection Team Leader (ATL-C)

Inspection Team Leaders for the inspection of a complex bridge must meet the following requirements:

1. Qualified Inspection Team Leader
2. Successful completion of FHWA-NHI-130078 within the last 5 years
3. Licensed Professional Engineer in the state of Indiana, or have 2 additional years of bridge inspection experience as a team leader.

The credentials must be approved by the SPM.
Subsection 2.4.8 Underwater Inspection Team Leader (ATL-U)

An Inspection Team Leader for an Underwater Inspection will meet the following requirements:

1. Qualified Inspection Team Leader
2. Divers must meet the requirements listed in 2.4.10
3. Registered PE licensed in the State of Indiana
4. Experienced in Underwater and In-Water Bridge inspections
5. Experienced in stream bed profiles and cross sections
6. Experienced in underwater nondestructive testing techniques
7. Responsible for the inspection, data integrity, and report preparation for bridge inspection projects in the last five years

The Inspection Team Leader shall:

- Lead the inspection team in actively planning, preparing, and performing bridge inspections. The ATL-U must be at the bridge at all times during the inspection.
- Be on site leading in the inspection of each bridge and participating in all in-water activities.
- Ensure worksite safety compliance, including traffic control, Inspection Team Members’ safety procedures, equipment, and the proper use of access equipment.
- Sign each bridge inspection report and take full responsibility for all data and comments contained in the report.
- Approve all data in the Central Database.
- Train Inspection Team Members working under his/her supervision, and provide opportunities to further his/her knowledge and professionalism in this field.
- Report any condition which is dangerous to persons or property, or any structural condition that would likely increase the potential for structure or member failure, to the SPM and the INDOT BIE or BIC as soon as possible.
- Report any Critical findings to the appropriate individuals and agencies identified in Part1, Chapter 7.
- Recommend load posting calculations be completed as needed.
- Recommend restrictions or bridge closings and ensure the related signage is in compliance with all applicable requirements.

Duties and responsibilities of the Inspection Team Leader are described in Part 1, Chapter 4, Section 4.2.
Subsection 2.4.9  Inspection Team Member (ATM)

An ATM shall meet, as a minimum, all of the qualifications listed below:

- High School Degree or equivalent
- Familiarity with NBIS
- Familiarity with the FHWA Recording and Coding Guide
- Familiarity with appropriate parts of this manual

The Inspection Team Member is encouraged to take FHWA-NHI-130055.

The Inspection Team Member is responsible for the following:

- Following all Inspection Team Leader instructions in a safe manner
- Assisting the Inspection Team Leader in the field
- Documenting his/her participation and experience
- Keeping a personal log of bridge inspection and related bridge experience
- Acting in a professional manner

Subsection 2.4.10 Nondestructive Testing Specialists

Individuals performing nondestructive testing (NDT) shall be qualified in accordance with American Society for Nondestructive Testing (ASNT) Level II or III. For all NDT work, other than dye penetrant, the NDT personnel must work hand-in-hand with a professional engineer, licensed in Indiana, who is qualified as a Bridge Inspection Team Leader.
Subsection 2.4.11 Divers

Diving operations shall be conducted in accordance with all applicable federal and state regulations. Each member of the team should be trained in accordance with Occupational Safety and Health Administration (OSHA) standards.

All divers shall have completed training accredited by the Association of Commercial Diving Educators to the appropriate level or documented evidence that the divers training meets the requirements specified by the national consensus standard published by the American National Standards Institute (ANSI) and the Association of Commercial Diving Educators (ACDE) (i.e. ANSI / ACDE-01-2009, American National Standard for Divers – Commercial Diver Training – Minimum Standard).

All divers shall have certification proving successful completion of the Underwater Bridge Inspection course (FHWA-NHI-130091). All proof of training and certifications must be on file with the INDOT Bridge Inspection Unit.

Subsection 2.4.12 Load Rating Team Leader (ATL-R)

Routine load ratings of state-owned bridges are generally performed and maintained by INDOT’s Bridge Load Rating Engineer in the office of Structural Services. The load rating of some large or complex bridges is performed and maintained by the SPM under the Major Bridge Program. The load rating of toll road, county, and local bridges is generally done by the BIC of record for owner.

The ATL-R must meet the qualifications listed below:

1. Have experience calculating load ratings and knowledge of load capacity rating computer programs and posting policies in Indiana

2. Registered PE licensed in the state of Indiana, qualified to oversee, review, and certify all load capacity ratings performed under his/her supervision

It is preferred, but not required, that the ATL-R successfully complete FHWA-NHI-130055.

The ATL-R must:

- Provide engineering judgment to those performing the load ratings.
- Be actively involved in reviewing the quality and accuracy of all load ratings.
SECTION 2.5 BRIDGE INSPECTION DATABASE

INDOT’s Central Database includes data used for FHWA’s NBI File and supplemental information used by the state.

All inspection data shall be entered into the state’s Central Database and approved by the Inspection Team Leader. All materials considered to make up the bridge file are to be uploaded into the state’s Central Database. These materials include, but are not limited to: bridge plans, inspection sketches, pictures, and load rating calculations.

INDOT inspectors and consultants working on state-owned bridges shall submit all approved data to the state within 30 days of an inspection unless the contract includes specific language due to the complexity of the inspection. Consultants for the toll road, counties, and local agencies will submit all approved data to the state within 60 days of an inspection. Data generated when a bridge is closed after a Damage or Disaster Inspection must be uploaded to the Central Database as soon as possible, but not later than 7 days after the Damage Inspection.
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CHAPTER 3 TYPES OF INSPECTIONS

SECTION 3.1 INTRODUCTION

There are numerous types of inspections, each designed to obtain specific information. For example, an Initial Inspection is performed after a bridge is constructed to document the as-built conditions, whereas Routine Inspections are used to monitor the condition of a bridge at regular intervals. Damage Inspections are used to assess damage resulting from events such as impacts, fires, or floods. The inspections help create a complete picture of a bridge’s condition and are described in detail in this chapter.

Visual inspection is the primary examination method for all inspections. Nondestructive testing (NDT) techniques may be required to identify internal flaws or hard-to-see external defects in critical members. NDT is detailed in Part 6 of this manual.

Figure 1:3-4: Arch Bridge Near Spring Village, Indiana
The Federal Highway Administration (FHWA) and the state of Indiana dictate the type of inspection each bridge requires, and the maximum interval between inspections. Figure 1:3-2 gives an overview of the types of inspections, the maximum interval between inspections, and the governmental unit responsible for the inspection policy.

<table>
<thead>
<tr>
<th>Inspection Type</th>
<th>Maximum Inspection Interval</th>
<th>Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>After Construction or Major Rehabilitation 90 Days</td>
<td>FHWA Mandate</td>
</tr>
<tr>
<td>Routine*</td>
<td>24 months</td>
<td>FHWA Mandate</td>
</tr>
<tr>
<td>Fracture Critical (92A)</td>
<td>24 months</td>
<td>FHWA Mandate</td>
</tr>
<tr>
<td>Underwater (92B)**</td>
<td>60 months</td>
<td>FHWA Mandate</td>
</tr>
<tr>
<td>Special (92C)**</td>
<td>60 months</td>
<td>FHWA Mandate</td>
</tr>
<tr>
<td>In-Depth</td>
<td>96 months</td>
<td>INDOT Policy</td>
</tr>
<tr>
<td>Damage</td>
<td>As needed</td>
<td>FHWA Mandate</td>
</tr>
<tr>
<td>Channel Survey</td>
<td>72 months</td>
<td>INDOT Policy</td>
</tr>
<tr>
<td>Large Culvert</td>
<td>60 months</td>
<td>INDOT Policy</td>
</tr>
</tbody>
</table>

*See Part 1, Section 3.5 for information on Plan of Action

**Plan of Action required

Figure 1:3-5: Bridge Inspection Types and Maximum Intervals
SECTION 3.3 INITIAL INSPECTIONS

Subsection 3.3.1 Purpose

An Initial Inspection is the baseline inspection that should be completed on every new bridge, after a major rehabilitation, or when the configuration or geometry of a bridge changes (e.g., when a bridge is widened). An Initial Inspection is a fully documented inspection using the bridge plans to determine basic data for entry into the Central Database. Initial Inspections are also used when a bridge is discovered that has not been previously inventoried. In this case, the bridge plans may not be available. As part of the Initial Inspection, inspectors evaluate the bridge and decide what other foreseeable inspections will be required throughout its life, including Fracture Critical, Special, or Underwater Inspections.

Figure 1:3-6: Inspector Performing an Initial Inspection
Subsection 3.3.2  Precision

The Initial Inspection should be a fully documented investigation. Inspectors must be able to identify any deficiencies and verify the geometric data. All observed deficiencies, cracks, construction errors, and alignment problems should be documented.

An Initial Inspection should include:

- Record all Structure Inventory and Appraisal (SI&A) data required by federal and state regulations.
- Complete an inspection and evaluation of all required data identified in the Indiana Coding Guide in accordance with relevant chapters of this manual.
- Complete a Basic Channel Survey, in accordance with Section 3.10 of this chapter.
- Complete a Scour Inspection for a bridge with substructure units in water in accordance with Part 4, Chapter 7.
- Complete an Underwater Inspection for a bridge with substructure units in water if unable to perform a Scour Inspection.
- Gather relevant information required to maintain an accurate bridge file.
- Determine and evaluate the baseline structural condition.
- Assess scour susceptibility.
- Identify the location and condition of any fracture critical members or details.
- Identify the location and condition of any details that may require a Special Inspection.
- Identify any substructure components requiring Underwater Inspection.
- Verify that all clearances and geometric dimensions are correct in the Central Database.
- Verify that any protection required to shield the bridge from traffic on navigable waters is in place.
- Identify any critical findings and notify the appropriate individuals and agencies identified in Part 1, Chapter 7, report the findings as directed in Part 1 Chapter 7.

All inspection results should be fully documented in the Central Database.

If a bridge is scheduled for an Initial Inspection, but the construction is not complete, the steps outlined for bridges closed to traffic in Section 3.12 of this chapter should be followed.

Subsection 3.3.3  Repairs

Rehabilitation repairs are permanent repairs that are intended to improve the structural condition of a member and/or component. Access to the repair plans is needed to determine if and to what extent rehabilitation improves any specific rating number.
Subsection 3.3.4 Frequency

For state-owned bridges, an Initial Inspection should be completed before the new construction or rehabilitation construction contract is finalized and the bridge is open to traffic. These inspections are often performed in conjunction with the construction department’s Pre-Final Inspection. Approved Initial Inspection data, including the SI&A data, must be entered in the Central Database within 90 days of the completion of the construction.

For toll road, county, and local agency bridges, Initial Inspections should be completed as soon as reasonable. Approved Initial Inspection data, including the SI&A data, must be entered in the Central Database within 90 days of the opening of the bridge.

A bridge not previously documented in the Central Database shall receive an Initial Inspection within 90 days of the discovery of the bridge. The data must be entered in the Central Database within 90 days of the discovery of the bridge.

Figure 1:3-7: Steel Girder Bridge
SECTION 3.4 ROUTINE INSPECTION

Subsection 3.4.1 Purpose

Routine Inspections are regularly scheduled inspections consisting of observations and/or measurements needed to determine the physical and functional condition of the bridge, and to identify any changes from previously recorded conditions. The Routine Inspection also ensures that the bridge continues to satisfy present service requirements.

Subsection 3.4.2 Precision

Routine Inspections for state-owned bridges must follow a Plan of Action, documented in the Central Database. The Plan of Action must include:

1. A time table for conducting the inspection.
2. The personnel requirements for the inspection.
3. The required access equipment.
4. The required traffic control.

Routine Inspections for toll road, county, and local agency bridges must follow a Plan of Action, documented in the Central Database, if the bridge has unique issues such as difficult access, polluted water or channel bed, or unusual traffic control requirements.

Routine Inspections are generally conducted from the deck, ground, water-level, or from permanent work platforms and walkways, if present. A complete walk-around visual inspection of all components of the structure, channel, and adjacent roadway is required.

If the water is not safe for wading access, the inspection team should return when the flow conditions allow safe access. If any portion of a substructure is in water and is not normally safely accessible to inspectors during the Routine Inspection, an Underwater Inspection (92B) is necessary. The conditions that mandate an Underwater Inspection are listed in Section 3.6. The Inspection Team Leader must send a written request to the State Program Manager to add, modify, or remove a bridge from the list of bridges needing an Underwater Inspection.

A Routine Inspection should include the following:

- Complete an inspection and evaluation of all required data identified in the Indiana Coding Guide in accordance with this manual.
- Complete a Basic Channel Survey for bridges with substructure units in water every 72 months in accordance with Section 3.10 of this chapter.
- Complete a Basic Channel Survey for bridges with substructure units in water in accordance with Section 3.10 of this chapter if required by the Scour Plan of Action, or if probing indicates a changed condition in the stream bed.
Complete a Scour Inspection for bridges with substructure units in water in accordance with Part 4, Chapter 7, if the bridge does not receive Underwater Inspections.

Verify SI&A data.

Gather other relevant information required to maintain an accurate bridge file.

Note any existing problems or components.

Note the condition of fracture critical members or details.

Identify the location and condition of details that may require a Special Inspection.

Note signs of bats and cliff swallows at state-owned bridges.

Report significant debris or drift to the bridge owner.

Take alignment photos from both ends of the bridge. Closing, posting, and/or restriction signs should be visible and legible in the photos.

Take elevation photos, preferably for both sides of the bridge, as a minimum on one side of the bridge. If only one elevation photo is taken, a picture of an important detail must be taken.

Take photos of all bridge National Bridge Inventory (NBI) Items with a condition rating of 4 or less.

If needed to complete the bridge file, take one clear photo under each superstructure type, clearly showing details.

If needed to complete the bridge file, take one clear photo of each substructure unit in the water.

If needed to complete the bridge file, take one photo looking at the upstream channel.

If needed to complete the bridge file, take one photo looking at the downstream channel.

If needed to complete the bridge file, take one photo of any fracture critical member or details.

If needed to complete the bridge file, take one photo of any detail that requires a Special Inspection.

Take photos of significant collision damage.

Note if a new load rating is warranted.

Verify that the protection required to shield the bridge from traffic on navigable waters is in place.

Identify any Critical Deficiencies and notify the appropriate individuals and agencies identified in Part 1, Chapter 7.
Subsection 3.4.3  Inspection Frequency

Bridges must receive a Routine Inspection every 24 months unless widespread deterioration dictates more frequent inspections. If only a portion of a bridge needs more frequent inspections, a Special Inspection is required.

Bridges with a rating of 4 or less for the deck, superstructure, substructure, or culvert rating shall have a reduced interval between Routine Inspections. *A maximum inspection interval of 12 months will be used.*
SECTION 3.5 FRACTURE CRITICAL INSPECTIONS

Subsection 3.5.1 Purpose

Fracture Critical Inspections (92A) are regularly scheduled inspections to examine the fracture critical members or member components of a bridge. Fracture critical members are steel tension members or steel tension components of members, whose failure would probably cause all, or a portion of, the bridge to collapse. Fracture critical members require more thorough and detailed inspections than the members of non-fracture critical bridges. Fracture Critical Inspections are explained in detail in Part 4, Chapter 11. In Indiana, some fracture critical details, such as pin and hanger connections, also require a Special Inspection.

Figure 1:3-8: Deteriorated Fracture Critical Detail (Pin and Hanger)
Subsection 3.5.2 Precision

Every Fracture Critical Inspection must follow a Plan of Action. The Plan of Action must include:

1. A time table for conducting the inspection.
2. The personnel requirements for the inspection.
3. A list detailing what is required to be inspected.
4. The required access equipment.
5. The required traffic control.
6. A sketch showing the location of all fracture critical members.
7. A table listing the locations of the fracture critical members and comments regarding the condition of the member.

A Fracture Critical Inspection is a hands-on inspection. “Hands-on” means a visual/manual inspection made at a distance no greater than arm’s length of the entire member or member component surface, including gusset plates. The observations and measurements are used to determine the structural capacity of the member or member component, identify critical findings, identify any changes from previous inspections, and ensure that the bridge continues to satisfy present safety and service requirements.

Under-bridge access equipment may be required to move the inspector within arm’s length of the critical members. There may be permanent work platforms and walkways available on some larger bridges to aid in inspection work.

Critical findings shall be reported to the appropriate individuals and agencies identified in Part 1, Chapter 7.

All inspection results should be fully documented in the Central Database.

If a bridge is scheduled for a Fracture Critical Inspection, but the road is closed to traffic, the inspection team should follow the steps outlined in Section 3.12 of this chapter.

Subsection 3.5.3 Frequency

A Fracture Critical Inspection is required at regular intervals not to exceed 24 months. A fracture critical member with a rating of 4 or less shall have the frequency of inspection reduced to no greater than 12 months.
Figure 1:3-9: Ultrasonic Testing for Crack Detection
SECTION 3.6 UNDERWATER INSPECTIONS

Underwater Inspections are a necessary part of an effective State Bridge Management Program, and are mandated by the FHWA on routine intervals for bridges with substructure units in water.

Figure 1:3-10: Inspector Conducting a Wading Inspection

Subsection 3.6.1 Purpose

Because most problems that occur under water do not become visible from the surface until they are critical, bridges with substructure units in water must be inspected to ensure they are sound.

Underwater Inspections are called for if scour and the condition of elements below water cannot be assessed because:

a) The substructure unit is in the water during the entire year.Inspectors are expected to visit the site at various times to find a time when the water level and current are low enough to safely gather the necessary data as a part of the Routine Inspection; and,

b) At the lowest flow during the year, the water is too deep (generally over three feet) or the current is too fast. Generally, if the velocity times depth is equal to or greater than 10, inspectors should not enter the water,

c) The channel bottom is too soft for safe wading, or

d) Hazardous water quality exists.
Every Underwater Inspection must follow a Plan of Action. The Plan of Action must include:

1. A time table for conducting the inspection.
2. The personnel requirements for each portion of the inspection.
3. A list detailing what is required to be inspected.
4. The required access equipment.
5. The required traffic control.

An Underwater Inspection should include:

a) A detailed listing of the divers participating in the inspection complete with duties performed and a complete listing of credentials. This will include diving credentials and Bridge Inspection Team Leader and Team Member numbers issued by the Bridge Inspection Unit. This information must be placed on the first section of the inspection report.

b) A detailed Channel Survey as described in Section 3.10 of this chapter, including channel soundings and waterline elevations.

c) A Scour Inspection as described in Part 4, Chapter 7.

d) Photographs including:
   - Overall views of the Bridge.
   - General views of each substructure unit (both fascias and noses).
   - Significant defects.
   - Typical material condition at the water line.

e) Sketches showing:
   - The substructure layout, including overall bridge length and each substructure unit length and width.
   - The shoreline limits upstream and downstream of the bridge.
   - A north arrow.
   - The width of the channel at the bridge.

f) A record of the water velocity at the deepest point in the channel.

g) A record of the channel bottom material adjacent to all submerged substructure units.

h) A record of the shoreline conditions and material.

i) A check of the foundation type to ensure it has been correctly coded in Item 113.
j) Complete pre-dive and post-dive checklists.

k) A record of defects, noting section loss and dimensions.

l) Notifying of the owner of any significant deficiencies.

m) Reviewing available plans against the current condition for changes.

n) Making preliminary recommendations if needed.

All inspection results should be fully documented in the Central Database. Critical findings shall be reported to the appropriate individuals and agencies identified in Part 1, Chapter 7.

If a bridge is scheduled for an Underwater Inspection, but the road is closed to traffic, the inspection team should follow the steps outlined in Section 3.12 of this chapter.

![Figure 1:3-11: Diver at Pier](image)

Due to limited underwater visibility, the inherent access restrictions of the underwater environment, and the presence of marine growth, the required underwater inspection precision depends on the level of effort. Three underwater diving inspection levels of effort are defined by the FHWA. A standard Underwater Inspection in Indiana requires a Level I effort on 100 percent of all underwater elements. A Level II or III effort shall be conducted only if defects or advance deterioration are found or suspected, and then only at the direction of the SPM.
A summary of the Inspection Levels and typical detectable defects is provided in Figure 1:3-10. A narrative description of each level follows.

<table>
<thead>
<tr>
<th>Level</th>
<th>Purpose</th>
<th>Steel</th>
<th>Concrete</th>
<th>Timber</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>General visual/tactile inspection to confirm as-built condition and detect severe damage</td>
<td>Extensive corrosion and holes</td>
<td>Major spalling and cracking</td>
<td>Major loss of section</td>
<td>Permanent deformation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe structural damage</td>
<td>Severe reinforcement corrosion</td>
<td>Broken piles</td>
<td>Broken piles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Broken piles</td>
<td></td>
<td>Major cracking or structural damage</td>
</tr>
<tr>
<td>II</td>
<td>To detect surface defects normally obscured by marine growth</td>
<td>Moderate structural damage</td>
<td>Surface cracking, spalling, erosion</td>
<td>External pile damage due to marine borers</td>
<td>Cracking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Corrosion pitting and loss of section</td>
<td>Rust staining</td>
<td>Splintered piles</td>
<td>Delamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Exposed reinforcing steel and/or prestressing strands</td>
<td>Loss of bolts and fasteners</td>
<td>Material degradation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rot or insect infestation</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>To detect hidden or interior damage, evaluate loss of cross-sectional area, or evaluate material homogeneity</td>
<td>Remaining thickness of material</td>
<td>Onset of reinforcing steel corrosion</td>
<td>Internal damage due to marine borers (internal voids)</td>
<td>Change in material properties</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrical potentials for cathodic protection</td>
<td>Internal voids</td>
<td>Decrease in material strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Change in material properties</td>
<td>Change in material properties</td>
<td>Change in material properties</td>
<td></td>
</tr>
</tbody>
</table>
LEVEL I EFFORT

A Level I Inspection is a visual or tactile examination using large sweeping motions of the hands where visibility is limited. A Level I effort must be detailed enough to detect obvious major damage or deterioration due to overstress or other severe deterioration. It should confirm the full-length continuity of all members and detect undermining or exposure of normally buried elements. A Level I effort also includes limited probing of the substructure and adjacent channel bottom.

LEVEL II EFFORT

The Level II effort is intended to detect and identify damaged and deteriorated areas that may be hidden by surface biofouling. A Level II inspection requires marine growth to be removed from portions of the bridge. The thoroughness of cleaning should be governed by what is necessary to discern about the condition of the underlying material. A detailed inspection of a representative sample of the components is required. For piles, a 12-inch high band should be cleaned at designated elevations, generally near the waterline, at the mudline, and midway between the waterline and the mudline. On an H-pile, marine growth should be removed from both flanges and the web. On a rectangular pile, the marine growth removal should include at least three sides; on an octagonal pile, at least six sides; and on a round pile, at least three-fourths of the perimeter. On piles with a diameter of three feet or greater, one-foot squares should be cleaned at four locations spaced approximately equally around the perimeter, at each designated elevation. On large, solid-faced elements such as pier shafts, one-foot squares should be cleaned at four random locations, at each designated elevation. The Level II effort should also focus on typical areas of weakness such as attachment points and welds. Figure 1:3-11 shows a view of a typical Level II effort.

Figure 1:3-13: Inspector Conducting a Level II Inspection Effort
LEVEL III EFFORT

The Level III effort is generally limited to key structural areas which are suspect or areas which may be representative of the underwater structure. A Level III Inspection typically involves NDT or partially-destructive testing (PDT) to detect hidden or interior damage, or to evaluate material homogeneity. Testing techniques typically include the use of ultrasonic, coring or boring, and in-situ hardness testing. Refer to Part 6 of this manual for additional information on NDT and PDT. Refer to Figures 1:3-12 and 1:3-13 for views of inspectors conducting Level III efforts.

The SPM and the FHWA Liaison should be notified of all Critical Deficiencies identified in this inspection, as detailed in Part 1, Chapter 7 of this manual. Critical Deficiencies should be noted in the Central Database for all bridges.

All inspection results should be fully documented in the Central Database.

Figure 1:3-14: Inspector Using a D-Meter to Conduct a Level III NDT Inspection
Subsection 3.6.3 Frequency

The standard interval for Underwater Inspections is 60 months. This interval is for bridges that are in good condition underwater, located in passive, nonthreatening environments, and have not had any significant changes in the submerged substructure units or channel bottom since the previous Underwater Inspection. If warranted due to deficiencies or deterioration, the inspection interval may be reduced to less than 60 months. Counties and local agencies generally use 48 months as their standard interval for Underwater Inspections.

A frequency of 48 months is to be used when there have been changes in the submerged substructure units or channel bottom since the previous inspection that are serious enough to warrant tighter scrutiny, but not serious enough to require corrective action.

A 36-month frequency is to be used when there have been substantial changes in the submerged substructure units or channel bottom since the previous inspection, or problems have developed that require corrective action.

A 24-month frequency is to be used when serious submerged substructure unit deterioration or scour/channel problems exist. The deficiencies should be immediately addressed, or the bridge should be rehabilitated or replaced in the very near future.
A 12-month frequency is to be used when very critical submerged substructure unit deterioration or scour/channel problems exist. The deficiencies should be immediately addressed or the bridge should be rehabilitated or replaced in the very near future.

An Underwater Inspection may be required as part of an Initial Inspection for bridges with substructure units in water that cannot be inspected safely while wading. Underwater Inspections are scheduled, modified, or deleted as a requirement by the SPM. When the current frequency is out of compliance to the frequencies outlined above, the Inspection Team Leader shall write the SPM requesting a change in frequency citing the reasons as listed above.

Increasing frequency: The inspection frequency may be increased from a reduced frequency if the situation that required the reduced frequency has been properly addressed or if it has been observed over several inspections the situation has stabilized. The increase in frequency will be made in writing and must have the approval from the SPM.
SECTION 3.7 SPECIAL INSPECTIONS

Subsection 3.7.1 Purpose

Special Inspections (92C) are scheduled to examine a portion of a bridge in more detail or at a greater or lesser frequency than is standard for Routine Inspections. Special Inspections may provide follow-up after a Routine, Damage, or Initial Inspection. Special Inspections are also required for complex structures which require a more comprehensive inspection than is possible in a Routine Inspection. The Special Inspection mandates the component being inspected is at arm’s length.

Details and bridges that require a Special Inspection include the following:

- Cover plates
- Fatigue category E and E’ details
- Hangers of all types
- Hinge or pin connections
- Triaxial Constraint
- Intermittent Welds
- Field Welds on tension members
- Known defects or damages severe enough to warrant extra scrutiny
- Unique or problematic details as determined by the SPM

Complex Bridges that require a Special Inspection include the following:

- Bridges designated by the SPM
- Cable-stayed bridges
- Movable bridges
- Suspension bridges
Subsection 3.7.2  Precision

Every Special Inspection must follow a Plan of Action. The Plan of Action must include:

1. A time table for conducting each inspection.
2. The personnel requirements for each portion of each inspection.
3. A list detailing what is required to be inspected under each inspection.
4. The required access equipment needed for each inspection.
5. The required traffic control for each inspection.
For bridges that require a Special Inspection because of unique or problematic details, the inspector must make sufficient measurements and observations to quantify the deficiencies to allow for future monitoring. Inspectors should document:

1. The physical and functional conditions of the known or suspected deficiency.
2. Any developing problems such as deterioration, foundation settlement, scour or erosion of the slopes, scour at the supports, ice damage, or other problems that, if left unchecked, would degrade the load-carrying capacity of the bridge.
3. Signage is in place and visible for load-posted or restricted bridges.
4. The ability of the bridge to satisfy its present service requirements.

Inspection results must be recorded in the Central Database. The date of the inspection and a list of the deficiencies investigated must be included. If any deficiency has become more severe, it may be necessary to notify the owner and re-evaluate the bridge load rating. Critical findings shall be reported to the appropriate individuals and agencies identified in Part 1, Chapter 7.

Some Special Inspection tasks need not be performed with an Inspection Team Leader on site. Inspection Team Members can be sent out to perform specific inspection or measurement tasks under the direction of an Inspection Team Leader. Such tasks might include measuring a crack, photographing a weld, or measuring section loss on specific members. These tasks must be clearly documented in the Special Inspection Plan of Action. The Inspection Team Leader is still required to review and sign off on all inspection data entered into the Central Database.

For state-owned complex bridges that require a Special Inspection, a lead Inspection Team Leader is assigned by the State Program Manager. The Plan of Action will be developed and modified by the lead Inspection Team Leader in consultation with the State Program Manager.

The lead Inspection Team Leader for state-owned complex bridges may or may not be the Inspection Team Leader for any individual inspection performed as a part of the Special Inspection. The Inspection Team Leader for each individual inspection will approve the inspection results entered in the Central Database for that inspection. The lead Inspection Team Leader must review all individual inspections performed as a part of the Special Inspection, as well as generate/approve a summary of the Special Inspection. This summary must be entered in the Central Database.

Inspection teams for state-owned complex bridges may consist of state personnel, consultants, or a combination. The lead Inspection Team Leader will ensure that each team is working within the scope of its professional ability. The INDOT District Inspectors normally assigned to the bridge will generally be assigned to complete the Routine Inspection of the bridge; but, they must also assist in any additional inspections, as directed by the lead Inspection Team Leader.

For toll road, county, and local agency complex bridges that require a Special Inspection, a lead Inspection Team Leader is assigned by the Inspection Consultant.
PART 1: ADMINISTRATION

Special Inspections

The Plan of Action will be developed and modified by the lead Inspection Team Leader in consultation with the State Program Manager.

The lead Inspection Team Leader must review all individual inspections performed as a part of the Special Inspection, as well as generate/approve a summary of the Special Inspection. This summary must be entered into the Central Database.

Depending on the extent of the damage or deterioration, a Special Inspection may include a recommendation for a load rating to assess the capacity of damaged or deteriorated members. Nondestructive tests and/or other material tests may be needed to assist in determining the safe load-carrying capacity.

Critical findings shall be reported to the appropriate individuals and agencies identified in Part 1, Chapter 7.

All inspection results should be fully documented in the Central Database.

Figure 1:3-17: Load-Posted Truss Bridge

Subsection 3.7.3 Frequency

Special Inspections for unique and problematic details are completed in addition to Routine Inspections. The maximum inspection interval for a Special Inspection is 60 months. A problematic detail that is performing well on a structure can have an inspection interval of 60 months. A structure with a problematic detail that has a rating of 4 or less shall be inspected on a 12 month interval.
A written request should be sent to the SPM requesting the Special Inspection be removed if the detail has been retrofitted or rehabilitated.

The inspection frequency of each component inspection of a Special Inspection for a complex bridge must be identified in the Plan of Action. It may be most efficient to conduct all of the inspections at one time, using the same inspectors. However, it may not be practical to schedule inspections requiring different types of traffic control, access equipment, or NDT at the same time.

Figure 1:3-18: Inspectors Performing a Special Inspection
SECTION 3.8 IN-DEPTH INSPECTION

Subsection 3.8.1 Purpose

An In-Depth Inspection is a close-up inspection that allows for the detection of deficiencies that aren’t readily identifiable during a routine inspection. The term close-up is used which indicates this is not a hands-on inspection but is still well within visual range so that defects can be seen.

An In-Depth Inspection is a scheduled inspection which is scheduled at a maximum 96 month interval for structures that meet the following criteria:

- The structure is of the type that does not require a scheduled hands on inspection
- The structure contains elements not easily inspected during a routine inspection
- The structure has been selected by the Program Manager

Subsection 3.8.2 Precision

The scope of an In-Depth Inspection should be to inspect the entire structure close-up. This is a relatively infrequent inspection scheduled for structures that typically do not require a scheduled inspection beyond the routine inspection. This inspection will give the inspector the opportunity to make sure that all of the components of the structure are performing as intended.

Subsection 3.8.3 Frequency

The maximum frequency of an in-depth inspection is 96 months.
SECTION 3.9 DAMAGE INSPECTIONS

Subsection 3.9.1 Purpose

A Damage Inspection is an unscheduled inspection to assess structural damage resulting from environmental factors or human actions. Flood damage, fire damage, barge impact, and vehicle impact are examples of events that may call for a Damage Inspection.

![Figure 1:3-19: Impact Damage to a Concrete Girder Bridge](image)

Subsection 3.9.2 Precision

The scope of a Damage Inspection should be sufficient to determine whether there is a need for emergency load restriction, or closure of part or all of the bridge to traffic. Inspectors of state-owned bridges should also assess the level of effort necessary to repair the damage. The amount of effort expended on this type of inspection may vary significantly and depends on the extent of the damage. If major damage has occurred, the inspector shall document the damage, including measuring section loss or misalignment, and any loss of foundation support.
Inspection data and pictures shall be entered into the Central Database as soon as possible, and no more than seven days after the inspection. This inspection may be supplemented by a timely Special Inspection to more fully document the extent of damage and the urgency and scope of repairs. A more refined analysis, to establish or adjust interim load restrictions, may also be required as follow-up for a Damage Inspection. A structural engineer may need to be consulted for the inspection or analysis. If the inspection identifies a Critical finding, the inspector must follow the notification procedures outlined in Part 1, Chapter 7.

A damage inspection is required for all bridges in which the event has left permanent physical evidence. The damage inspection data and pictures shall be entered into the Central Database as soon as possible and no more than seven days after the inspection.

The Inspector of state-owned bridges should gather data on the vehicles and drivers involved and any police report after a crash. This information will be used to bill the appropriate insurance company for damages.

**Subsection 3.9.3 Frequency**

A Damage Inspection is an unscheduled inspection that is performed to determine if significant damage has been done to the bridge. Based on the findings of the damage inspection, the inspector will determine if the damage warrants placing the structure on a special detail inspection. Pictures of any damage will be uploaded to the bridge file with a complete description of the event. Generally, a law enforcement officer on the site of an accident involving a bridge will notify the owner who will request a Damage Inspection be performed to determine if the bridge should be closed. Damage Inspections are also needed after flooding or earthquakes.
Subsection 3.10.1 Purpose

Scour is the movement of channel bed material by the action of moving water. This movement may result in degradation (i.e., erosion of material), as well as aggradation (i.e., accumulation of material). These changes in the channel bed may lead to bridge instability and are generally identified by profiling the channel bottom. Comparison of previous profiles is typically needed to detect and assess scour. Plotting the underwater measurements of the stream bottom and probing bridge foundations are two of the most important aspects of inspecting a bridge for scour.

Channel cross section data is used to evaluate trends in channel bottom movement and to compare channel bottom elevations to footing elevations. Indiana has two levels of Channel Survey: basic and in-depth.

Subsection 3.10.2 Precision

For all Channel Surveys, the elevation of the waterline must be determined and referenced to a known elevation on the bridge.

For a basic Channel Survey, bottom elevations are required:

- At the upstream fascia, locate enough points between substructure units to identify any problems or deficiencies. Typically the elevations are taken at locations spaced between 10 and 25 feet depending on the contours of the channel. The notes of how to layout the survey must be kept in the bridge file. Once the survey method and points are determined, the process must be repeated so that the profiles can be compared. Create a profile sketch and plot the profile on the sketch. Future profiles data will be added in a tabular form as well as adding to the sketch which will have each profile entry dated.

For an in-depth Channel Survey, bottom elevations are required:

- Around each substructure unit in the water at enough points to identify any problems or deficiencies.
- Between substructure units along the centerline of the bridge, or between twin bridges at enough points between substructure units to identify any problems or deficiencies. A minimum of three points between each substructure and one point at each substructure is required.
- At the upstream fascia, at enough points between substructure units to identify any problems or deficiencies. A minimum of one point at each substructure and three points between each substructure is required.
- At the downstream fascia at enough points between substructure units to identify any problems or deficiencies. A minimum of one point at each substructure and three points between each substructure is required.
• 100 feet upstream at enough points between substructure units to identify any problems or deficiencies. A minimum of one point at each substructure and three points between each substructure is required.

• 200 feet upstream at enough points between substructure units to identify any problems or deficiencies. A minimum of one point at each substructure and three points between each substructure is required.

• 100 feet downstream at enough points between substructure units to identify any problems or deficiencies. A minimum of one point at each substructure and three points between each substructure is required.

• 200 feet downstream at enough points between substructure units to identify any problems or deficiencies. A minimum of one point at each substructure and three points between each substructure is required.

• At additional locations, if required, to adequately determine the thalweg of the waterway.

• As needed when an unusual change in the channel has been identified.

Where the bridge length is less than 100 feet, the upstream and downstream profiles should be taken at locations equal to the bridge length and twice the bridge length.

Every in-depth Channel Survey Inspection must follow a Plan of Action. The Plan of Action must include:

1. A time table for conducting the survey.
2. The personnel requirements for the survey.
3. A list detailing what is required to be surveyed.
4. The required access equipment.
5. The required traffic control.

Water depth measurements should be recorded to the nearest tenth of a foot. Scour evaluations are typically based on changes in elevations greater than 0.5 foot since most channel bottoms are irregular surfaces with random cobbles, debris, and sand ripples.

The water surface elevation should be referenced to a known elevation or reference point on or near the bridge.

The individuals taking the profiles need not be bridge inspectors. However, the profiles must be reviewed and compared to known substructure elevations and past profiles by the Inspection Team Leader.

**Subsection 3.10.3 Frequency**

Channel Surveys are performed concurrently with many of the required inspections of a bridge over water. A basic Channel Survey is required every 72 months and as required
in the Scour Plan of Action for Scour Critical Bridges. A basic Channel Survey is required for all Initial Inspections, all Underwater Inspections, and as required in the Scour Plan of Action for Scour Critical Bridges.

Figure 1:3-20: Aggradation and Vegetation in Channel
SECTION 3.11 LARGE CULVERT INSPECTION

Large culverts are bridges and culverts with spans greater than four feet and less than or equal to 20 feet.

Subsection 3.11.1 Purpose

Large Culvert Inspections are Routine Inspections for small structures. They are regularly scheduled inspections consisting of observations and measurements needed to determine the physical and functional condition of the structure to identify any changes from previously recorded conditions. The Large Culvert Inspection also ensures that the structure continues to satisfy present service requirements.

Subsection 3.11.2 Precision

These inspections should be conducted with the same precision and attention to detail outlined for Routine Inspections in Section 3.4.

The State Program Manager should be notified of all Critical Findings identified in this inspection as detailed in Part 1, Chapter 7 of this manual. Critical Findings should be noted in the Central Database for all bridges.

All inspection results should be fully documented in the Central Database.

Subsection 3.11.3 Frequency

All state-owned large culverts should be inventoried. State-owned large culverts with a condition rating of 6 or above may be scheduled for a large culvert Inspection not to exceed 60 months.

State-owned large culverts with a condition rating of 5 should be scheduled for a Large Culvert Inspection every 24 months. State-owned large culverts with a condition rating of 4 or less should be scheduled for a Large Culvert Inspection every 12 months as a minimum.

All Indiana Toll Road large culverts should be inventoried. Indiana Toll Road large culverts should be inspected as described above for INDOT large culverts.

County and local agency large culverts should be inspected at the discretion of the owner in consultation with the Inspection Consultant. It is recommended that all counties inventory all large culverts.

Large Culvert Inspections may be scheduled in conjunction with any other inspection type.
Figure 1:3-21: Large Culvert
SECTION 3.12 BRIDGES CLOSED TO TRAFFIC

If a bridge is **closed for construction** when an inspection is due, the inspection team shall:

- Document the bridge is properly closed with photos at both ends of the bridge. If the bridge is not properly closed, the bridge must be inspected.
- Code NBI #41 as “G” (new structure not yet open to traffic) or “K” (closed to traffic), as appropriate, in the Central Database.
- Code the appropriate NBI Date Item(s) with the date the inspectors were at the bridge.
- Note that the inspection date was changed in the Central Database.
- Verify the estimated date of completion of the construction.
- Schedule a new Initial Inspection and all other required inspections for the estimated completion date or at the next inspection interval if the bridge is expected to be closed longer than that inspection interval. All rescheduled inspections must be completed prior to the bridge being re-opened to traffic.
- Leave other NBI data items unchanged.
- Request that local officials verify the bridge is properly closed every 12 months.

If a bridge has been **closed permanently** when inspection is due, the inspection team shall:

- Document the bridge is properly closed with photos at both ends of the bridge. If the bridge is not properly closed, the bridge must be inspected.
- Code NBI #41 as “K” (closed to traffic) in the Central Database.
- Code the appropriate NBI Date Item(s) with the date the inspectors were at the bridge.
- Request that local officials verify the bridge is properly closed every 12 months.
- Note that the inspection dates were changed in the Central Database.
- Schedule the next Routine, Fracture Critical, and Special Inspections in 24 months.
- Schedule the next Underwater Inspection in 60 months.
- Leave other NBI data items unchanged.
- Recommend the removal of the bridge be scheduled as soon as possible.
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SECTION 4.1 INTRODUCTION

A bridge inspection involves a series of tasks that require dedicated, well-trained inspectors to successfully complete. The purpose of this chapter is to explain the fundamentals required for an inspector to do the job well.

An inspector needs to perform many duties. Inspector qualifications, outlined in Part 1, Chapter 2, set minimum requirements for the inspector’s knowledge, experience, and ability to perform the inspection work.

Before going out to the field, inspectors should properly plan an inspection. This must include a review of available data, and arranging for qualified personnel, appropriate equipment, and traffic control.

In the field, good inspectors are meticulous and pay great attention to details. Inspectors must have experience to know what to look for, the knowledge to understand what they see, and the skills to accurately document what is significant. After the inspection is complete, inspectors need to know how to prepare and submit the inspection results.

Figure 1:4-1: Emergency Inspection After Flooding
SECTION 4.2  INSPECTOR RESPONSIBILITIES

Inspectors ensure the safety of the traveling public. This job comes with several key responsibilities detailed below.

Subsection 4.2.1  Ensure Public Safety and Confidence

The primary responsibility of the inspector is to ensure public safety and confidence. The people of Indiana depend on safe transportation facilities to carry the public traffic of daily life, as well as the commercial traffic that fuels our economy. Failures can result in property damage, traffic congestion, lost investment in infrastructure, and potentially, loss of life. To minimize the potential for a failure, inspectors must make thorough inspections to identify the bridge condition and defects. They must also document these deficiencies and provide recommendations for remediation.

Bridge inspectors often work within the sight of the public and may be under close scrutiny. Inspectors should always exercise responsible behavior and, if approached, should be courteous and professional. However, inspectors should not discuss inspection findings unless authorized to release such information by the bridge owner.

Subsection 4.2.2  Protect the Public’s Investment

Inspectors have a duty to detect and report serious defects before they cause failures. The cost of the maintenance required to avoid a failure is always significantly less than the cost of the failure. Thorough and regular inspections, coupled with timely and consistent maintenance, will save the public money and help to prevent loss of property or life. Early detection of minor problems is also important. If these are corrected in a timely manner, more costly future repairs can be avoided.

Subsection 4.2.3  Identify and Assess Needs

Inspectors need to evaluate the general condition, safety level, and serviceability of each bridge with certainty and recognize those in need of repair or replacement. Experienced inspectors should be able to identify critical or failure prone members. Inspectors should make recommendations for the repair of any problems or deficiencies noted. Inspectors also perform the primary role in bridge management programs by the nature of the data they collect and their recommendations.
Subsection 4.2.4  Provide Accurate Records

The inspector is responsible for providing accurate bridge records. The inspector is responsible for documenting structural or functional deficiencies, bridge dimensions, and maintenance items identified in the field. Documentation should be thorough enough that a qualified individual who has not seen the bridge can understand the condition of the bridge. Clear notes and photographs are required. Inspectors must verify that all data is correct in the Central Database. The inspector must review and understand the data to make sure the input information is logical and consistent with all of the information available for the bridge, as well as check the input for errors.

Subsection 4.2.5  Fulfill Legal Responsibilities

The inspection report is a legal document, and concise descriptions using language consistent with the terms used in this manual needs to be used. An inspection report becomes a legal record when it is approved in the Central Database by the Inspection Team Leader. By approving an inspection report, the Inspection Team Leader is attesting to having been at the site and having taken an active part in the inspection. The Inspection Team Leader’s approval certifies that the information in the inspection report is accurate.

The District Bridge Engineer or the Bridge Inspection Consultant is responsible for quality control and quality assurance. Part 2 identifies the quality control and quality assurance process and the actions considered in violation of the State Bridge Inspection Program set forth in this manual and the consequences of such actions.
SECTION 4.3 INSPECTION PREPARATIONS

Good preparation will increase the quality of the field inspection. To develop an effective and efficient plan, the inspection team should research the bridge history, develop an inspection sequence, identify personnel requirements, and estimate a time frame for the inspection. They must ensure that all needed tools and safety devices are available. The team should format field notes, secure needed permits, anticipate traffic control and weather conditions, and plan for any material testing and bridge access. The team must determine if other measures are required to ensure the productive use of time in the field. Many of the steps used in planning an inspection are detailed below.

Subsection 4.3.1 Historical Research

It is critical to gather all available historical information. This may include:

- Original design plans.
- As-built plans.
- Original shop drawings.
- Construction history.
- Maintenance history.
- Rehabilitation history.
- Bridge inspection reports and photographs.
- Opening logs for movable bridges.

This information should be reviewed by the Inspection Team Leader prior to performing the inspection in order to identify members or components that need special attention, including fatigue-prone members and details, failure-prone details, and fracture critical components. Only copies of original plans and documents should be taken to the field.

Subsection 4.3.2 Identification of Critical Members or Details

As part of the inspection planning, the Inspection Team Leader should review bridge plans and inspection reports to determine the type and extent of any critical members or details. Critical details include fatigue-prone details, failure-prone members and details, fracture critical members, and member components. These members, components, and details must be identified in the Central Database. The Inspection Team Leader should review the load rating calculations to determine the locations of the lowest rated members. This is especially critical on bridges with load postings. The Inspection Team Leader should identify locations where cracks are likely to be found on the inspection plan.
Subsection 4.3.3  Confirm Bridge is Clean

A bridge must be clean enough for the inspection team to observe the conditions at the level of detail required. Generally inspectors are able to clean problem areas in the course of the inspection. However, if the amount of dirt or vegetation is such that this is not possible, the owner must clean the bridge before the inspection takes place. Inspectors should document any cleaning request to the owner. The level of effort in the cleaning is a function of the size of the bridge and the type of inspection. Extra attention must be given to cleaning a bridge for a Fracture Critical or Special Inspections. If possible, drift and debris should be removed prior to any Underwater or Scour Inspections.

Subsection 4.3.4  Plan Access

The proximity of a bridge to live traffic, waterways, rail lines, and utilities can make inspection access difficult. Inspectors must use good judgment and be safe.

Access equipment must provide the required level of access for the inspection and any required testing. The equipment, safety features, and procedures need to be evaluated prior to inspection. The safety documentation provided with the equipment, including emergency evacuation procedures, should be reviewed and understood. A sheet containing relevant safety information should be a part of the Plan of Action and attached to the bridge file in the Central Database. Access equipment typically used for inspections is discussed in Section 4.5 of this chapter. Inspectors should coordinate with railroads and property owners if necessary.

The bridge load capacity should be checked against the weight of any access equipment. The Inspection Team Leader should estimate the length of time the equipment will be needed. Obstacles such as utility lines, fences, adjacent buildings, and cross bracing must be considered. Trees and other vegetation may need to be cut back up to 20 feet from the copings, as well as under the bridge in order to provide unrestricted movement of access equipment.

Subsection 4.3.5  Formulate an Inspection Sequence

The Inspection Team Leader should formulate a logical sequence for inspection using the bridge plans, if available. If the bridge members are already identified and numbered on a set of structure plans, repair plans, or in a previous report, that same identification and numbering system should be used for continuity. If there is no existing numbering system, abutments and piers should be numbered from lowest to highest, from the south increasing to the north, or from the west increasing to the east. Abutments (end bents) are usually numbered with the piers, beginning with number one. Occasionally they are labeled A and B. In this case, the first pier to the north or east of Abutment A is labeled as number one. Pier columns and longitudinal superstructure elements, such as girders or stringers, should also be numbered from west to east or from south to north. The inspector should document any abnormal numbering system.
Subsection 4.3.6   Formulate an Inspection Plan

From the information gathered, a field inspection plan needs to be compiled prior to the inspection. A pre-inspection visit to the site may be required to develop or finalize this plan. A good plan should include most of the following:

- The type of inspection(s) to be completed
- A brief historical fact statement about the bridge type and condition
- Confirmation that the bridge has been properly cleaned for the type of inspection planned
- Copies of essential plans
- A mapped route to the site
- Keys for any locked access points
- Identification of tension members and fatigue-prone details, failure-prone details, and fracture critical members or member components
- Identification of access equipment and arrangements for it to be on-site
- Identification of inspection personnel and arrangements for them to be on-site
- Identification of inspection tools, safety equipment, and arrangements for these to be on-site
- Identification of required nondestructive testing (NDT) equipment and arrangements for it to be on-site
- Identification of traffic control requirements and arrangements for on-site implementation
- Press releases, if necessary
- Inspection time estimate
- Coordination with the owner and other agencies as required

All of the required information should be noted in the appropriate locations of the Central Database. On larger or more complex bridges, it may be necessary to create individual sections for each of the required areas of the inspection plan.
Subsection 4.3.7    Special Considerations

The Inspection Team Leader has many additional items to consider when planning an inspection including set-up time, the overall condition of the bridge, and the weather.

Set-up time can be significant and needs to be considered when planning an inspection. For example, rigging can take several days to complete before the inspectors arrive on site. Traffic control set up may take significant time before inspection work can start. Equipment, such as man lifts or compressors, may need to be set up and torn down or stowed daily.

It takes longer to document and inspect a bridge or component that is deteriorated because extra sketches, photographs, and measurements are required. Inspectors should use old inspection reports to estimate the time required for the inspection and reporting.

Unexpected weather conditions can adversely affect inspection work. Rain and wind can make bridges slippery or make man lift operation unsafe. Snow and fog can make traffic restrictions impractical and unsafe. Bridges in low lying, wet areas may have fog cover until mid-morning. The inspector should try to anticipate what types of weather could halt or slow the work and provide a contingency plan. Inspections should be halted, delayed, or postponed if there is any risk to the public or inspectors in the work zone due to inclement weather.
Inspectors should adhere to the procedures laid out in this manual. Inspection procedures are used to implement the inspection plan. It is critical that the Inspection Team Leader guide the inspection process to assure that each inspection is done safely and to the desired level of quality.

Uniform inspection techniques and recording are required for efficiency and completeness. No element of the bridge should be overlooked. The time spent on each element should be in proportion to the importance of the element. The inspector should systematically record all observations that affect the bridge at the time of the inspection or that may cause concern in the future.

**Subsection 4.4.1 Historical Review and Critical Member Plan Review**

The construction history, rehabilitation and maintenance history, and previous inspection records should be reviewed at the bridge site prior to performing an inspection. The bridge orientation should be reviewed to determine the location of critical members. The location of panel points in relation to bridge orientation should be confirmed.

The critical members identified in the inspection plan should be reviewed prior to performing the inspection. Look for details known to cause specific problems or deterioration. Note any maintenance, repairs, or rehabilitation made to the bridge since the last inspection and determine how this has affected the condition of the bridge.

**Subsection 4.4.2 Traffic Control**

Traffic control requirements should be reviewed prior to performing an inspection to assure safety of the inspection team and the traveling public. Traffic Control should be designed in accordance with Section 4.8 The inspection team should review safety considerations and the traffic control requirements with the people setting up and operating the traffic control if they are not part of the inspection team. All traffic control requirements, including railroad traffic control, should be documented.

**Subsection 4.4.3 Inspection Tools**

A review of the bridge and its condition should be performed to determine what tools may be required to perform a thorough visual or hands-on inspection and any required NDT. Section 4.5 lists common inspection equipment. Section 4.6 lists common equipment used for Underwater Inspections.

**Subsection 4.4.4 Field Inspection**

It is paramount that an inspection is thorough and complete. The condition of each member or component needs to be determined, including any deficiencies such as section loss, cracks, impact damage, and material flaws. To ensure a complete inspection, members should be checked off on the plan as they are inspected.
For a Routine Inspection, all members can be inspected from the ground or a suitable work platform as long as the inspector can determine with certainty that all bridge members are functioning properly.

Underwater Inspections require specialized procedures. These are discussed in Part 1, Chapter 3.

For Special and Fracture Critical Inspections, inspectors should perform a hands-on inspection of all pertinent members and components. For a Damage Inspection, inspectors should perform a hands-on inspection of all pertinent members and components, if possible.

NDT is required for certain details and may be required to further analyze defects. An inspector needs to meet the qualifications listed in Part 1, Chapter 2 in order to perform an official NDT investigation.

**Subsection 4.4.5 Data**

The team should discuss its findings before leaving the bridge site. The inspection data should be collected in its entirety at the bridge site. All notes need to be easy to understand and appropriate pictures should be labeled and dated. Follow good quality control practices to eliminate any errors or omissions.

Inspectors should document any defect(s) and list the recommended remedial actions. Items requiring immediate attention should be reported to the bridge owner and entered in the Central Database. See Part 1, Chapter 7, Emergency Notification, for problems that require prompt action to maintain public safety.

**Subsection 4.4.6 Re-rating, Load Posting, or Closure**

The inspection team may recommend the re-rating, load posting, or closure of a bridge based on the findings of the inspection. For state-owned bridges, the Office of Structural Services will perform or review any necessary load rating and maintain all required calculations. For county or locally owned bridges, the Inspection Consultant will perform or review any necessary load rating and maintain all required calculations. A copy of the load rating calculations and all supporting drawings and documentation shall be loaded into the Central Database. Additional information on load ratings is contained in Part 3 of this manual.

In Indiana, Inspection Team Leaders have the authority to close a bridge that poses an immediate danger to the public or shows signs of imminent failure. When an inspector finds a defect or damage that warrants closure, the inspector should close the bridge and secure the location to ensure that nobody gets injured. The inspector should enlist the help of the state highway patrol, county sheriff, local law enforcement, and state or county personnel to assist in restricting public access. Once the location is secure, the inspectors should follow the appropriate procedures described in Part 1, Chapter 7 of this manual.
Inspectors need the correct tools to perform their jobs safely, effectively, and efficiently. Most of the tools that the inspector will use are listed below. Equipment required for Underwater Inspections is discussed in Section 4.6.

**Subsection 4.5.1 Personal Protection Equipment**

Typical personal safety equipment includes the following:

- Two-way radio or cell phone
- Hard hat
- Steel-toed/steel shank shoes or boots
- Work gloves
- Class 3 reflective safety vest
- Safety glasses
- Fall protection equipment such as safety harnesses and lanyards

*Figure 1:4-2: Body Harness/Tie-Off*
• Life jacket for work over or near water
• Safety boat for work over water for long periods
• Hip boots or waders for work in relatively shallow, slow-moving waterways
• First aid kit
• Flashing light or beacon on the inspection vehicle to warn the public of the inspector’s presence
• Dust mask or respirator
• Air monitor
• Insect repellent
• Hearing protection

Subsection 4.5.2 Access Equipment

Common access equipment includes the following:

• Extension ladders
• Man lift
• Bucket truck
• Truck-mounted, moveable, under-bridge work platform
• Rigging (structure-mounted cables and platforms)
• Scaffolding and staging
• Boats, rafts, or barges
• Climbing equipment including safety harnesses and lanyards
• Climbers or spiders (mobile inspection platforms that “climb” steel cables; well-suited for tall vertical surfaces)
• Boatswain chair (one-man chair suspended by a rope and raised/lowered from above with a block and tackle system)
• Free-climbing apparatus (some bridges can be free-climbed by inspectors who have experience with appropriate climbing procedures, ropes, and equipment; method should be used only upon approval of the bridge owner)
Subsection 4.5.3 Cleaning Tools

Typical cleaning tools include the following:

- Whisk broom
- Shovel (for removing large amounts of debris)
- Two-inch scraper (for removing corrosion or plant/fungus growth)
- Steel wire brush (to remove light corrosion; for use on steel only)
- Brass wire brush (for use on metals other than steel)
- Spray primer (for priming steel where the inspector scraped or brushed off paint)
- Flathead screwdriver (for scraping or probing)
- Pressure washer
Subsection 4.5.4 Visual Aid Tools

Tools used to enhance the visual capabilities of the inspection include the following:

- Binoculars
- Magnifying glass (5x or 10x)
- Flashlight or similar light sources
- Telescoping, hinged inspection mirror

Subsection 4.5.5 Inspection Tools

Common hand tools used by inspectors include the following:

- Geologist hammer (or similar hammer)
- Sounding chains
- Pocket knife
- Ice pick
- Incremental borer
- Tool belt
- Probing rod
- Screwdriver and paint scraper

Subsection 4.5.6 Measuring Tools

Common tools used for measuring include the following:

- 100-foot tape
- 25-foot tape
- Six-foot rule
- Four- and two-foot levels
- Protractor
- Calipers
- Micrometer
- Feeler gauges
• Optical crack gauge
• Plumb bob
• Telescoping vertical clearance rod or laser rod device
• Thermometer
• Chaining pin
• Line string
• Chalk, keel, and paint sticks

Subsection 4.5.7 Sounding Equipment

A variety of equipment can be used to take water depth measurements. These water depth measurements, called soundings, can be obtained using the following:

• Calibrated weighted line approximately 50 feet long (often called a lead line)
• Range or sounding pole
• Fathometer (see Part 6)
• Sonar (see Part 6)
• Radar (see Part 6)

Subsection 4.5.8 Documentation Materials

Common tools used for documentation include the following:

• Inspection forms or laptop computer
• Digital camera with zoom capability and large storage capacity
• Clip board
• Extra paper
• Pencils/pens
• Straight edge
• Permanent marker
• Paint stick/marker and spray paint
• Lumber crayon
Subsection 4.5.9  Nondestructive Testing Equipment

Information on NDT equipment is contained in Part 6 of this manual.

Subsection 4.5.10  Confined Space Entry Equipment

Indiana requires a continuous air monitor and harnesses or some form of retrieval system to be used during any confined-space entry, whether it is a permit-required or non-permit confined space. See Subsection 4.7.3 for further information on confined spaces.

Subsection 4.5.11  Survey Equipment

Transits, levels, and other specialized survey equipment may be required when movement in a bridge needs to be measured in relation to a reference point.

Subsection 4.5.12  Mechanical Electrical Inspection Equipment

Refer to Part 5 for a description of the equipment required to perform a Mechanical or Electrical Equipment Inspection.
SECTION 4.6 UNDERWATER EQUIPMENT

Underwater inspectors require a mix of common inspection tools and specialized equipment to complete the inspection. These items provide a breathing medium for underwater work and a means of movement, and aid the inspector in collecting data.

Subsection 4.6.1 Underwater Personal Equipment

For Underwater Inspections, personal equipment generally includes the following:

- Wet or dry exposure suit
- Dive mask or helmet
- Breathing apparatus
- Air supply such as a portable tank or surface compressor unit
- Reserve air tank or J-valve on the tank
- Weight belt
- Dive fins
- Buoyancy compensator
- Depth gauge/pressure gauge
- Wristwatch
- Light source
- Knife

Subsection 4.6.2 Underwater Tools

The inspection team should have access to the appropriate tools and equipment warranted by the type of inspection being conducted. Power tools are rarely used. Typical hand-tools include the following:

- Ruler
- Calipers
- Probes such as ice picks, awls, screwdrivers, Geologist hammer (or similar hammer)
- Scrape
- Wire brush
- Pry bar
Subsection 4.6.3  Underwater Access Equipment

While access is often gained from the shoreline, some bridges are best accessed using a boat. Typically, an 18-foot or larger vessel can safely carry the equipment and crew. At some locations, access may be gained from the bridge itself.

Subsection 4.6.4  Underwater Communication Equipment

While it is not mandatory to be in voice communication during shallow water dive inspections, two-way voice communication greatly aids in the efficiency of the inspection data collection and recording while providing an added level of safety. For deep-water inspections, the use of two-way voice or hand-signal communication is recommended. With direct voice communication:

- The diver can communicate directly with the note-taker to describe the location, type, and size of any observed defects.
- The diver can discuss any observations with surface personnel.
- The surface personnel, while using video equipment, can direct the diver to specific areas that appear suspect or where closer investigation needs to be conducted.
- The diver can immediately report the extent of any problems.

Subsection 4.6.5  Underwater Testing Equipment

Often an inspection requires some level of material testing to ascertain the condition of the substructure unit that may not visually show any significant signs of deterioration. Testing is also the main component of a Level III inspection. Testing may be either nondestructive or partially-destructive and is described in detail in Part 6 of this manual. Nearly all the methods applicable for use on substructures discussed in Part 6 can be adapted for use underwater.

Subsection 4.6.6  Underwater Photography and Videography Equipment

A still or video camera can provide a visual record of defects or deterioration. This information can be reviewed with others to better define and evaluate the significance of the defect.

A still camera can be fitted with a variety of lenses and flash units suitable for different conditions. In low visibility, a wide-angle lens can be placed close to the object. A clear water box, constructed of clear plastic and filled with clean water, can help when visibility is low. By placing the box against the object to be photographed, the clean water will displace the murky water, allowing for a clear photograph. Refer to Figure 1:4-4 for a view of a typical clear water box.
Video equipment is generally available as self-contained submersible units, or as a submersible camera lens attached to the diver with a cable connection extending to a surface monitor and controls. The latter allows a surface operator to direct the shooting, control the lighting and focusing, and communicate with the diver to obtain the optimum image. A sound track could also be dubbed with the video image by the diver or topside personnel to provide a running commentary pertaining to the observations.
SECTION 4.7  SAFETY

The safety of the public and of bridge inspection personnel is paramount. Accidents can cause injury, suffering, and death. Accidents cost money in terms of lost equipment, lost production, medical expenses, and possible litigation costs. There is no safety guideline that can replace common sense and good judgment. Each bridge site is unique. If unusual working conditions exist, specialized safety precautions may be required.

Subsection 4.7.1 Public Safety

To protect the public, inspectors must:

- Use appropriate traffic control for vehicles and pedestrians. See Section 4.10.
- Maintain all traffic control, including cones and signs, in good working order.
- Make sure all tools and equipment are secure and cannot fall onto people or traffic below. A tool pouch, belt, or bucket is a good way to secure tools and items. Make certain not to push or drop debris onto people or traffic below.
- Discuss the needs of the public in a daily safety briefing before starting the inspection work.

Subsection 4.7.2 Inspection Team Safety

Inspectors should operate in groups of two or more when performing any inspection fieldwork. At least one of the team members should carry a mobile phone or a radio for use in case of an emergency. Three people are required for Underwater Inspection teams and inspection of any confined space. See Subsection 4.8.3 for details on confined spaces. Inspection personnel should have certified first aid training.

Inspectors should be alert and follow all safety instructions and procedures. Inspectors should be familiar with federal (Occupational Safety and Health Administration [OSHA]) and local safety standards and requirements. OSHA requirements are minimum standards to be followed. Requirements that are more stringent may exist, depending on the activity or the bridge owner. The inspector is responsible for knowing this information and adhering to the applicable requirements and standards. Work areas should be kept clean and uncluttered.
If the water or channel bottom is so polluted that it poses a hazard to an inspector, special precautions must be taken to ensure inspector safety. The details of these precautions are dependent on the type of pollution, the water depth, the water velocity, and the channel bottom condition. The Plan of Action for these inspections must outline how the inspector will be protected.

When performing any type of inspections during or immediately after a disaster or flood event, it is important to take extra precautions. Approach bridges to be inspected cautiously:

- Do not dive or enter on foot into flood waters.
- Avoid channel banks and flooded areas.
- Watch out for and stay away from downed power lines.
- Stay away from the bridge if there is any indication of structure settlement due to scour, such as substructure tipping or superstructure misalignment.
- Do not drive on or stand beneath any suspect bridge.

Follow the traffic control plan at all times. See Section 4.9 for traffic control information.

Appropriate personal protective equipment should be worn at all times. A Class 3 safety vest must be worn by inspectors and others in the work zone at all times. Other necessary safety items include, but are not limited to, steel-tipped safety boots, hard hats in construction zones or per owner requirements, and proper safety harnesses and lanyards where applicable. Proper hand, hearing, sight, breathing, and face protection should be used whenever appropriate such as when scraping paint, corrosion, or bird droppings from any inspection area, or during the use of any manual or power tools.
Inspectors should be familiar with and use the proper tools. All equipment, safety devices, and machinery should be kept in good operating condition. Lanyards, safety harnesses, life jackets, and other personal safety equipment should be used in accordance with applicable standards. All safety equipment should be in good working order. Worn or damaged equipment should be discarded. Inspection personnel should keep safety equipment clean and away from potentially harmful chemicals such as gasoline, dye penetrant, or oil.

The Inspection Team Leader should conduct daily safety briefings to discuss the unique nature of each job site and to reinforce the basic safety tenants.

**Subsection 4.7.3  Confined Space Entry Safety**

A confined space is a space that:

- Is large enough and so configured that an employee can bodily enter and perform assigned work.
- Has limited or restricted means for entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
- Is not designed for continuous human occupancy.

Work safety in a confined space must address the lack of oxygen and possible toxic or explosive gasses such as pollutants, carbon monoxide, methane, or petroleum fumes. Confined spaces can be deadly if an inspector does not follow the proper procedures. The interior of a box girder, a vaulted abutment, or a long culvert can all be confined spaces.

Confined spaces are classified as permit-required or non-permit confined spaces. A permit-required confined space is one that:

- Contains or has potential to contain a hazardous atmosphere.
- Contains material that has the potential for engulfing an entrant, has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by floors which slope downward and tapers to a smaller cross section.
- Contains any other recognized serious safety and health hazard.

A non-permit confined space is a confined space that does not contain or, with respect to atmosphere hazards, have the potential to contain any hazard capable of causing death or serious physical harm.

The classification of a confined space must be verified in the field by the inspection team and documented in the Central Database. Although the bridge file should contain information documenting past testing and the classification of the confined space, the space should be treated as permit-required until on-site data is collected to support the designation as a non-permit confined space.
As a minimum, all OSHA requirements should be followed. The OSHA standard for “Permit-Required Confined Spaces” can be found in Chapter 29 of the Code of Federal Regulations, Part 1910.146. The Inspection Team Leader must contact the bridge owner and the team’s employer to determine if his/her entry requirements are more restrictive than the OSHA requirements. The most restrictive requirements will govern. The Inspection Team Leader is responsible for the safe execution of the work in a confined space, the documentation of all required safety measures, and for the correct implementation of all required permits or certificates.

Three people are required for any permit-required or non-permit confined space inspection. Two Inspection Team Members, called entrants, are allowed to enter the confined space. Entrants should wear harnesses or some form of retrieval system while working in a confined space. One person, called the attendant, must remain outside of the space at the point of entry at all times and be in constant communication with those working in the confined space. The attendant keeps the permit for permit-required spaces or certification for non-permit spaces. The attendant must have an emergency/rescue plan that includes local emergency contact information and details on the method of communication to be used between the attendant and those entering the confined space.

Before any team member enters any permit-required or non-permit confined space, the internal atmosphere shall be tested for all of the following, in the given order, with a calibrated direct-reading instrument:

1. Oxygen content
2. Flammable gasses for vapors
3. Potential toxic air contaminants
4. Stratified/layered atmospheres if work is at different levels

Continuous air monitoring is required during any confined space inspection.
Subsection 4.7.4 Vehicle Safety

All nonparticipating inspection vehicles and equipment should be parked off the roadway. If appropriate traffic control exists, inspection vehicles or equipment can be parked inside the safe work zone. A driveway, parking lot, or even a large gore area can be safer than parking along the roadway. If no such suitable area exists near the bridge, then vehicles should be parked on a nearby roadway with the least traffic or the widest shoulders. If parking adjacent to a roadway, use flashers or an amber warning light on the vehicle and set cones or reflectors behind all parked vehicles. Make sure all vehicles are running before any inspectors leave the site.
Inspection vehicles, underbridge access equipment, trucks, and vans should be inspected, operated, and maintained in accordance with the manufacturer’s recommendations. Personnel should be trained in the safe use of the vehicles and emergency procedures in the event of an equipment failure. Inspection vehicles should be kept away from live traffic. Equipment such as man lifts should never be extended over live lanes of traffic. Man lifts and similar equipment should not be operated directly adjacent to live traffic, for example, on a narrow shoulder, without providing appropriate traffic control.

If an inspection vehicle is required to be on the bridge, the Inspection Team Leader should arrange to provide personnel, proper lane closure, traffic control equipment, and communication for vehicle operations.

Underbridge access units should be operated by a minimum of two people. At least one person in the truck and one person in the bucket should be trained to operate the vehicle.

If one inspector is performing aerial work, it is required to have another inspector on the ground. The inspector on the ground should observe vehicle and pedestrian traffic and relay pertinent information, such as stray vehicles or pedestrians in the work zone, to the aerial inspector. The inspector on the ground can also take notes for the aerial inspector and guide him around the bridge. By following this procedure, the aerial inspector can concentrate on inspecting and the inspector on the ground can protect the work zone. Both inspectors should have radios in order to communicate.
Subsection 4.8.1 Introduction

Inspection operations can create unexpected and unusual situations for motorists. Effective traffic control eliminates surprises and routes traffic safely around any hazards, inspection personnel, or equipment. Indiana utilizes the Handbook for Temporary Traffic Control, Construction, Maintenance, and Utility Operations, 2009, developed by the Local Technical Assistance Program in West Lafayette, Indiana. The handbook illustrates the principles of proper work zone traffic controls and covers the basic requirements of Part VI of the Manual on Uniform Traffic Control Devices (MUTCD). Part VI of the MUTCD and the Indiana MUTCD supplement contain the standards for work zone traffic control.

In urban areas, an inspection that requires traffic lane closures may be restricted to certain hours of low traffic volume. Some days, such as holiday weekends, may be banned from any traffic restrictions. The Inspection Team Leader should be aware of this and plan the inspection work with input from the bridge owner.

For work on interstate highways, see the Indiana Department of Transportation’s (INDOT’s) complete interstate lane closure policy, at http://www.in.gov/dot/div/contracts/standards/memos/memos.html.

Figure 1:4-8: Barrels Channel Traffic Away From Work Zone
Subsection 4.8.2 Traffic Control Plan

Traffic control plans are required for any inspection work that will adversely affect the smooth flow of traffic through the work zone. A traffic control plan should be designed by the Inspection Team Leader, state or county traffic personnel, or a qualified employee of a traffic control subcontractor and documented in the Plan of Action. Consultants working on state-owned or toll road bridges must submit any traffic control plans to the owner for approval at least two weeks prior to the start of the work. Inspectors for counties and local agencies should coordinate with the bridge owner for traffic control. A traffic control plan is a plan view drawing of the proposed work zone that shows where traffic control devices will be placed, what devices will be used, and how they will be oriented. All parties that will be operating in the work zone should review and be familiar with the traffic control plan. If the traffic control plan changes, the changes need to be approved by the Inspection Team Leader. All affected parties should become familiar with the changes prior to working in the field.

Subsection 4.8.3 Fundamentals of Traffic Control

Traffic control should be designed and implemented to inform and guide motorists and pedestrians, and to provide a clearly marked path of travel.

Figure 1:4-9: Truck-Mounted Crash Attenuator
There should not be any surprises. Proper use of signs can keep the motorist informed of unexpected conditions. The geometry, signs, and lights used for traffic control should resemble the unobstructed roadway conditions as closely as possible. Speed limit signs can be used to slow traffic in the work zone. Warning signs must be used to inform motorists of unusual or changing conditions. All traffic control devices should be promptly removed once they are no longer needed.

Channelizing devices include, but are not limited to, traffic cones, barrels, barricades, and wands. They should be used properly to define a clear, definite path for drivers to follow. Channelization devices should also provide drivers with a smooth, gradual transition from one lane to another, onto a bypass or a detour, or through the narrowing of a traveled lane or shoulder. Abrupt changes should be avoided. Channelization devices need to be monitored regularly to ensure that they are in place, according to plan, and functional.
It may be necessary to secure access to private properties, obtain permits, or complete special training prior to doing field inspection work.

**Subsection 4.9.1 Railroad Permits**

Inspectors in the state of Indiana, including consultants, may cross onto any railroad right-of-way to conduct their regular inspection work in accordance with IC-8-23-7-26 and IC 8-3-15-3. Nevertheless, the Inspection Team Leader shall contact the subject railroad prior to the inspection and shall request a flagman if they need to work over a live track. The Inspection Team Leader must document his/her efforts to request a flagger. If the railroad does not respond, this must be documented in the Central Database and inspectors must restrict their inspection to avoid working over the tracks.

Railroads may send a railway flagman to the site to direct and caution railroad traffic when inspectors are working in a railway corridor. Railroads may pass the cost of the flagman onto the agency that ordered the inspection. In some cases, railroads may require that inspectors receive special safety training and/or obtain special insurance prior to performing the inspection. Railroads may have restrictions on the proximity of people and equipment to all railroad tracks. These details need to be finalized prior to the field inspection.

![Figure 1:4-11: Inspectors Working Next to a Live Railway](image-url)
Subsection 4.9.2   Waterway Permits

The Inspection Team Leader must notify the appropriate United States Coast Guard (USCG) District Office if an inspection will require the placement of equipment in a navigable waterway, or will reduce navigation clearances (e.g., when a snooper truck platform or arm is used under a bridge). The Indiana Natural Resources Commission Web site lists navigable waterways, as determined by the US Army Corps of Engineers: http://www.in.gov/dnr/water/files/Appdx_G-3.pdf.

The Coast Guard Eighth District includes most of the state south of Fort Wayne and the Coast Guard Ninth district includes the northern portion of the state. District contact information is listed below. For jurisdiction details, see the USCG Web site: http://www.uscg.mil/top/units.

Commander (dwb)                                  Commander (dpb)
Eighth Coast Guard District                        Ninth Coast Guard District
1222 Spruce Street                                 1240 East 9th Street, Room 2025
St. Louis, MO 63103                                Cleveland, OH, 44199-2060
E-mail: Roger.K.Wiebusch@uscg.mil               E-mail: Scot.M.Striffler@uscg.mil
Phone: 314-269-2378                                  Phone: 216-902-6087

The Corps of Engineers must be notified if an inspection will require the placement of equipment in a reservoir. Contact the US Army Corps of Engineers at hq-publicaffairs@usace.army.

Subsection 4.9.3   Confined Space Permits

If a confined space has been determined to be a permit-required confined space, inspectors must follow the OSHA standard for permit-required confined spaces in Chapter 29 of the Code of Federal Regulations, Part 1910.146.
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CHAPTER 5  REPORTING SYSTEMS

SECTION 5.1  BRIDGE FILE

Indiana uses a Central Database to collect the information required by National Bridge Inspection Standards (NBIS). The database allows the bridge owner to manage all inspection records electronically for the life of each structure.

The Central Database is the only official bridge file for all inventoried bridges in Indiana. This file shall include all National Bridge Inventory (NBI) data and supplemental data including the following as a minimum:

- Inspection History – The bridge file shall contain as a minimum two complete bridge inspection files for an existing bridge. Each file will include the items as outlined in chapter three for the type of inspection required.

- Construction Plans and Repair History – All available bridge plans are to be uploaded into BIAS. This will include as-built drawings and working drawings.

- Rating Records – The bridge file will include a complete record of the determination of the bridge's load-carrying capacity. If posting is necessary, a summary of all posting actions taken for the bridge, including load capacity calculations, date of posting, and description of signing used.
SECTION 5.2 STRUCTURE IDENTIFICATION

Subsection 5.2.1 NBI Item 8 Structure Number

NBI Item 8, Structure Number, is called Item 8, Structure Number (NBI number) in the Central Database. This number is assigned by the Inspection Consultant for county bridges and by the State Program Manager for state bridges. This number is seven digits long for county bridges. The first two digits are the county number. State bridges use up to six digit numbers. The NBI number is unique and remains unchanged throughout the life of a bridge. When a bridge is replaced, the new bridge gets a new NBI number.

Subsection 5.2.2 INDOT Bridge Number

The state uses an alpha-numeric numbering system to identify an Item 8S, Indiana Department of Transportation (INDOT) Bridge Number. Up to 19 digits are reserved for this number, excluding parentheses and dashes, and for new bridges it is generally in the form “A (123)456-789-12345 BCDE.” The following describes each part of the INDOT Bridge Number:

- **A**: Up to one letter to indicate property designation:
  - I for Interstate bridges
  - P for state properties including parks, prisons, and hospitals
  - Blank for bridges on a designated United States (U.S.) or state route

- **(123)456**: Up to six digits to designate the road number. Parentheses are required only if the road number has changed. For these situations, indicate the current road number within the parentheses and indicate the old road number to the right of the parenthesis. Do not include leading zeros if the road number is less than three digits (e.g., use 8 and not 008 for Route 8). If the bridge is carrying multiple routes, as in the example, (123) is the current route with the highest status and 456 is the route with the second highest status.

- **789**: Up to three digits to designate log mile or county number, depending on the bridge. If the bridge is located on an interstate, this number is up to three digits long, with no leading zeros, and designates the mile post rounded to the nearest whole mile. If the bridge is located on any other type of road, this is always a two-digit number, with a leading zero if necessary, that designates the county number. There are 92 counties in Indiana. County number 93 is used for border bridges that are inventoried by Kentucky or Illinois, or are Indiana’s inventoried bridges located south of the state line on US 41.
• 12345: Five digits to designate the Structure Number. It is a consecutively assigned number assigned by the State and is not related to Item 8, the Structure Number (NBI Number). Leading zeros are required to ensure five digits. Typically, the 02000 series bridges are reserved for bridges over or under a railroad.

• BCDE: Up to four letters to designate the structure designation.
  o The first letter indicates:
    ▪ J Parallel, but different bridge
    ▪ A First contract rehabilitation
    ▪ B Second contract rehabilitation
    ▪ C Third contract rehabilitation, etc.
  o The remaining three letters complete the structure designation as follows:
    ▪ EBL Eastbound Lane
    ▪ WBL Westbound Lane
    ▪ NBL Northbound Lane
    ▪ SBL Southbound Lane
    ▪ ADJ Adjacent to Mainline
    ▪ CD Collector Distributor
    ▪ DR Directional Ramp
    ▪ R Ramp
    ▪ NC Northbound Collector
    ▪ NWE Northwest-to-East Ramp
    ▪ SC Southbound Collector
    ▪ DRN Directional Ramp North
    ▪ RWN Ramp West to North

When a bridge is both a parallel bridge and has been rehabilitated, use the first two letters of BCDE to show this and drop the third letter describing the structure designation. For example; JCNB would indicate that the bridge is one of two parallel structures, has been rehabilitated three times, and serves northbound lanes.
Many older bridges within Indiana do not adhere to these guidelines. Bridges along state borders may have special agreements that determine the ownership of the bridges and the bridge number.

Subsection 5.2.3  Toll Road Bridge Numbers

The Indiana Toll Road uses a numbering system similar to the state bridge numbering system for item 8S that is generally in the form “A(123)456-78-91234 BCD.” The following describes the state bridge numbering system:

- **A**: One letter coded I for all toll road bridges.
- **(123)**: Current road number. The leading zero is sometimes omitted.
- **456**: Original road number. This number is omitted if the road number has never changed.
- **78**: Two-digit county code.
- **91234**: Five-digit structure number assigned by the Toll Authority according to the mileage east of the Illinois state line. The Toll Authority does not utilize any special conventions for bridges over or under railroads.
- **BCD**: Structure designation similar to the state bridge numbers except the Indiana Toll Road does not assign letters to identify parallel structures or the number of rehabilitations a structure has undergone.

There are several Indiana Toll Road-owned and maintained bridges that were designed and built by the State which have bridge numbers similar to those used by the State.

Subsection 5.2.4  County and Local Agency Bridge Numbers

County and local agency bridge numbers are preceded by one letter. “A” indicates that the bridge is the first bridge at a particular location. A “B” indicates the bridge is the second bridge at this location, etc. This letter is followed by a five-digit number determined by the county. Some counties use a numbering system similar to the state bridge numbering system, but most systematically number bridges by route or location.
 SECTION 5.3 COUNTY BORDER INVENTORY

For state bridges, inventory all bridges along or crossing the north and west borders of a county as being in that county. Inventory all bridges along or crossing the south and east borders of a county as being in the adjacent county.

For county bridges, inventory all bridges along or crossing the south and east borders of a county as being in that county. All bridges along or crossing the north and west borders of a county are inventoried in the adjacent county. See Indiana Code IC: 8-17-1-45(a).

For bridges along the state borders, special agreements may determine the ownership of the bridges.
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CHAPTER 6 DISASTER RESPONSE

SECTION 6.1 INTRODUCTION

The road and bridge system is an essential component of the lifelines to a community following a disaster. A disaster that would trigger the response described in this chapter is usually a widespread incident such as a flood, ice storm, or earthquake greater than 5.0 in magnitude. However, a more localized incident such as a fire or tornado could precipitate such a systematic appraisal.

When a disaster hits, it is critical to quickly assess the road and bridge system for safety and functionality. An accurate damage assessment is needed to allocate resources required to restore transportation routes which will, in turn, enable all relief and reconstruction efforts.

The purpose of these initial assessments, called Level 1 assessments, is to restrict traffic on unsafe bridges and roads, identify those bridges and roads that are safe, and identify those in need of a Damage Inspection by bridge inspectors.

These assessments are conducted under the jurisdiction of the bridge owner and may be performed by a wide range of personnel. In the event of a State Disaster, the State Emergency Management protocol will be followed.

It is critical that these initial, Level 1 inspections are thorough and uniform. This chapter describes the Level 1 assessment of the transportation network.

Safety of the individuals performing this work is paramount. While performing any type of inspections during or immediately after a disaster, it is important to take extra precautions. Approach bridges to be inspected cautiously.

- Do not dive or enter on foot into flood waters.
- Avoid channel banks and flooded areas.
- Watch out for and stay away from downed power lines.
- Stay away from the bridge if there is any indication of structure settlement due to scour, such as substructure tipping or superstructure misalignment.
- Do not drive or stand beneath any suspect bridge.
A basic understanding of bridge construction is required to perform a Level 1 inspection. Highway bridges have a superstructure and a substructure, or they are underfill structures.

The superstructure is the part of the bridge that carries the traffic. It includes the deck, and the beams, girders, or truss members that support the deck. The substructure carries the loads from the superstructure to the ground and includes the abutments, piers, columns footings, and piles. Bearings are often placed between the superstructure and substructure and act to support the beams, girders, and trusses in the superstructure and transfer the superstructure loads to the substructure. Figure 1:6-1 identifies the key components of a typical highway bridge.

![Figure 1:6-1: Typical Bridge Components](image)

Underfill structures do not have a roadway deck and there is no distinction between the substructure and the superstructure. Underfill structures are often called culverts or tunnels, but are classified as bridges if they span more than 20 feet. They are usually covered by roadway fill material. Figure 1:6-2 shows a typical two-cell, reinforced, concrete underfill structure.
Indiana has many types of bridges made from various materials including steel, concrete, timber, and masonry. Some typical Indiana bridge types and girder configurations are shown below. Also shown are some typical bearings.
Figure 1:6-4: Continuous Reinforced Concrete Slab Bridge

Figure 1:6-5: Precast Concrete Underfill Bridge
Figure 1:6-6: Reinforced Concrete Girder Bridge

Figure 1:6-7: Steel Girder Bridge

Figure 1:6-8: Steel Box Girder Bridge
Figure 1:6-9: Steel Through Girder Bridge

Figure 1:6-10: Steel Pony Truss

Figure 1:6-11: Steel Through Truss
Figure 1:6-12: Steel Tied Arch Truss

Figure 1:6-13: Continuous Steel Beam Bridge
Figure 1:6-14: Prestressed Concrete Box Beams

Figure 1:6-15: Prestressed Concrete I Beams

Figure 1:6-16: Rocker Bearing With Seismic Restraint
Figure 1:6-17: Elastomeric Bearing

Figure 1:6-18: Pot Bearing
Figure 1:6-19: Five-Barrel Corrugated Steel Underfill Structure
Each District and Subdistrict should have Level 1 Disaster Inspection route maps organized for efficient coverage of the area. Paper copies of the Rapid Assessment Form, discussed below, and a list of equipment should be stored with these route maps in a designated cabinet. For safety, a minimum of two people should be on each assessment team.

Each Level 1 assessment team should carry the following equipment:

- Safety vest, hard hat, first aid kit
- Radio or cellular phone
- Paper copies of the Level 1 Rapid Assessment Form
- Route maps, county maps, and a state map
- A list of the bridges on each route
- Clipboard, pen, pencil, and waterproof marker
- Camera
- Binoculars
- Tape measure
- Flashlight and extra batteries
- Red, yellow, and green ribbons
- Road Closed signs, flashers, and standards
- Barrels, cones, and traffic control paddles
- Hammer and probing rod

The Rapid Assessment Form for a Level 1 Disaster Inspection is shown in Section 6.7. This form is for multiple bridges. Each bridge is assessed on one line of the form.
The goal of a Level 1 disaster assessment is to make a quick and accurate decision as to whether the bridge is able to remain open, needs further study, or must be closed. The information gathered can save lives, so this work must not be interrupted except in a life-or-death situation.

Safety is paramount. Never walk on or under a bridge unless you are confident there is no serious problem. Stay away from any bridge if there is indication of structure settlement due to scour, such as substructure tipping or superstructure misalignment. Walk around the bridge, if possible, to assess the overall condition. Never walk under any bridge after an earthquake. Expect earthquake aftershocks and check water levels for changes that may indicate the escalation of a flooding problem. Take extra precautions during and immediately after a flood event. Approach structures cautiously and avoid channel banks and flooded areas. Do not dive or enter on foot into flood waters. Stay away from downed power lines.

Notify the owner and the appropriate Indiana Department of Transportation (INDOT) Unit, District, or Subdistrict if any road or bridge needs to be closed to traffic, as soon as you realize this is necessary. Proceed with the closure protocol discussed in Section 6.6.

At each bridge, follow these steps:

- Record the bridge number.
- Assess the safety of the site for hazards that might preclude walking on or under the bridge, including misalignment.
- Complete one line of the Rapid Assessment Form for each bridge. The Rapid Assessment Form is available in Section 6.7.

An outline of Items 1-6 on Rapid Assessment Form includes the following:

- Item 1: Roadway assessment
  - Check Green if:
    - Any damage is minor and does not impede traffic.
    - There is less than one-inch settlement between sections.
  - Check Yellow if:
    - Any damage impedes traffic.
    - There is one to six inches of settlement between sections.
PART 1: ADMINISTRATION

Assessment

- Check Red if:
  - Travel is dangerous for traffic.
  - There is more than six inches of settlement between sections.

![Figure 1:6-20: Roadway With More Than Six Inches of Settlement: Red](image)

- Item 2: Superstructure Assessment
  - Check Green if:
    - There is less than one inch of offset in the vertical or horizontal alignment at any joint.
    - The only cracks in any concrete beams are vertical.
  - Check Yellow if:
    - There is an offset between one and six inches in the vertical or horizontal alignment anywhere.
    - There are any diagonal cracks in any concrete beams.
    - The reinforcing steel is visible on any concrete member.
    - There are cracks in any steel member.
    - Large debris, such as a tree trunk, is caught on the superstructure.
Check Red if:

- There is any buckling in any beam or column.
- Any connections, such as bolts, are broken or missing.
- Water has overtopped the bridge deck.
- There is visible displacement of the superstructure while sighting along the bridge.

Figure 1:6-21: Superstructure With Offset Between One and Six Inches: Yellow

Figure 1:6-22: Superstructure With Broken Bolts: Red
Figure 1:6-23: Buckled Steel in Superstructure: Red

Figure 1:6-24: Superstructure With More Than Six Inches of Alignment Offset: Red
Figure 1:6-25: Superstructure Overtopped: Red

- Item 3: Substructure Assessment
  - Check Green if the only cracks in piers or abutments are horizontal.
  - Check Yellow if:
    - There are one to six inches of offset in the vertical or horizontal alignment of any part of the substructure.
    - There are any diagonal cracks in the concrete substructure component.
    - Reinforcing steel is visible on any concrete substructure component.
    - There are any cracks in any steel substructure member.
    - Large debris, such as a tree trunk, is caught on the substructure.
  - Check Red if:
    - Any member has tipped or buckled, or has localized buckling of any part.
    - Any member is offset more than six inches.
    - The bottom of any substructure unit is exposed.
Figure 1:6-26: Substructure With Diagonal Crack: Yellow
Figure 1:6-27: Concrete Substructure With Visible Steel: Yellow

Figure 1:6-28: Substructure Misalignment Greater Than Six Inches: Red

Figure 1:6-29: Substructure Failure; Reinforcing Steel Has Buckled: Red
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- Item 4: Bearings
  - Check Green if there is no obvious problem.
  - Check Yellow if a bearing is tipped or has moved.
  - Check Red if a bearing is no longer supporting the beam.

Figure 1:6-30: Bearing No Longer Supporting the Beam: Red

Figure 1:6-31: Bearing With Movement: Yellow

Figure 1:6-32: Bearing With Excessive Tipping: Yellow
Item 5: Ground and Soil Assessment

- Check Green if there is less than six inches of space between the base of any substructure component and the surrounding soil.

- Check Yellow if:
  - There is more than six inches of space between the base of any substructure component and the ground.
  - There is significant erosion of the embankment that could threaten the stability of an abutment or the approach.

- Check Red if:
  - Any ground condition makes the route impassible.
  - There is evidence of bank instability, such as sloughing due to scour or lateral stream movements.
  - The soil around foundation units or roadway embankments has moved significantly due to the event.
  - The piling or the bottom of any foundation unit has been exposed.

Figure 1:6-33: Vertical Movement Indicates Soil Shear Failure: Red
Figure 1:6-34: Soil More Than Six Inches From Column: Yellow

- Item 6: Other Problems
  - Check Green if no additional problems are visible.
  - Check Yellow if you are unsure of the safety of any component not identified above, such as a damaged utility or pipeline.
  - Check Red if there is a hazard to the public such as a leaking gas main or debris blocking traffic, or if elements that are essential to safe passage are missing.

- For the Overall assessment:
  - Check Green if Items 1 through 5 have been checked Green and any problems noted under Item 6 are checked Yellow and do not endanger the traveling public. Green means the bridge structure was not damaged in this disaster.
  - Check Yellow if any of the Items 1 through 6 have been checked Yellow or if you are unsure of the safety of any component. Yellow means the bridge can be used, but further inspection and/or repairs are needed.
  - Check Red if any Item 1 through 6 has been checked Red. Red means the bridge should be closed to traffic.
SECTION 6.5 FOLLOW-UP

After the assessment is complete:

- Notify the owner and the appropriate INDOT Unit, District, or Subdistrict if any road or bridge needs to be closed to traffic as soon as you realize this is necessary. Proceed with the closure protocol.

- Attach the appropriate green, yellow, or red ribbon to the most readily visible component of the bridge or approach guardrail on each end of the bridge you are able to access.

- Mark each ribbon with the time and date of the assessment and the names of the inspectors.

- If possible, proceed to the next bridge until all are inspected. If closure(s) require a new route, proceed to the next route and continue inspecting bridges on that route.

- Record the time of departure from the last bridge on the page.

- Return to base for further instructions.
SECTION 6.6 CLOSURE PROTOCOL

The bridge owner has a responsibility to take all reasonable actions to notify and protect the public as soon as the need for a road closure is known. In a disaster, an abbreviated version of the standard closure policy is required to expedite this critical safety component.

Each assessment team shall maintain a minimum of one set (two signs) of “Road Closed” signs (Figure 1:6-35) with type B flashers and sign supports for each primary disaster route in its unit. If a bridge needs to be closed, the team should install a sign at each approach and notify the INDOT Unit/District/Subdistrict immediately so that a detour can be established and appropriate signage and barricading can be placed in a timely manner by follow-up personnel. Once this is done, Level 1 inspectors shall continue the inspection on their primary route using the state and county maps to find a way around the closure. If additional closures are encountered, that information must be relayed back to the INDOT Unit/Subdistrict for assistance. One inspector may have to remain at the closure until relieved if no signage or other traffic control is available. Local law enforcement may be able to assist with the traffic control.

Figure 1:6-35: Road Closed Signs for Disasters
## Rapid Assessment Form

<table>
<thead>
<tr>
<th>Item 1: Roadway structure</th>
<th>Item 4: Bridge bearings</th>
<th>Item 5: Soil</th>
<th>Item 6: Other problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Bridge Assessment</th>
<th>Red Yellow Tag</th>
<th>Green Tag</th>
<th>Tag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Date:**

**Route:**

**Team:** From Intersection:

**Time of Arrival:**

**Notes:**

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**June 2010**

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CHAPTER 7     EMERGENCY NOTIFICATION

SECTION 7.1     INTRODUCTION

The procedures in this chapter set forth a uniform method for timely notification of serious bridge deficiencies that require an immediate response. They also document the baseline requirements for assuring that appropriate corrective or protective measures have been taken within a reasonable time frame and that established documentation protocol has been followed. Counties and other local government agencies may have additional guidelines for alternate route information, public relations, and information dissemination procedures that should be followed.

Each county, the Indiana Toll Road, and each Indiana Department of Transportation (INDOT) District has a Comprehensive Emergency Management Plan (CEMP). While these plans will not typically need to be implemented for the closure of a bridge, District Inspection Engineers and Inspection Consultants should be thoroughly familiar with these plans and the need for bridge emergency notification plans and disaster plans to work together.

The procedures outlined in this chapter should be used to report conditions posing danger to persons or property or conditions that, if left unattended, would likely become such a danger.

This chapter outlines the responsibilities of the Inspection Team Leader, Inspection Consultants, District Inspection Engineers, and the State Program Manager in an emergency. Any Inspection Team Leader may close any bridge if it appears to be unsafe. For state-owned bridges, closure should be done in accordance with the state protocol described below and shown in Figure 1:7-4. Any state, county, or local representative, such as a law enforcement officer or maintenance worker, may also temporarily close a bridge if safety concerns exist.
SECTION 7.2 CRITICAL DEFICIENCIES

A critical finding is a structural or safety related deficiency that requires immediate follow-up inspection or action.

A structure-related deficiency can interrupt the load path, not allowing the loads to be transferred as designed. This can cause surrounding elements to become overstressed or unstable, potentially leading to partial or total collapse of the structure. Critical findings may also be non-structural deficiencies which jeopardize the safety of motorists or pedestrians.

The follow-up action may be a structural review to determine the strength or serviceability of an element or bridge.

Subsection 7.2.1 Procedures for Inspectors

Upon identifying a potential critical finding, immediately report the deficiency to the appropriate agency officials. For non-state owned bridges, the finding is to be first reported to the employee of responsible charge (ERC). The finding for state owned bridges and the second reporting for non-state owned bridges is to be the State Bridge Inspection Program Manager (SBIPM).

The immediate actions taken by the inspector will vary with the circumstance. The inspector may close all or part of the structure until further analysis can be performed to determine the structural integrity of the structure. Alternatively, the inspector may recommend that remedial work be performed within a short time frame. Even if no immediate action is taken, it is still required to report the potential critical finding immediately, even in situations where the structural review will ultimately resolve the structure as having adequate strength.

In addition to the initial reporting of the potential critical finding, which may be verbal notification, a written notification is required within 24 hours. The notification will include complete identification of the structure, the structure location, and a plan of action indicating how the critical finding will be remedied. The electronically written notification serves to document the critical finding by describing the extent of the deficiency complete with notes, photographs, sketches and drawings, measurements, possible causes, and recommendations for repair. Temporary actions may also be taken to safeguard the public until repairs can be completed. These actions may include:

- Load posting
- Traffic restrictions from the damaged area
- Speed restrictions
- Temporary lane closure
- Temporary shoring
- Complete bridge closure

The SBIPM will record the critical finding for tracking and will notify the FHWA in a timely manner. The inspector must submit electronically a written explanation of the actions taken to close the critical finding file with the SBIPM. This written explanation
may include calculations which demonstrate the structural capacity of the structure, pictures which show the structure has been properly closed, or pictures showing the structure has been structurally fortified.

**The following information will be included in the critical finding notification:**

1. Name of Bridge Inspection Team Leader and Team Leader Number:

2. Bridge Structure Number:

3. Bridge NBI Number:

4. County:

5. Route:

6. Location of structure measured from the nearest intersection:

7. Date of finding:

8. Date of notification:

9. Reason for Critical Finding Report: This portion of the report shall include pictures and sketches to support the report. The date of the finding shall be included.

10. Inspector’s Immediate Recommendations: If these recommendations include actions that must be taken by others, a time necessary to take these actions will be given.

11. Follow-up Actions: Give a complete description of the actions taken and when these items were complete.

12. Close out document: Describe how the critical finding was resolved and when. This item may include picture, sketches, plans, or calculations to fully explain how the critical finding was resolved. The close out document will be sent to the Program Manager to officially close the critical finding.

**Subsection 7.2.2 Documentation**

Critical Deficiencies must be documented in the Central Database within 24 hours for all bridges. The Critical Deficiency should be described in the comment box. Note, in the comment box, each person notified of the Critical Deficiency. Reference the INDOT Coding Guide, Bridge Reporting for Appraisal and Greater Inventory (BRAGI) for coding instructions.
Figure 1:7-1: Critical Deficiency – Shear Crack in Pier Column
Figure 1:7-2: Critical Deficiency – Impact Damage

Figure 1:7-3: Critical Deficiency – Section Loss
Figure 1:7-4: Bridge Restriction/Closure Protocol Flowchart for State-Owned Bridges
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CHAPTER 1 INTRODUCTION

SECTION 1.1 PURPOSE

Federal Regulation 23 CFR 650.313(g) requires each state use systematic quality control and quality assurance procedures to maintain a high degree of accuracy and consistency in the State Bridge Inspection Program. In order to meet this requirement, bridge owners shall implement the quality control and quality assurance measures described herein.

Quality control and quality assurance procedures shall include periodic field review of inspection teams, periodic bridge inspection refresher training, and independent review of inspection reports and computations.

SECTION 1.2 SCOPE

This manual outlines the following items in the state quality control and quality assurance program:

- Bridge inspection training
- Quality control roles and review procedures
- Quality assurance roles and review procedures
- Maintenance of the bridge file
- Identification and resolution of data errors, omissions, and/or changes
- Disqualification and requalification processes
SECTION 1.3  DEFINITIONS

- **Bridge Inspection Training:** Training that covers all aspects of bridge inspection and enables inspectors to relate conditions observed on a bridge to established criteria.

- **Critical Finding:** A structural or safety related deficiency that requires immediate follow-up inspection or action.

- **Inspecting Agency:** The organizational unit responsible for conducting or overseeing bridge inspection. The inspecting agency for a state-owned bridge is the appropriate District. The inspecting agency for a county, toll road, or other locally owned bridge is the Inspection Consultant.

- **Load Rating:** The determination of the live load-carrying capacity of a bridge using bridge plans and supplemented by information gathered from a field inspection.

- **Quality Assurance (QA):** The use of sampling and other measures to assure the adequacy of quality control procedures in order to verify or measure the quality of the inspection and load rating programs. Typically conducted from outside of the inspecting agency for the purpose of evaluating the quality of the program overall.

- **Quality Control (QC):** Procedures intended to maintain the quality of a bridge inspection and load rating at or above a specified level. Typically conducted from within an inspecting agency for the purpose of providing consistency within the inspecting agency, or from an external source when reviewing data for a specific district, county, toll road, or local agency.
CHAPTER 2 QUALITY CONTROL

SECTION 2.1 INSPECTION AND LOAD RATING TEAMS

The qualifications and responsibilities for the individuals performing inspections and load ratings are discussed in Part 1, Chapter 2, Section 2.4.

SECTION 2.2 INSPECTION PROCESS

For information related to LPA – Consultant Bridge Inspection Contracts please refer to the Local Public Agency Project Development Process Guidance Document which can be found on the INDOT website.

SECTION 2.3 QUALITY CONTROL REVIEWER (QCR)

A designated quality control reviewer must have team leader credentials. For firms without an active second Inspection Team Leader, another consulting firm with a qualified Inspection Team Leader will need to act as the quality control reviewer.

The QCR:

- Shall not be a member of the original inspection team to ensure an independent review.
- Shall have knowledge of required procedures and practices, as well as federal or state requirements.
SECTION 2.4 QUALITY CONTROL OFFICE REVIEW

Subsection 2.4.1 Purpose and Scope
The primary goal of the Quality Control Office Review is to ensure the accuracy and consistency within an Inspecting Agency, and completeness of the inspection data and all required reports. This should include reviewing the data and reports to make certain that they meet both federal and state requirements. Prior to the Quality Control Office Review, the Inspection Team Leader should run all data checks and make all required corrections.

It is not practical to thoroughly review all items required for submission as part of the Quality Control Office Review. The items and level of review should be determined by the QCR as he/she is responsible for the data and reports of the Inspecting Agency.

Subsection 2.4.2 Quality Control Criteria
This review by the QCR shall include the following as a minimum:

- Verify that the appropriate inspection was performed at the appropriate time as set forth for any time-based inspection cycles
- Review noted deficiencies and compare to recommended maintenance and repair items
- Ensure that critical findings were properly handled and that the bridge owner or representative was notified in a timely manner as directed in section 7.2
- Review load ratings to ensure the selected bridges have been load rated and that computations reflect on-site conditions
- Verify that all condition ratings of 4 or less for Items 58, 59, 60, and 62, or a rating of 3 or less for Item 113A, have been documented properly with photos and notes
- Verify compliance with posting policies, including photos
- Verify that, if required, a scour Plan of Action has been developed and is on file
- Verify the bridge file meets the requirements set forth in Part 1, Chapter 5, Section 5.1. This should include all available plans, load ratings, bridge-specific correspondence, maintenance/repair costs, Plans of Action, photographs, field notes and reports, and any other pertinent information.

Subsection 2.4.3 Sampling
The Quality Control Office Review shall be performed on bridges selected from a group that meet any of the following criteria if available:

- A rating of 4 or less for Items 58, 59, 60, or 62
- A rating that changed by two or more for Items 58, 59, 60, or 62
- A rating of 3 or less for Item 113A
For the purposes of quality control, each team leader will ensure that two bridge files are reviewed per year. On or before June 1st and November 1st of each year a report will be submitted to the INDOT Bridge Inspection Data Manager which will include the quality control office review forms filled out for that portion of the year.
SECTION 2.5 QUALITY CONTROL FIELD REVIEW

Subsection 2.5.1 Purpose and Scope

The primary goal of the Quality Control Field Review is to ensure consistency within an Inspecting Agency of the field inspection and data collection. The review will evaluate the consistency and accuracy of component ratings, inventory items, and adequacy of photographic documentation, notes, and recommended maintenance actions.

A Quality Control Field Review involves a field inspection of a bridge, including verification of data incorporated in the inspection report. The field inspection should take place within twelve months of the original inspection to ensure that conditions have not changed significantly.

Subsection 2.5.2 Quality Control Criteria

This review should include the following as a minimum:

- Perform a field verification of condition ratings and that the documentation is commensurate to the ratings
- Verify adequacy of photographs, notes, and sketches
- Verify that all critical findings have been identified and that the procedures in section 7.2 were followed
- Verify recommended maintenance and repair recommendations
- Review documentation of inspection notes for Items 58, 59, 60, or 62 with a condition rating of 4 or less. Verify the notes adequately describe the condition and that deficiencies are adequately described with sketches, pictures, and notes
- Verify load limit and one-lane bridge postings if present and that the load rating reflects on-site conditions
- Verify scour documentation and any required scour Plans of Action

The Quality Control Field Review Forms are to be completed by the reviewer and submitted to the INDOT Bridge Inspection Data Manager with the November 1st quality control submission. The Quality Control Field Review Form is shown in appendix B.

Subsection 2.5.3 Sampling

The Quality Control Field Review shall be performed on bridges selected from a group that meet any of the following criteria if available:

- A rating of 4 or less for Items 58, 59, 60, or 62
- A rating that changed by two or more for Items 58, 59, 60, or 62
- A rating of 3 or less for Item 113A
- Posted for 10 tons or less
- A Critical Finding has been reported
For the purposes of quality control, each team leader will ensure that one bridge is field reviewed per year. On or before November 1st of each year, a report will be submitted to the INDOT Bridge Inspection Data Manager which will include the quality control field review forms.

SECTION 2.6 CORRECTIVE ACTIONS
The team leader is responsible for any corrective action that is needed for an existing bridge file under review. The office and field reviews are intended to be an instructive process where errors and omissions can be found and eliminated. The only repercussion to the quality control reviews would be the lack of quality of the review or if corrections were recommended but not completed or explained by the team leader.

The INDOT Data Manager will review the submitted files.
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SECTION 3.1 QUALITY ASSURANCE
SECTION 3.2 CONTROL BRIDGE
SECTION 3.3 INDEPENDENT OVERSIGHT
  SECTION 3.3.1 INDEPENDENT OVERSIGHT CLOSEOUT
SECTION 3.4 BRIDGE FILE AND LOAD RATING REVIEW
  Subsection 3.4.1 Purpose and Scope
  Subsection 3.4.2 Bridge File Review
  Subsection 3.4.3 Load Rating Verification Review
SECTION 3.5 CORRECTIVE ACTIONS

CHAPTER 4 DISQUALIFICATION & REQUALIFICATION

SECTION 4.1 DISQUALIFICATION PROCESS
SECTION 4.2 DISQUALIFICATION CRITERIA
SECTION 4.3 REQUALIFICATION PROCESS
CHAPTER 3 QUALITY ASSURANCE

SECTION 3.1 QUALITY ASSURANCE

The INDOT Bridge Inspection Unit has revised the procedures for quality assurance, incorporating two quality assurance methods.

The first method will incorporate a procedure for inspecting a control bridge or bridges. The control bridge will be evaluated by a designated team of highly qualified bridge inspectors which will establish the target values for the control bridge. The team leaders will then be assigned a time to inspect the control bridge or bridges.

The second quality procedure will be independent oversight. In this method, a third party is enlisted to re-inspect a bridge previously inspected by a team leader. The independent reviewer will then compare the inspections.

These two new procedures will be further developed in the next two sections of the manual.
SECTION 3.2  CONTROL BRIDGE

As a minimum, one bridge will be selected every 24 months as a control bridge. The control bridge will be evaluated by a designated team of inspectors. The team members will be highly qualified and will independently determine the rating values for the bridge. The team members will also identify any deficiencies and critical findings. Any required notes or explanation of findings will be noted in the inspection. The inspection team will then meet and determine the values and findings to assign to the structure.

All team leaders will inspect the control bridge. The directions and expectations will be clearly defined well in advance of the date selected for the control bridge inspection. The exact testing procedures and review of results may vary for testing sessions, but all expectations will be outlined in the testing instructions.

All team members are required to inspect the control bridge. Failure to inspect the control bridge will be cause for review of the team member’s credentials. This review may include a review of bridge files submitted into BIAS and/or the basis for an independent oversight review. A team member missing two consecutive control bridge inspections will be disqualified.

Team members performing poorly on the control inspection will be subject to corrective actions.

On 12 month cycles not in the same year as a test bridge, the Bridge Inspection Program Manager may elect to have a training workshop. If scheduled, these training workshops will be mandatory and will include testing.
SECTION 3.3 INDEPENDENT OVERSIGHT

As a minimum, 24 bridge files will be selected annually for independent oversight. These structures in part will be selected from the list of team leaders that failed to participate in the inspection of the control bridge. A portion of the files will be selected from team members that performed poorly on the control bridge inspection. The final portion of the selected files will be selected at random.

For the selected bridge files, a third party will re-inspect the bridge. This inspection will be a complete inspection which will generate a comparison of the original inspection. This will give a very accurate comparison for consistency and accuracy.

SECTION 3.3.1 INDEPENDENT OVERSIGHT CLOSEOUT

For Quality Assurance Independent Oversight Reviews, after the inspections have been concluded, the reviewer will generate a Quality Assurance Report summarizing the findings. The findings shall be discussed with the State Program Manager and submitted to all Inspection Team Leaders involved in the inspections. An annual report will be generated which summarizes the findings.
SECTION 3.4 BRIDGE FILE AND LOAD RATING REVIEW

Subsection 3.4.1 Purpose and Scope

The primary goal of the Quality Assurance Bridge File Review is to ensure the completeness of the individual bridge files. The Quality Assurance Bridge File Review ensures that the QC efforts are effective across Inspecting Agencies, resulting in overall quality in the State Bridge Inspection Program. Bridge files should be reviewed to ensure that the bridges are properly load-rated and documented and that they contain any other required/available bridge documentation.

Subsection 3.4.2 Bridge File Review

The INDOT Data Base Manager will select a minimum of 10 bridge files per quarter for quality control review. One half of those files will be selected by searching files for known or suspected inaccuracies. The remaining files will be selected at random.

The bridge files will be reviewed for accuracy and completeness. The items checked for the bridge file will be as outlined in the AASHTO Manual for Bridge Evaluation, Section 2.

The findings of the quarterly review will be submitted to the INDOT Bridge Inspection Program Manager.

Subsection 3.4.3 Load Rating Verification Review

The INDOT Bridge Load Rating Engineer will select a minimum of 10 bridge files per quarter for quality control review. These files may have been selected for a bridge file review where the load rating section of the file was in question or the files may be selected at random.

The file will be reviewed for accuracy and completeness. The file must contain the summary sheet from the load rating and all supporting computations which must include a clear statement of all assumptions used in calculating the load rating. For computer modeling, an input data file will be included in the file.

The findings of the quarterly review will be submitted to the INDOT Bridge Inspection Program Manager.

SECTION 3.5 CORRECTIVE ACTIONS

Data errors, omissions, and/or changes can occur during the inspection and inventory process, as well as during the quality assurance process. The identification and resolution of these items shall be done in an expedited manner. Notification of the issue shall occur immediately to the appropriate INDOT inspector or Inspection Consultant. The issue will be discussed in-depth. Any revision to the report shall be documented and submitted to the State Program Manager. Once reviewed and accepted by the State Program Manager, the corrected information shall be submitted to the Inspecting Agency for their files or further action.
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SECTION 4.2  DISQUALIFICATION CRITERIA .................................................... 3
SECTION 4.3  REQUALIFICATION PROCESS .................................................... 4
CHAPTER 4 DISQUALIFICATION & REQUALIFICATION
SECTION 4.1 DISQUALIFICATION PROCESS

When Quality Assurance Reviews indicate that an Inspection Team Leader and/or an Inspecting Agency continue to make the same or similar mistakes or omissions, the State Program Manager shall implement disqualification procedures as follows:

1. Upon receiving INDOT's Quality Assurance Report, the team leader shall address the findings of the report and take steps to correct the problems to ensure they will not be repeated in the future.

2. The Inspection Team Leader will be placed on probation and two inspected bridges will be reviewed within the next inspection cycle. This review will be conducted by a team selected by the Program Manager.

3. If the inspections are found to be of poor quality, the team leader will be disqualified.

4. INDOT reserves the right to disqualify immediately and indefinitely if gross negligence, misconduct, and/or major omissions are found. These errors may adversely affect the safety of the public and/or the capacity of the bridge.
SECTION 4.2 DISQUALIFICATION CRITERIA

The criterion for disqualification of an Inspecting Agency or Inspection Team Leader includes, but is not limited to, the following:

1. Lack of proper follow-up with the bridge owner for Critical Deficiencies, such as broken load-carrying members, critical scour at foundations, vehicular impacts which could adversely affect load-carrying members, or bridges requiring closure
2. Lack of follow-up with the bridge owner for correcting load-posting deficiencies
3. Failure to satisfy the required testing for quality control
4. Failure to correct findings from Quality Control or Quality Assurance Reviews, including recurring unacceptable scores
5. Recurring miscoded critical inventory items such as National Bridge Inventory (NBI) Items 41 (Open, Posted, or Closed), 43 (Structure Type), 51 (Bridge Roadway Width), 54 (Vertical Underclearance), 90 (Inspection Date), 92 (Critical Feature Inspection), 93 (Critical Feature Inspection Date), and 113A (Scour Critical Bridge)
6. Recurring miscoded critical rating items such as condition states
7. Recurring condition rating deviations of more than one above or below an independent condition review
8. Failure to submit completed inspection data and/or corrections in a timely manner
9. Failure to maintain the bridge file to meet minimum requirements
10. Failure to maintain or update any required scour Plans of Action
11. Failure to inspect the bridges within the required frequency (unless the notice to proceed was given too late to make this possible)
12. Dishonest or unethical behavior that adversely affects the inspection results

INDOT has the final authority to carry out this disqualification process. Inspecting Agencies must accept these procedures as part of any bridge inspection agreement before they will be allowed to perform any bridge inspections.
SECTION 4.3 REQUALIFICATION PROCESS

1. A disqualified Inspection Team Leader and/or Inspection Agency may be re-qualified after the two-year period if they explain in writing how they will correct their deficiencies. Upon approval by INDOT, the Inspection Team Leader or Inspecting Agency shall be placed back on the qualified list and under probation for 12 months.

2. A disqualified Inspection Team Leader may also be re-qualified following the two-year disqualification period after he/she has retaken the Safety Inspection of In-Service Bridges (FHWA-NHI-130055) class and achieved a score of 70 percent or better on the examination given at the end of the course. Attendance in the entire course is mandatory for requalification.

3. Henceforth, prospective Inspection Team Leaders taking the Safety Inspection of In-Service Bridges (FHWA-NHI-130055) class must attend the entire course and achieve a score of 70 percent or better on the examination given at the end of the course to be considered re-qualified.
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<table>
<thead>
<tr>
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<th>Title</th>
<th>Page</th>
</tr>
</thead>
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<td>QUALITY ASSURANCE OFFICE REVIEW – LEVEL I</td>
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<td>15</td>
</tr>
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<td>H</td>
<td>QUALITY ASSURANCE POST-INSPECTION REVIEW FORM</td>
<td>25</td>
</tr>
<tr>
<td>I</td>
<td>FLOW CHART FOR INSPECTION PROCESS (INSPECTION/CONSULTANT/LPA)</td>
<td>33</td>
</tr>
</tbody>
</table>
The Quality Control Office Review shall be performed on selected bridges that meet any of the following criteria:

- A rating of 4 or less for Items 58, 59, 60, or 62
- A rating that changed by 2 or more for Items 58, 59, 60, or 62
- Posted for 10 tons or less
- A rating of 3 or less for Item 113A

For bridges inspected by Inspection Consultants, the minimum number of bridges to undergo the Quality Control Office Review shall be the greater of five percent of the total number of bridges, or five bridges.

The maximum number of bridges required to undergo the Quality Control Office Review shall be 15 bridges.

If the number of bridges which meet the sampling criteria is less than the minimum number listed above, the bridges with the lowest sufficiency ratings shall be selected for the remaining bridges for the Quality Control Office Review. If multiple Inspection Team Leaders are involved in the inspections, all efforts shall be made to review every Inspection Team Leader.

For bridges inspected by state employees, five bridges per Inspection Team Leader, per quarter, shall be reviewed by the Quality Control Officer for the above criteria. In addition, if the Inspection Team Leader is responsible for any Fracture Critical or Special Inspections, one of each shall be sampled for each of these inspection types, per quarter.
### Office Review Form

(One copy of this sheet shall be filled out for each bridge.)

<table>
<thead>
<tr>
<th>Item #</th>
<th>Items to Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All inspectors qualified</td>
</tr>
<tr>
<td>2</td>
<td>Inspection completed within the required frequency</td>
</tr>
<tr>
<td>3</td>
<td>Ratings of 4 or less for Items 58, 59, 60, or 62 have been documented properly (photos, notes, and sketches)</td>
</tr>
<tr>
<td>4</td>
<td>Critical Deficiencies properly handled (Part 1 – Section 7)</td>
</tr>
<tr>
<td>5</td>
<td>Load ratings performed and reflect current site conditions (Part 3)</td>
</tr>
<tr>
<td>6</td>
<td>Posting policies have been complied with (Part 3)</td>
</tr>
<tr>
<td>7</td>
<td>Maintenance and repair items reflective of noted deficiencies</td>
</tr>
<tr>
<td>8</td>
<td>“Estimated Year Remaining Life” values consistent with the condition ratings</td>
</tr>
<tr>
<td>9</td>
<td>Bridge files contain all available data (Part 1 – Section 5)</td>
</tr>
<tr>
<td>10</td>
<td>Priority schedule consistent with the bridge usage and deterioration</td>
</tr>
<tr>
<td>11</td>
<td>If required, scour Plan of Action developed, on file, and current (Part 4 – Section 7)</td>
</tr>
<tr>
<td>12</td>
<td>Printed inspection report uses standard format</td>
</tr>
</tbody>
</table>

Provide items reviewed, printed name, and signature in space below.

<table>
<thead>
<tr>
<th>Item(s)</th>
<th>Inspection Team Leader</th>
<th>Quality Control Officer</th>
</tr>
</thead>
<tbody>
<tr>
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Comments:

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APPENDIX B QUALITY CONTROL FIELD REVIEW FORM (INTERNAL)

(One copy of this sheet shall be filled out for each Inspection Team Leader.) Date: _____________

Company/District: _______________________________________________

Quality Control Officer: _______________________________________________

Team Leader No.: _______________________________________________

Team Leader: _______________________________________________

Team Leader No.: _______________________________________________

Team Members: _______________________________________________

County/County No.: _______________________________________________

List Selected Bridges _________   _________   __________

(5% or 5 min) (15 max):  _________   _________   __________

_______   _________   __________

_______   _________   __________

_______   _________   __________

_______   _________   __________

The Quality Control Field Review shall be performed on selected bridges that meet any of the following criteria:

- A rating of 4 or less for Items 58, 59, 60, or 62
- A rating that changed by two or more for Items 58, 59, 60, or 62
- A rating of 3 or less for Item 113A
- Posted for 10 tons or less

The minimum number of bridges to undergo the Quality Control Field Review shall be the greater of five percent of the total number of bridges inspected, or five bridges.

The maximum number of bridges required to undergo the Quality Control Field Review shall be 15 bridges.

If the number of bridges which meet the sampling criteria exceeds 15 bridges, then only 15 bridges are required to be reviewed. If multiple Inspection Team Leaders are involved in the inspections, all efforts shall be made to review every Inspection Team Leader.

For bridges inspected by state employees, five bridges per Inspection Team Leader, per quarter, shall be reviewed by the Quality Control Officer for the above criteria. In addition, if the Inspection Team Leader is responsible for any Fracture Critical or Special Inspections, one of each shall be sampled for each of these inspection types, per quarter.
<table>
<thead>
<tr>
<th>QC #</th>
<th>Items to Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Main structure type correct (43A)</td>
</tr>
<tr>
<td>2</td>
<td>“One Lane Bridge” or “Narrow Bridge” (51, 28A, 102, &amp; 41) postings in place; if not, is it recommended (41)?</td>
</tr>
<tr>
<td>3</td>
<td>Load limit (66B) bridge postings in place (66C &amp; 70); if not, is it recommended (41)?</td>
</tr>
<tr>
<td>4</td>
<td>Bridge rail and approach coding (36A) acceptable</td>
</tr>
<tr>
<td>5</td>
<td>Foundation type acceptable (113B)</td>
</tr>
<tr>
<td>6</td>
<td>Maintenance and repair items properly addressed</td>
</tr>
<tr>
<td>7</td>
<td>Photos taken of load posting</td>
</tr>
<tr>
<td>8</td>
<td>Photos taken of condition ratings of 4 or less for Items 58, 59, 60, or 62</td>
</tr>
<tr>
<td>9</td>
<td>Channel profiles or cross-sections taken for all bridges</td>
</tr>
<tr>
<td>10</td>
<td>If scour noted, was it adequately documented?</td>
</tr>
<tr>
<td>11</td>
<td>If deterioration noted, was it adequately documented?</td>
</tr>
<tr>
<td>12</td>
<td>Stream channel alignment problems are noted using sketches</td>
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</tbody>
</table>

Comments:

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## Part 2: QA/QC Quality Control Field Review Form (Internal)

- **Date:** _________  
- **Bridge No.:** __________

<table>
<thead>
<tr>
<th>QC #</th>
<th>Ratings</th>
<th>QCO Concur*</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Item 58: Deck</td>
<td>☐</td>
</tr>
<tr>
<td>16</td>
<td>Item 59. Superstructure</td>
<td>☐</td>
</tr>
<tr>
<td>17</td>
<td>Item 60: Substructure</td>
<td>☐</td>
</tr>
<tr>
<td>18</td>
<td>Item 62: Culvert</td>
<td>☐</td>
</tr>
<tr>
<td>19</td>
<td>Item 113A: Scour Critical Bridge</td>
<td>☐</td>
</tr>
</tbody>
</table>

*The Quality Control Officer shall provide concurrence for all items coded a 4 or less, or a change of two or more from the previous inspection. If no ratings are 4 or less, a minimum of one item is to be concurred with.

### Comments:

______________________________________________________________________
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Provide items reviewed, printed name, and signature in space below.

<table>
<thead>
<tr>
<th>QC Nos.</th>
<th>Inspection Team Leader</th>
<th>Quality Control Officer</th>
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</table>
All bridges that meet the sampling criteria shall be input into the Quality Control Log Form; however, only bridges reviewed by the Quality Control Officer (QCO) should have values in the “Date of Field Review” field. If additional structures were added to meet the minimum number of reviewed bridges criteria, these should also be listed on the form.

Submitted by QCO: ___________________________ Date: ___________________________
(Signature)

Printed Name: ______________________________ Company/District: ____________________
APPENDIX D QUALITY ASSURANCE QUESTIONNAIRE
(To be completed by the District Engineer or Inspection Consultant)

<table>
<thead>
<tr>
<th>Date</th>
<th>Inspection Agency Under Review</th>
<th>District/County/Toll Road/LA</th>
</tr>
</thead>
</table>

QUALIFICATIONS
Refer to Part 1, Section 2.4 of the Indiana Bridge Inspection Manual for personnel qualification requirements.

**Quality Control Officer** – Person in charge of inspection program

| Name: | _____________________________________________________________ |
| Team Leader No: | _____________________________________________________________ |
| Registered Professional Engineer: | ☐ Yes ☐ No | Complex Bridge Certified: | ☐ Yes ☐ No |

**Inspection Team Leaders** – Personnel that sign the inspection reports

| Name: | _____________________________________________________________ |
| Team Leader No: | _____________________________________________________________ |
| Registered Professional Engineer: | ☐ Yes ☐ No | Complex Bridge Certified: | ☐ Yes ☐ No |

| Name: | _____________________________________________________________ |
| Team Leader No: | _____________________________________________________________ |
| Registered Professional Engineer: | ☐ Yes ☐ No | Complex Bridge Certified: | ☐ Yes ☐ No |

| Name: | _____________________________________________________________ |
| Team Leader No: | _____________________________________________________________ |
| Registered Professional Engineer: | ☐ Yes ☐ No | Complex Bridge Certified: | ☐ Yes ☐ No |
### Inspection Team Members
Personnel that assisted Inspection Team Leaders with Field Inspections and do not sign inspection reports

<table>
<thead>
<tr>
<th>Date:</th>
<th>_____________________________________________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>_____________________________________________________________</td>
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</tbody>
</table>

- On INDOT Inspection Team Member list: [ ] Yes  [ ] No
- Registered Professional Engineer: [ ] Yes  [ ] No

<table>
<thead>
<tr>
<th>Experience:</th>
<th>_____________________________________________________________</th>
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</thead>
<tbody>
<tr>
<td>Training:</td>
<td>_____________________________________________________________</td>
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<table>
<thead>
<tr>
<th>Name:</th>
<th>_____________________________________________________________</th>
</tr>
</thead>
</table>

- On INDOT Inspection Team Member list: [ ] Yes  [ ] No
- Registered Professional Engineer: [ ] Yes  [ ] No

<table>
<thead>
<tr>
<th>Experience:</th>
<th>_____________________________________________________________</th>
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</thead>
<tbody>
<tr>
<td>Training:</td>
<td>_____________________________________________________________</td>
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<thead>
<tr>
<th>Name:</th>
<th>_____________________________________________________________</th>
</tr>
</thead>
</table>

- On INDOT Inspection Team Member list: [ ] Yes  [ ] No
- Registered Professional Engineer: [ ] Yes  [ ] No

<table>
<thead>
<tr>
<th>Experience:</th>
<th>_____________________________________________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training:</td>
<td>_____________________________________________________________</td>
</tr>
</tbody>
</table>
RECORD KEEPING

Bridge owners should maintain a complete, accurate, and current record of each bridge under their jurisdiction. Complete information, in good usable form, is vital to the effective management of bridges. Such information also provides a record which may be important in legal action.

Bridge File – The bridge file should contain all cumulative information about each individual bridge.

Location of bridge file: __________________________________________________________

Date: __________________________________________________________________________

File accessible to users: ☐ Yes ☐ No

Length of time information is kept in the file: ___________________________________________

Comments: _______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

Planning and Scheduling

Number of bridges Inspection Team Leaders responsible to inspect (per Inspection Team Leader): ____

Number of inspections performed in the past calendar year (per Inspection Team Leader): _________

Load-Posted/Closed Bridges

Number of bridges posted or closed: _________________________________________________

Computations or summary on file for load-posted/closed bridges (provide number): __________

Computations or summary not on file for load-posted/closed bridges (provide number): __________

Comments: _______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

Routine Inspections

Number of inspections performed within the recommended frequency (provide number): _________

Number of inspections performed outside of the recommended frequency: _________________

Number of bridges scheduled for a Routine Inspection at less than a 24-month frequency: _________

Comments: _______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________
Special Inspections
Number of bridges that require part or all of the bridge to be examined in more detail or at a greater frequency than standard for Routine Inspections:

_____ Cantilevered Bearings
_____ Cover Plates
_____ Fatigue Details E and E’
_____ Hinge Connections
_____ Pin or Hinge Connections
_____ Hangers
_____ Hoan Details
_____ Bridges or Details as Determined by the State Program Manager
_____ Primary Truss Gusset Plates With Corrosion and Difficulty Quantifying Section Loss

Fracture Critical Inspections
Number of bridges requiring a Fracture Critical Inspection: ________________________________

Number of Fracture Critical Inspections performed within the recommended frequency: ______________

Number of Inspections performed outside of the recommended frequency: ___________

Underwater Inspections
Number of bridges requiring an Underwater Inspection: ________________________________

<table>
<thead>
<tr>
<th>Bridge No.</th>
<th>Inspection Frequency</th>
<th>Bridge No.</th>
<th>Inspection Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scour Critical Bridges
Number of Scour Critical Bridges: ________________________________

Number of bridges that require inspections at a reduced frequency due to scour issues: ____________

Number of Scour Critical bridges with a scour Plan of Action on file: __________________________

Number of Scour Critical bridges without a scour Plan of Action on file: _________________________

Comments: __________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________
Unknown Foundations
Review the steps taken to eliminate unknown foundations, classify the scour risk for bridges with unknown foundations, and provide an appropriate Plan of Action:

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

Movable Bridge Inspections
Number of movable bridges: __________________________________________________________

<table>
<thead>
<tr>
<th>Bridge No.</th>
<th>Inspection Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coordination with Bridge Owner
The bridge file should contain all cumulative information about each individual bridge.

List inspector’s contacts for emergency closures or repairs: ________________________________

__________________________________

List who has authority to close a bridge in an emergency: ________________________________

__________________________________

List who has authority to open a bridge: ________________________________________________

__________________________________

____________________________________________________________________________________
____________________________________________________________________________________

____________________________________________________________________________________

(Inspection Team Leader Printed Name) (Inspection Team Leader Signature) (Date)
APPENDIX E QUALITY ASSURANCE OFFICE REVIEW – LEVEL I

Date | District/Consultant Under Review | Bridge Number
--- | --- | ---

RECORD KEEPING

Bridge owners should maintain a complete, accurate, and current record of each bridge under their jurisdiction. Complete information, in good usable form, is vital to the effective management of bridges. Such information also provides a record which may be important in legal action.

**Bridge File** – The bridge file should contain all cumulative information about each individual bridge.

Location of bridge file: ________________________________________________________________

File accessible to users: ☐ Yes ☐ No

Comments: ________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

Bridge File Documents

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Bridge design plans, as-builts, and/or rehab plans</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Correspondence</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Load rating analysis computations or load rating summary</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Initial/inventory update inspection reports</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Inspector qualification records</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Routine Inspection performed within 24 months of previous inspection</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Critical Deficiency documentation current</td>
</tr>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Scour Plan of Action</td>
</tr>
</tbody>
</table>

**Additional Inspections**

| ☐ | ☐ | ☐ | Damage Inspection reports |
| ☐ | ☐ | ☐ | Special Inspection reports |
| ☐ | ☐ | ☐ | Fracture Critical reports |
| ☐ | ☐ | ☐ | Underwater Inspection reports |
| ☐ | ☐ | ☐ | Border Bridge Inspection reports |
| ☐ | ☐ | ☐ | Other |
Date: _________ Bridge No.___________

SUMMARY OF LEVEL I REVIEW COMMENTS
Reviewer's Comments:

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

Reviewer’s Confidence Level

Good

Poor

Typical Deduction Items:
-2 If load rating computations or load rating summary is not on file
-2 If scour Plan of Action is required, but current copy is not on file
-3 If Critical Deficiency documentation is not on file, but a Critical Deficiency was noted since previous inspection
-3 If inspector was not a certified Inspection Team Leader at the time of inspection
-1 If not performed within a 24-month period (and the notice to proceed was given within 23 months of previous inspection)

(Inspection Team Leader Printed Name) __________________________ (Inspection Team Leader Signature) __________________________ (Date) __________

(Quality Control Officer Printed Name) __________________________ (Quality Control Officer Signature) __________________________ (Date) __________

(Quality Assurance Officer Printed Name) __________________________ (Quality Assurance Officer Signature) __________________________ (Date) __________
APPENDIX F QUALITY ASSURANCE OFFICE REVIEW – LEVEL II

Date | Inspection Agency Under Review | Bridge Number
--- | --- | ---

RECORD KEEPING

Bridge owners should maintain a complete, accurate, and current record of each bridge under their jurisdiction. Complete information, in good usable form, is vital to the effective management of bridges. Such information also provides a record which may be important in legal action.

**Bridge File** – The bridge file should contain all cumulative information about each individual bridge.

<table>
<thead>
<tr>
<th>Location of bridge file:</th>
<th>File accessible to users:</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
</tr>
</thead>
</table>

**Bridge File Documents**

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Document</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Available bridge design plans, as-buils, and/or rehab plans</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Correspondence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Load rating analysis computations or load rating summary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Initial/inventory update inspection reports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inspector qualification records</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Routine Inspection performed within 24 months of previous inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Critical Deficiency documentation current</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scour Plan of Action</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Additional Inspections</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Damage Inspection reports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Special Inspection reports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fracture Critical reports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Underwater Inspection reports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Border Bridge Inspection reports</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Other</td>
</tr>
</tbody>
</table>
INSPECTION
Bridge Inspections are conducted to determine the physical and functional condition of the bridge. Successful bridge inspection is dependent on proper planning and techniques, adequate equipment, and the experience and reliability of the personnel performing the inspection.

Planning and Scheduling
Previous inspection reports available for review: □ Yes □ No
Comments: ____________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

Initial Inspections – New and Rehabilitated Structures
Previous inspection reports available for review: □ Yes □ No □ NA
Bridge inspection forms updated to reflect modifications: □ Yes □ No □ NA
Comments: ____________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

Routine Inspections
List frequency for Routine Inspection (in months): ________________________________

ADDITIONAL INSPECTIONS
Damage Inspections
Bridge load posted due to damage: □ Yes □ No □ NA
Bridge closed due to damage: □ Yes □ No □ NA
Previous inspection reports available for review: □ Yes □ No □ NA
Bridge Inspection Report Form updated to reflect modifications: □ Yes □ No □ NA

Load Posted/Closed Bridges
Bridge re-load rated: □ Yes □ No □ NA
Load limit reduced: □ Yes □ No □ NA
Describe how load posting and/or closure was determined: □ Calculated □ Deterioration □ Other □ NA
Comments: ____________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
Fracture Critical Inspections
List frequency for Fracture Critical Inspection (in months): _____________________________________
Fracture Critical Inspection Plan of Action adequately documented: □ Yes □ No □ NA

Scour Critical Bridges
Describe how Scour Critical Rating determined (N/A if determined previously and not documented):
□ Calculated □ Visually □ Other □ NA
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

LOAD RATINGS
Stage I
Load rating performed (by summary or calculation): □ Yes □ No □ NA
Professional Engineer involved: □ Yes □ No □ NA
Calculations checked: □ Yes □ No □ NA
How was the load rating determined?
□ Calculation □ Deterioration □ Summary □ Standards □ Other
Comments: _______________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________
Stage II (Complete Stage I Also)
Adequate documentation of assumptions: □ Yes □ No □ NA
Deterioration of bridge accounted for: □ Yes □ No □ NA
Stage III (Complete Stage I & II Also)
Post-inspection review performed on subject bridge: □ Yes □ No
Quality Assurance Officer’s calculated load rating: ___ H-20 Inv ___ HS-20 Inv. ___ HS-20 Oper.
Inspection Agency’s load rating: ___ H-20 Inv ___ HS-20 Inv. ___ HS-20 Oper.
Inspection Agency’s load rating within two tons of QAO’s load rating: □ Yes □ No _____ Difference
Comments: _______________________________________________________________________
________________________________________________________________________________
________________________________________________________________________________

December 2013
FOLLOW-UP ACTIONS

Each inspection report shall be reviewed by the owner for completeness and recommendations. The inspector’s recommendations should be considered for implementation within the limits established for public safety, cost effectiveness, and fiscal restraints.

Inspectors inform maintenance personnel/owner about maintenance/repair needs: ☐ Yes ☐ No ☐ NA

Repair/maintenance recommendations are consistent with deterioration: ☐ Yes ☐ No ☐ NA

Estimated repair costs provided to owner (N/A for state-owned bridges): ☐ Yes ☐ No ☐ NA

Deterioration provided to Load Rating Team Leader (Load Rating Team Leader may also be the Inspection Team Leader): ☐ Yes ☐ No ☐ NA

INSPECTED AGENCY COMMENTS

1. Please take this opportunity to ask questions or make comments about the State Bridge Inspection Program.

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

2. Do the bridge Inspection Team Members feel they have enough time / equipment / training / experience to do their jobs properly?

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

December 2013
SUMMARY OF LEVEL II REVIEW COMMENTS

Reviewer’s Comments

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________

Reviewer’s Confidence Level

<table>
<thead>
<tr>
<th>Good</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
</tr>
</tbody>
</table>

Deduction Items:

-2 If load rating computations or load rating summary is not on file
-2 If scour Plan of Action is required, but current copy is not on file
-3 If Critical Deficiency documentation is not on file, but a Critical Deficiency was noted since previous inspection
-3 If inspector was not a certified Inspection Team Leader at the time of inspection
-1 If not performed within a 24-month period (and the notice to proceed was given within 23 months of previous inspection)
-2 If load rating computations are not within two tons of QAO value (Stage III review only)

(Inspection Team Leader Printed Name)  (Inspection Team Leader Signature)  (Date)

(Quality Control Officer Printed Name)  (Quality Control Officer Signature)  (Date)

(Quality Assurance Officer Printed Name)  (Quality Assurance Officer Signature)  (Date)
APPENDIX G  QUALITY ASSURANCE PEER FIELD REVIEW

Quality Control Officer: ________________________________

Team Leader No.: ______________________________________

Company/District: ______________________________________

Team Leader: _________________________________________

Team Leader No.: ______________________________________

Company/District: ______________________________________

Team Members: _________________________________________

County: _____________________________________________

County No.: __________________________________________

Bridge No: __________________________________________

NBI No.: _____________________________________________

Road Name: __________________________________________

Crossing: _____________________________________________

Inspection Date: _________________________________

Inspection Type:  □ Routine  □ Fracture Critical  □ Underwater  □ Special

Inspection Start Time: _______________________________

Inspection Complete Time: ___________________________
Routine Inspection Review

Review each question below and record the score reduction in each blank below. It is possible to use a lower reduction than the maximum possible reduction listed below. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th>Performance Review</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Max Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inspections completed in a thorough manner</td>
<td></td>
<td></td>
<td></td>
<td>-15</td>
<td></td>
</tr>
<tr>
<td>2. Bridge cleaned if needed (Part 1 – 4.3.3)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>3. Critical areas inspected</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>4. Deficiencies measured</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>5. Proper equipment and appropriate safety measures used (Part 1- 4.5, 4.6, 4.7)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>6. Channel profile or cross-section measured (Part 1 – 3.4.2)</td>
<td></td>
<td></td>
<td></td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>7. Submerged substructure units probed (if an Underwater Inspection not required) (Part 1 – 3.4.2)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>8. Photos taken of deteriorated portions of the structure (Part 1 – 3.4.2)</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>9. Inspection team has the proper qualifications (Part 1 – 2.4)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
</tbody>
</table>

Score: 100-_____ = __________

Comments:

________________________________________________________________________
________________________________________________________________________

Safety Equipment Used/Not Used:

________________________________________________________________________
________________________________________________________________________

December 2013
Fracture Critical/Special Inspection Review

Review each question below and record the score reduction in each blank below. It is possible to use a lower reduction than the maximum possible reduction listed below. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th>Performance Review</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Max Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Inspections completed in a thorough manner</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-15</td>
<td></td>
</tr>
<tr>
<td>2. Bridge cleaned if needed (Part 1 – 4.3.3)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>3. Critical areas inspected</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>4. Deficiencies measured</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>5. Proper equipment and appropriate safety measures used (Part 1 – 4.5, 4.6, 4.7)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>6. 100% hands-on inspection of all nonredundant members performed (Part 1 – 3.5.2)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-15</td>
<td></td>
</tr>
<tr>
<td>7. Photos taken of deteriorated portions of the structure (Part 4 – 11.6.6)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>8. Inspection team has the proper qualifications (Part 1 – 2.4)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
</tbody>
</table>

Total Score: 100-______ = __________

Comments:
____________________________________________________________________________
____________________________________________________________________________

Safety Equipment Used/Not Used:
____________________________________________________________________________
____________________________________________________________________________
Underwater Inspection Review

Review each question below and record the score reduction in each blank below. It is possible to use a lower reduction than the maximum possible reduction listed below. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th>Performance Review</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Max Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Safety briefing conducted with emergency information and pre-dive checks</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>2. Waterline measured to reference point on bridge (Part 1 – 3.9.2)</td>
<td></td>
<td></td>
<td></td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>3. All required soundings recorded (Part 1 – 3.9.2)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>4. Photos taken</td>
<td></td>
<td></td>
<td></td>
<td>-5</td>
<td></td>
</tr>
<tr>
<td>5. All appropriate dive equipment checked and used</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td>6. Inspection notes recorded</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>7. Inspection team has the proper qualifications (Part 1 – 2.4)</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Score: 100-____ = ________

Comments:
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Safety Equipment Used/Not Used:
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
Acceptable Scores: Any score lower than an 80 shall be considered unacceptable.

Routine Inspection Review:

- Acceptable: [ ]
- Unacceptable: [ ]
- N/A: [ ]

Fracture Critical/Special Inspection Review:

- Acceptable: [ ]
- Unacceptable: [ ]
- N/A: [ ]

Underwater Inspection Review:

- Acceptable: [ ]
- Unacceptable: [ ]
- N/A: [ ]

________________________________________________________________________

(Quality Assurance Officer Printed Name)  (Quality Assurance Officer Signature)  (Date)
APPENDIX H QUALITY ASSURANCE POST-INSPECTION REVIEW FORM

Quality Control Officer: _______________________________________________

Team Leader No.: ________________________________________________

Company/District: ________________________________________________

Team Leader: ____________________________________________________

Team Leader No.: ________________________________________________

Company/District: ________________________________________________

Team Members: ____________________________________________________

County: __________________________________________________________

County No.: ______________________________________________________

Bridge No: ________________________________________________________

NBI No.: _________________________________________________________

Road Name: ______________________________________________________

Crossing: _________________________________________________________

Inspection Date: _________________________________________________

Inspection Type: __☐ Routine __☐ Fracture Critical __☐ Underwater __☐ Special

Inspection Start Time: _____________________________________________

Inspection Complete Time: _________________________________________
Routine Inspection – Inventory Review – Part 1

Review each question below and record the score reduction in each blank below. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Main structure type (43A), main widening type (43C), and approach structure type (44A) correct</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>2. Bridge rail and approach coding (36A) acceptable</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>3. Required maintenance and repair items properly documented and address deterioration</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>4. Load limit (66B) bridge posting in place (66C &amp; 70); if not, is it recommended (41)?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>5. Foundation type acceptable (113B)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>6. “One-Lane Bridge” or “Narrow Bridge” posting in place; if not, is it recommended (51, 28A, 102 &amp; 41)?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>7. Inspection team has the proper qualifications (Part 1 – 2.4)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-20</td>
<td></td>
</tr>
</tbody>
</table>

Total Score: 100-_____ = __________

Comments:
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Score: 100-_____ = __________
Routine Inspection – Inventory Review – Part 2

Review each question below and record the score reduction in each blank below. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Measurement</th>
<th>w/in ± 3&quot;</th>
<th>Inspector (Team Leader)</th>
<th>QAO</th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Max Span Length (48)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>2. Structure Length (50)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>3. Bridge Roadway Width (51)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>4. Vertical Clearance/Deck  (53)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>5. Vertical Underclearance (54)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>6. Lateral Clearance (55)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-5</td>
<td></td>
</tr>
</tbody>
</table>

Total

Score: 100-_____ = ________

Comments:
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

December 2013  Page 2-H-27
### Routine Inspection – Condition and Appraisal Review

The Quality Assurance Officer is to inspect the bridge and provide his/her condition ratings below. He/she should compare the ratings to the Inspection Team Leader under review and record the score reduction in each blank to the right. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th>Condition and Appraisal</th>
<th>Inspector (Team Leader)</th>
<th>QAO</th>
<th>w/in ± 1</th>
<th>Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 58: Deck</td>
<td>□ □ □ □</td>
<td></td>
<td>-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 59: Superstructure</td>
<td>□ □ □ □</td>
<td></td>
<td>-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 59B: Paint Rating</td>
<td>□ □ □ □</td>
<td></td>
<td>-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 60: Substructure</td>
<td>□ □ □ □</td>
<td></td>
<td>-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 61: Channel</td>
<td>□ □ □ □</td>
<td></td>
<td>-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 62: Culvert</td>
<td>□ □ □ □</td>
<td></td>
<td>-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 65: Approach Roadway</td>
<td>□ □ □ □</td>
<td></td>
<td>-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 71: Waterway Adequacy</td>
<td>□ □ □ □</td>
<td></td>
<td>-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 72: Roadway Alignment</td>
<td>□ □ □ □</td>
<td></td>
<td>-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Item 113A: Scour Critical</td>
<td>□ □ □ □</td>
<td></td>
<td>-10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Score: 100-_____ = __________**

**Comments (include section loss documentation):**

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

December 2013
Fracture Critical/Special Inspection Review

The Quality Assurance Officer is to inspect the bridge and provide his/her condition ratings below. He/she should compare the ratings to the Inspection Team Leader under review and record the score reduction in each blank to the right. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Correct elements identified (Fracture Critical or Special)</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-10</td>
</tr>
<tr>
<td>2. Condition ratings within ±1 for all inspected elements</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-10</td>
</tr>
<tr>
<td>3. Fatigue Details correctly identified (Part 4 – 11.6.6)</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-10</td>
</tr>
<tr>
<td>4. Reported section loss reasonable (within 10%) (Part 4 – 11.6.6)</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-10</td>
</tr>
<tr>
<td>5. All cracks noted (Part 4 – 11.6.6)</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-10</td>
</tr>
<tr>
<td>6. Damage to elements documented</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-10</td>
</tr>
<tr>
<td>7. Bridge appeared to be cleaned during original inspection (Part 1 – 4.3.3)</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-10</td>
</tr>
<tr>
<td>8. Inspection team has the proper qualifications (Part 1 – 2.4)</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>-20</td>
</tr>
</tbody>
</table>

Total

Score: 100-_____ = __________

Comments (include section loss documentation):
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

December 2013
Underwater Inspection – Inventory Review

The Quality Assurance Officer is to inspect the bridge and provide his/her condition ratings below. He/she should compare the ratings to the Inspection Team Leader under review and record the score reduction in each blank to the right. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>N/A</th>
<th>Max Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Waterline elevation accurately recorded (Part 1 – 3.9)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>2. All required soundings accurately recorded (Part 1 – 3.9)</td>
<td></td>
<td></td>
<td></td>
<td>-15</td>
<td></td>
</tr>
<tr>
<td>3. All required photos obtained and documented (Part 1 – 3.6)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>4. C.B. Material adjacent to Superstructure Units determined (Part 1 – 3.6)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>5. Scour and debris noted (Part 4 – 7.4)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>6. Defects noted with dimensions and section loss</td>
<td></td>
<td></td>
<td></td>
<td>-15</td>
<td></td>
</tr>
<tr>
<td>7. Shoreline conditions noted (Part 4 – 7.4)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>8. Plan view showing bridge configuration with north arrow, flow arrow, shorelines, etc. (Part 1 – 3.6)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>9. Foundation type correct (Item 113B)</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>10. Underwater Inspection frequency reasonable</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>11. Inspection team has the proper qualifications (Part 1 – 2.4)</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
</tbody>
</table>

Score: 100-_____ = __________

Comments:
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

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**Underwater Inspection – Condition and Appraisal Review**

The Quality Assurance Officer is to inspect the bridge and provide his/her condition ratings below. He/she should compare the ratings to the Inspection Team Leader under review and record the score reduction in each blank to the right. At the conclusion of the inspection, add up the reductions and subtract from 100. Record the score below. “Yes” and “N/A” answers shall be scored with a zero reduction.

<table>
<thead>
<tr>
<th>Condition and Appraisal</th>
<th>Ratings</th>
<th>Within ± 1</th>
<th>Reduc.</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inspector (Team Leader)</td>
<td>QAO</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Item 60: Substructure</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
</tr>
<tr>
<td>Item 61: Channel</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
</tr>
<tr>
<td>Item 113A: Scour Critical</td>
<td></td>
<td></td>
<td></td>
<td>-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

Score: 100-_____ = _________

Comments (include section loss documentation):

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Acceptable Scores: Any score lower than an 80 shall be considered unacceptable.

<table>
<thead>
<tr>
<th>Routine Inspection – Inventory Review – Part 1:</th>
<th>Acceptable</th>
<th>Unacceptable</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Routine Inspection – Inventory Review – Part 2:</th>
<th>Acceptable</th>
<th>Unacceptable</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Routine Inspection – Condition and Appraisal Review:</th>
<th>Acceptable</th>
<th>Unacceptable</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Fracture Critical/Special Inspection Review:</th>
<th>Acceptable</th>
<th>Unacceptable</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Underwater Inspection – Inventory Review:</th>
<th>Acceptable</th>
<th>Unacceptable</th>
<th>N/A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Underwater Inspection – Condition and Appraisal Review:</th>
<th>Acceptable</th>
<th>Unacceptable</th>
<th>N/A</th>
</tr>
</thead>
</table>

(Quality Assurance Officer Printed Name) (Quality Assurance Officer Signature) (Date)
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CHAPTER 1  INTRODUCTION ........................................................................... 2
CHAPTER 1  INTRODUCTION

The primary purpose of this part of the manual is to establish a uniform policy of load rating procedures and standards for the posting of bridges within the state of Indiana. This will ensure every bridge is rated as to its safe load-carrying capacity. When the maximum unrestricted legal loads or state routine permit loads exceed the inventory rating or equivalent rating factor, those bridges shall be posted or restricted in accordance with the American Association of State Highway and Transportation Officials (AASHTO) or state law.

This part of the manual is a reference tool for rating bridges. It outlines guidelines and procedures for load rating and the documentation required. Although this is intended to be used for the load rating of bridges, many of the processes and procedures can be applied to small structures not classified by 23CFR650 as a bridge.
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CHAPTER 2    REFERENCE MATERIAL................................................................................. 2
CHAPTER 2  REFERENCE MATERIAL

These references set forth procedures to be used in the load rating of bridges. Persons involved with load rating of bridges must be knowledgeable of these references. The information in this Bridge Inspection Manual supplements the information in these references:


BRIDGE INSPECTION MANUAL

PART 3: LOAD RATING


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CHAPTER 3 LOAD RATING POLICY STATEMENT ................................................ 2
CHAPTER 3      LOAD RATING POLICY STATEMENT

All state, county, toll road, and local agency bridges shall have a load rating performed in accordance with this part of the manual. The Inspection Team Leader shall be responsible for ensuring that the Load Rating Team Leader has performed the load rating based on the current findings, and that they are developed in a timely fashion.

Inspection Consultants may obtain the existing load ratings from the previous Inspection Consultant. It is the responsibility of the Inspection Team Leader to review, or have reviewed the previous load rating and verify the thoroughness and accuracy of the load rating. By re-using the existing load rating, the Inspection Team Leader accepts the responsibility and liability for the load rating and relieves the liability of the load rating from the previous Inspection Consultant.

This policy will be reviewed periodically as its implementation is assessed.
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CHAPTER 4  DEFINITIONS ........................................................................................................... 2
CHAPTER 4 DEFINITIONS

Bridge: Bridges are defined by the National Bridge Inspection Standards (NBIS) published in the Code of Federal Regulations (23 CFR 650 Subpart C). See Part 1, Chapter 2, Section 2.2. Small structures with spans less than or equal to 20 feet should be load rated using the same basic procedures set forth in this manual.

Load Rating Team Leader: The qualifications and responsibilities of the Load Rating Team Leader are defined in Part 1, Chapter 3, Section 2.4. The Load Rating Team Leader should use sound engineering judgment when completing load ratings and when using the provisions of this manual. The Load Rating Team Leader is responsible for completing quality control of the load ratings and the data that is submitted to the Indiana Department of Transportation (INDOT) for the National Bridge Inventory (NBI).

Load Rating Levels: Bridges are load rated to determine the safe live load capacity. Bridges are rated at two different load levels referred to as “Inventory” and “Operating.” Additionally, bridges are rated to determine posting requirements.

Inventory Level: The inventory rating level generally corresponds to the customary design level of stresses, but reflects the existing bridge and material conditions with regard to deterioration and loss of section. Load ratings based on the inventory level allow comparisons with the capacity for new bridges and, therefore, determine a live load which can safely utilize an existing bridge for an indefinite period of time. This approximates the design load level.

Operating Level: Load ratings based on the operating rating level generally describe the maximum permissible live load to which the bridge may be subjected. This is the overload permit maximum. Routine application of live loads at or near the operating level may shorten the life of the bridge.

Posting Level: Posting level is a load capacity selected by the governing agency for load posting bridges.

Allowable Stress (AS): This method compares unfactored load stresses to an allowable stress for a given material.

Load Factor (LF): This method compares factored load effects and stresses to the strength of a member of a given material, which typically is less than the material’s strength limit.

Load and Resistance Factor Rating (LRFR): This method compares factored load effects to the resistance of a member of a given material.
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SECTION 5.1 BRIDGE OWNERS .................................................................................. 2
SECTION 5.2 INDIANA DEPARTMENT OF TRANSPORTATION .................................... 3
SECTION 5.3 CONSULTANTS PERFORMING RATINGS ............................................. 4
CHAPTER 5    ROLES AND RESPONSIBILITIES

SECTION 5.1    BRIDGE OWNERS

Bridge owners in Indiana include the state, counties, toll roads, other local agencies, and private firms owning bridges open to public traffic without restriction. For bridges within their authority, bridge owners are responsible for the following items:

- Ensuring all bridges within their jurisdiction are load rated
- Ensuring new bridges are load-rated prior to opening to public traffic
- Quality control of the load ratings
- Maintaining complete bridge records in the bridge file
- Properly posting bridges, as required

Bridge owners and their Inspection Consultants are responsible for determining when a bridge must be re-rated in conjunction with these requirements. Bridge owners shall load a copy of the load rating summary in the Central Database and ensure a copy is in the official bridge file. The load rating summary requirements are discussed in Part 3, Chapter 9 of this manual.
SECTION 5.2    INDIANA DEPARTMENT OF TRANSPORTATION

The Indiana Department of Transportation (INDOT) is responsible for ensuring bridge owners are in compliance with the National Bridge Inspection Standards (NBIS) as given in CFR 650 Subpart C, Bridges, Structures, and Hydraulics. The Federal Highway Administration (FHWA) mandates that inventory and operating ratings be reported by INDOT yearly as part of the National Bridge Inventory (NBI).
SECTION 5.3  CONSULTANTS PERFORMING RATINGS

Inspection Consultants are responsible for being familiar with the State Bridge Inspection Program policies and procedures. Inspection Consultants performing load ratings are responsible for the quality control of their work, checking both accuracy and completeness.

Inspection Consultants are prequalified by INDOT to load-rate state-owned bridges and bridges being inspected using federal funds. This includes most county, toll road, and local agency bridges. Prequalification requirements are as follows:

- Have at least one Registered Professional Engineer, licensed in the state of Indiana, qualified to oversee, review, and certify all load capacity ratings performed by that firm.

- Have a load capacity rating program or method that produces all load rating results required by the federal regulations and INDOT. As a minimum, this must check moments and shear. All calculations must be performed by an engineer or engineering intern (EI) and must be reviewed by a professional engineer (PE).
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SECTION 6.2 FREQUENCY OF LOAD RATINGS ......................................................................... 3
SECTION 6.3 ASSUMPTIONS .................................................................................................. 4
SECTION 6.4 CONDITIONS ..................................................................................................... 5
SECTION 6.5 QUALITY CONTROL/QUALITY ASSURANCE .................................................... 6

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Figure 3:6-1: Load Rating Procedure Flowchart ....................................................................... 6
Federal bridge inspection regulations require that a bridge load capacity rating be performed for each bridge carrying vehicular traffic. A number of rating vehicles and rating methods have been identified by the Federal Highway Administration (FHWA) and the Indiana Department of Transportation (INDOT) as being required in order to meet federal regulations. Since July 2004, INDOT has required that state-owned bridges be load-rated in the design stage, as well as after being placed in service. INDOT’s Production Management Division is currently using the American Association of State Highway and Transportation Officials (AASHTO) load rating program called Virtis to rate state bridges. Since this load rating program cannot rate all types of bridges, other load rating methods are used when appropriate to get an accurate and realistic load capacity rating.

Other analyses, such as fatigue and fracture analysis or bridge load testing, should be left to the discretion of the owner at this time.
SECTION 6.2 FREQUENCIES OF LOAD RATINGS

A bridge does not require load rating if stamped plans are on file for current design criteria and the superstructure rating is greater than 5. If these conditions are not met, the frequency of load rating or re-rating should be based on the following:

- Within 180 days of opening, bridge files for county, toll road, and local agency bridges should include a load rating or a stamped set of bridge plans. All state bridges shall be load-rated prior to opening to the public. The Indiana Design Manual requires that the load rating for state-owned bridges shall be performed by INDOT’s Production Management Division’s Load Rating Team Leader within 30 days of receipt of INDOT Stage 3 Review Submission, with analysis results available to the designer prior to the final tracings submission.

- A bridge should be re-load-rated when it is reconstructed, repaired, or overlaid in a manner that would affect the existing load rating.

- When significant deterioration is noted during an inspection, resulting in a National Bridge Inventory (NBI) rating of 4 or less for any primary superstructure member, the Inspection Team Leader shall immediately notify the Load Rating Team Leader. Substructures shall be load-rated whenever they have a condition rating of 3 or less.

- Bridges should be load-rated when there are unexpected changes in the load carrying capacity of a bridge resulting from damage due to member failure, natural or unnatural causes, or collision.

- When an overweight vehicle requests a permit, the load rating may need to be reviewed for evaluation of the operation rating. See Chapter 11, Permitting.
SECTION 6.3       ASSUMPTIONS

Due to the wide variety of structural materials available, the number of bridge types, and the variations in
the quality and strength of the materials, assumptions have to be made in order to efficiently analyze
bridges. These assumptions consider the policies and procedures with which the bridges were designed,
the recommendations published by AASHTO, and INDOT policies.

For bridges with stamped design plans and superstructure ratings of 6 or higher, it can be assumed that
the minimum capacities for the design vehicles(s) listed on the plan sheets were met when the bridge was
originally constructed and/or rehabilitated. Since design criteria may be different than load rating criteria,
this assumption can be made as long as the bridge does not show signs of distress.

For bridge types, materials, and analysis methods not dealt with in this manual, please contact a Load
Rating Team Leader in the Production Management Division of the Structural Services Division or the
Bridge Inspection Unit of INDOT for assistance.
SECTION 6.4 CONDITIONS

The safe load capacity of a bridge is to be based on existing structural conditions. Bridges with design plans and/or as-built plans with deterioration, or those where structural elements can be measured to determine structural capacity, should be load-rated using an acceptable AASHTO load rating method except as noted in Section 6.3. All superstructure members should be checked for moment, shear, and where applicable, axial loading. Deck elements, substructure elements, and underfill structures, such as pipes and boxes, should have their load capacities calculated or assessed in a systematic manner, especially when condition ratings indicate that there may be a structural capacity concern.

Although plans may indicate a bridge was designed for future load case possibilities, the bridge should be rated for the actual conditions. For example, if the plans state the bridge was designed for a load of 15 pounds per square foot for stay-in-place forms, the load should not be applied to the load rating model unless stay-in-place forms have been visually identified during the inspection.
SECTION 6.5 QUALITY CONTROL/QUALITY ASSURANCE

A number of bridges shall have their load ratings reviewed in detail each year to ensure the accuracy and consistency of bridge inspections and bridge inspection reports. Part 2 of this manual discusses the load rating quality control and quality assurance review processes.

In-house quality control should verify load rating computations and their consistency. All assumptions, and documentation of such, should be verified. This includes checking that any rehabilitation or deterioration of the structural members has been included.

Figure 3:6-1: Load Rating Procedure Flowchart
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CHAPTER 7       VEHICLES

With the Federal Highway Administration’s (FHWA’s) adoption of the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design Specifications, the FHWA has issued a clarification of policy regarding the appropriate methodology and loads to be used in reporting operating and inventory rating data. It is necessary to accommodate and support Load and Resistance Factor Rating (LRFR), while continuing to accept Allowable Stress (AS) and Load Factor (LF) for the large inventory of in-service bridges that have been designed by a method other than Load and Resistance Factor Design (LRFD). It is not the intent of FHWA to mandate re-rating existing, valid bridge load ratings by LRFR.

Load ratings are to be reported to the National Bridge Inventory (NBI) annually. For bridges designed using LRFD using HL-93 loading, load ratings are to be computed and reported in tons and must indicate the rating method used. Ratings shall be based on LRFR methods using HL-93 vehicular live load consisting of the design truck or design tandem and the design lane load.

For bridges designed using Allowable Stress Design (ASD) or Load Factor Design (LFD), load ratings are to be computed and reported in tons and must indicate the rating method used. Rating factors shall be based on LRFR methods using HL-93 loading or LFR methods based on the HS-20 vehicle. Bridges designed using LFD, and being rehabilitated, should be load-rated for the AASHTO LFD design vehicles.

Load ratings and respective locations should be entered into the Central Database for the following vehicles: H-20 Inventory (Truck and Lane); HS-20 Inventory & Operating (Truck and Lane); HS-25 Operating; Fatigue Truck Operating; and HL-93 Operating.

SECTION 7.1       LEGAL LOADS

Load limits restrict how much weight can be carried on an axle, a single tire, a pair of tires, and on the vehicle or vehicle combination in total. Load limits are necessary for protecting bridges from structural weakening or fatigue, preventing unsafe conditions, and the early replacement of bridges.

Vehicles meeting Indiana Code Article 20, Size and Weight Restrictions, are considered legal loads and should be able to use any highway or bridge within the state (see Appendix A). Some routes, and many bridges, must be posted to protect them from possible damage. A posted bridge may restrict a legal load from use. At this time, a bridge with a load capacity of H-20 is considered to best represent the state's load limit for the evaluation of the need for load posting.
SECTION 7.2 STANDARD AASHTO VEHICLES

The following standard AASHTO vehicles are used in load rating structures:

- H20-44 Truck/Lane
- HS20-44 Truck/Lane
- HS25 Truck/Lane
- Fatigue Truck
- HL-93 Design Truck
- HL-93 Design Tandem
- HL-93 Design Truck Pair
Figure 3:7-1: AASHTO H-20 and HS-20 Loads
Figure 3:7-2: AASHTO HS-25 and Alternate Military Loads
Figure 3:7-3: AASHTO Fatigue and HL-93 Loads
SECTION 7.3 SPECIAL ROUTE VEHICLES

Special Route Vehicles are identified in the Indiana Code and can change annually depending on state legislature.

- The Alternate Military Loading should be applied for any route falling on the National Highway System (NHS) (http://www.in.gov/indot/3029.htm) with a design date prior to December 31, 2005.

- In addition to the legal loads, the Indiana Toll Road live load (Heavy Duty Highway) should apply to each state highway bridge located within 15 miles of an Indiana Toll Road entrance or exit. A single truck with the design lane load should be used in each design lane. Factors for multiple presence and dynamic load allowance should be the same as those used for regular design trucks.

- In addition to the legal loads, the Michigan Truck Train live load (Extra-Heavy-Duty Highway) should apply to each bridge located on the Indiana Extra Heavy Duty Highway system. A single truck with design lane load should be limited to one design lane located to cause extreme force effects, while the other design lanes are occupied by regular design loads. Factors for multiple presence and dynamic load allowance should be the same as those used for regular design trucks.
Figure 3:7-4: Toll Road Truck Loads
Figure 3:7-5: Michigan Train Truck Loads
The following routes are designated as extra-heavy-duty highways:

1. US 41, from 129th Street in Hammond to SR 312.
2. SR 312, from US 41 to SR 912.
3. SR 912, from Michigan Avenue in East Chicago to the US 20 Interchange.
4. US 20, from Clark Road in Gary to SR 39.
5. US 12, from 0.25 mi west of the Midwest Steel entrance to SR 249.
7. US 12, from 1.5 mi east of the Bethlehem Steel (now Arcelor Mittal) to SR 149.
8. SR 149, from US 12 to a point 0.36 mi south of US 20.
13. SR 23, from US 31 to Olive Street in South Bend.
14. US 35, from South Motts Parkway 0.34 mi southeast to the point where US 35 intersects with the overpass for US 20/SR 212.
15. SR 249, from US 12 to the point where SR 249 intersects with Nelson Drive at the Port of Indiana.
16. SR 912, from the 15th Avenue and 169th Street interchange 1.06 mi north to the US 20 interchange.
17. US 20, from the SR 912 interchange 3.17 mi east to US 12.
18. US 6, from the Ohio State Line to SR 9.
19. US 30, from Allen/Whitley County Line Road (also known as Co. Rte. 800 E.) to SR 9.

*Figure 60-3D of the Indiana Design Manual, 2009*
Figure 3:7-7: 11-, 13-, and 14-Axel Superload Vehicles
Figure 3:7-8: 19-Axel Superload Vehicles
SECTION 7.4 SCHOOL BUSES

It is recommended that a notice be sent by the county to the school districts advising them of the location of all bridges with a 12-ton or less weight limit. This notice should be sent annually, or whenever a bridge’s posting status changes.

Figure 3:7-9: School Buses
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CHAPTER 8 LOAD RATING GUIDELINES

SECTION 8.1 ANALYSIS

Load rating requires engineering judgment in determining a rating value that is applicable to maintaining the safe use of the bridge and arriving at posting and permit decisions. Parameters such as load factors and distribution factors should be determined by the Load Rating Team Leader using the latest American Association of State Highway and Transportation Officials (AASHTO) manuals. Stress levels for operating and inventory ratings should be determined by the Load Rating Team Leader using the latest AASHTO manuals. All superstructure elements for each bridge type should be load-rated in accordance with the latest AASHTO manuals.
SECTION 8.2 BRIDGE CROSS-SECTION AND GEOMETRY

The following guidelines should be used when computing load ratings:

- A bridge with a sidewalk or shoulder without a barrier on the traffic side will be analyzed for moment and shear capacity as though the entire bridge width were available for traffic.

- The distance between the centerlines of bearing is to be used for the span length for analysis purposes.

- In spans with variable stringer/beam spacing, live load distribution factors should be computed based on the average of the stringer spacing on either side. If an average spacing is used, this must be noted since a more exact model may be needed to rate a permitted vehicle.
SECTION 8.3  DECK SECTION ADJUSTMENTS

The following guidelines should be used when considering the role of the deck in load ratings:

- When computing section properties on a bridge with a one-course concrete deck, the Load Rating Team Leader will determine if it is appropriate to deduct the sacrificial wear surface thickness shown on the plans. Take note of all rehabilitations to ensure total sacrificial depth does not exceed the design sacrificial wear thickness. If the overall sacrificial depth exceeds the sacrificial wear thickness, the remaining deck thickness is to be used as the structural depth. Adjust the distance to the top reinforcing bars to represent final cover.

- A concrete overlay or bridge deck wearing surface should be considered as composite dead load, but is ignored as a structural slab on the initial rating calculations.

- If the overlay is needed to get realistic ratings, this may be used on subsequent calculations.

- When analyzing a bridge with precast concrete deck panels, it is state policy to treat the panel as being monolithic with the deck and analyzed as if it were a one-course pour.
SECTION 8.4 SUBSTRUCTURES

Substructures generally do not control the load rating. Load ratings shall be evaluated for substructures whenever they have a condition rating of 3 or less.
SECTION 8.5  REINFORCED CONCRETE

If details are not available for the reinforcing steel in reinforced concrete decks or girders, it is acceptable to assume 75 percent balanced design procedures were used.
SECTION 8.6  PRESTRESSED OR POST-TENSIONED CONCRETE

The following guidelines should be used when load rating prestressed or post-tensioned concrete bridges:

- Previous codes should not be used to determine the prestressed shear capacity.

- If the inspection of a prestressed box-beam bridge indicates longitudinal cracking, the cracked beam should be evaluated with a reduced number of strands. Using engineering judgment, assume that at least one strand on each side of the crack is not functioning. If rust is visible, it may be appropriate to assume that two or more rows of strands on each side of the rust stain are not functioning.

- Review box beam standards for depth and strand configuration based on the span length and spacing if details are not provided.

- The Indiana Department of Transportation (INDOT) no longer allows the use of a transformed section in design without permission from the design manager. Currently, INDOT code requires that a note on the plans indicates when a transformed section was used for the design of the beams. However, prior to this code change, designs may have incorporated the transformed section without any indication on the plans. A load rating assuming a nontransformed section may result in a lower rating than the original design capacity.
SECTION 8.7  STRUCTURAL STEEL

The following guidelines should be used when load rating steel bridges:

- Stiffeners should be included in the determination of the shear capacity.

- Girders that have been made with plates, angles, and channels may be modeled as equivalent plate girders.

SECTION 8.8  FRACTURE CRITICAL BRIDGES

The following guidelines should be used when load rating fracture critical bridges:

- The load rating for steel fracture critical bridges with fatigue-prone connection details (pins, welds on fracture critical members in tension, E & E’ fatigue details, etc.) will be rated if the connection shows any sign of deterioration, or if the dead load supported by the bridge has increased since the bridge was built.

- For load rating bolted or riveted gusset plates in truss bridges, reference FHWA-TA-5140.29, *Load-carrying Capacity Considerations of Gusset Plates in Non-load-redundant Steel Truss Bridges*, 15 January, 2008. Accordingly, the following actions are recommended to supplement the provisions of the AASHTO manual:
  - Bridge owners are strongly encouraged to check the capacity of gusset plates in new or replaced non-load-path-redundant steel truss bridges as part of the initial load ratings.
  - Bridge owners are strongly encouraged to check the capacity of gusset plates as part of the load rating calculations of existing non-load-path-redundant steel truss bridges conducted to reflect changes in condition or dead load, to make permit or posting decisions, or to account for structural modifications or other alterations that result in significant changes in stress levels.
  - It is recommended that bridge owners review past load rating calculations of non-load-path-redundant steel truss bridges which have been subjected to significant changes in stress levels, either temporary or permanent, to ensure that the capacities of gusset plates were adequately considered.

- When load rating gusset connections of non-load-path-redundant steel truss bridges, reference the analysis as described in FHWA-IF-09-014, *Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates In Truss Bridges*, February 2009.
SECTION 8.9 TIMBER

The following guidelines should be used when load rating timber bridges:

- Design stress values should be based on species and grade as given in AASHTO when they are known or when they can be readily established. Assumptions can be made based on typical species within the area.

- Impact allowances shall not be applied to timber bridges.
SECTION 8.10 TRUSS BRIDGE WITH TIMBER DECK

For truss bridges with timber decks, the following elements should be load-rated as a minimum:

- Timber deck
- Steel stringers
- Floor beams
- Steel truss members
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CHAPTER 9    DOCUMENTATION

The documentation of the load rating for each bridge must be a complete record of the load rating. This will ensure that concise and complete data is available in the future should the bridge need to be re-rated for bridge retrofit, modification, age, or deterioration.

SECTION 9.1    SUBMITTAL REQUIREMENTS

Inspection Consultants shall submit a load rating summary for each bridge rated, in an electronic format, and shall include the following information:

- Date bridge was load-rated
- Person(s) that conducted the calculations and person that reviewed the results
- Load rating method used (Allowable Stress Design [ASD], Load Factor Design [LFD], Load and Resistance Factor Rating [LRFR])
- Load rating program(s) used
- Data sources (design plans, as-built plans, measurements, inspection report, etc.)
- Basic data (bridge geometry, deck thickness, overlay thickness, concrete/steel properties, assumptions, etc.)
- H-Vehicle rating results (moment, shear, etc.)
- HS-Vehicle rating results (moment, shear, etc.)
- Plans and field measurements (Portable Document Format [PDF] file)

For county, toll road, and other local agency bridges, the Central Database load rating items identified in the Indiana Department of Transportation (INDOT) Bridge Reporting for Appraisal and Greater Inventory (BRAGI) Coding Guide shall be completed. An overall summary report of all load ratings completed for each county, toll road, or other local agency shall be generated by the Central Database and included in the report book. All load rating documentation shall be initialed by the Load Rating Team Leader, dated, sealed, scanned, and attached in the Central Database. Additional information used for the load rating should be attached to the Central Database.

For state-owned bridges, the Central Database load rating items identified in the INDOT BRAGI Coding Guide shall be completed. Additional information relevant to the load rating should be attached to the Central Database.
Keeping this information in the Central Database will allow inspectors to have access to detailed load rating information in the field during inspections, and help them gather important measurements on deteriorated and damaged structural members. This information can also be used when load rating information must be accessed in an emergency.

During the inspection process, inspectors shall measure section loss and provide sketches or other documentation. If the loss warrants re-rating, the Inspection Team Leader should contact the Load Rating Team Leader and request the bridge be re-rated.
SECTION 9.2    LOAD RATING SUMMARY

Figures 3:9-1 through 3:9-4 show a sample load rating summary. Similar documentation should be developed for each load-rated bridge. This report shall be attached to the Central Database. For state-owned bridges, a copy shall be submitted to INDOT’s Production Management Division’s Load Rating Team Leader.

Figure 3:9-1: Load Rating Summary Page 1
## Load Rating Summary

<table>
<thead>
<tr>
<th>Bridge ID:</th>
<th>NBI:</th>
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<td>Rated By:</td>
<td>Date:</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject:</th>
<th>Load Rating Analysis</th>
</tr>
</thead>
</table>

### Load Rating Method:
- ASD / LFD / LRFR

### Structure Type:

### Year Built: Year Reconstructed:

### Design Loading:

### Units:

### Location Information
- County:
- District:
- Reference Post:

### Bridge Geometry
- Span Length(s):
- Shear:
- C-O Caping:
- Clear RDWY:

### Slab Thickness
- Total Depth:
- Structural Depth:

### Materials
- Deck Concrete:
- Reinforcing Steel:
- Structural Steel:
- Prestressed Concrete:
- Timber:

### Superimposed Dead Load:

### LL DISTRIBUTION FACTOR
- Code:
- Member:
- LLD Factor:

### Notes
(comments by engineer, information from drawings, field measurements, material & load test results, etc.)
Figure 3:9-3: Load Rating Summary Page 3
### Load Rating Summary

**Subject:** Load Rating Analysis

<table>
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<th>Rating Values (ASD/LFD/LRFR):</th>
<th>INV. (Location)</th>
<th>OPER. (Location)</th>
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<tbody>
<tr>
<td>Member # (Length)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*H20.44</td>
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<tr>
<td>*HS20.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HL 93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatigue Truck</td>
<td></td>
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<tr>
<td>HS25</td>
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<td></td>
</tr>
<tr>
<td>Michigan Train #5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Michigan Train #8</td>
<td></td>
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<tr>
<td>Military Loading</td>
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**Rating (Dist Along Member):**

### Inv. (Location)

<table>
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<th>INV. (Location)</th>
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<tr>
<td>SuperLoad – 11 Axles</td>
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<tr>
<td>SuperLoad – 13 Axles</td>
</tr>
<tr>
<td>SuperLoad – 14 Axles</td>
</tr>
<tr>
<td>SuperLoad – 19 Axles (305k)</td>
</tr>
<tr>
<td>SuperLoad – 19 Axles (480k)</td>
</tr>
<tr>
<td>Toll Road Truck 126K</td>
</tr>
<tr>
<td>Toll Road Truck 89.6K</td>
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<tr>
<td>Toll Road Truck 90K</td>
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</table>

*Minimum Load Rating Required for Evaluating County Bridges*

Figure 3:9-4: Load Rating Summary Page 4
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CHAPTER 10 POSTING

In Indiana, a number of bridges cannot carry legal loads for various reasons. These include deterioration of load-carrying members, increases in dead load from overlays or other alterations, and design for loads that were lower than what is currently legal. Since most of these bridges need to be kept open to traffic, load posting guidelines have been developed by the Indiana Department of Transportation (INDOT).

SECTION 10.1 POSTING GUIDELINES

The main objective of this guideline is to ensure the safety of the public. The guidelines must not conflict with Indiana vehicle and traffic laws, or federal regulations. This means that the following minimum criteria must always be met:

- Bridges shall never be posted for a load that will cause the operating stress level, as defined by American Association of State Highway and Transportation Officials (AASHTO), to be exceeded.

- The minimum load posting value is three tons. Bridges not capable of carrying a minimum gross live load weight of three tons must be closed.

- Load posting signs shall conform to the INDOT standards or the minimum requirements of the current Indiana Manual of Uniform Traffic Control Devices (INMUTCD) for Streets and Highways.

- Only one value may be used for posting. Silhouette signing is not recommended by INDOT.

- Bridge files should contain all pertinent posting information, along with photographs of the postings in place at both ends of the bridge.

A bridge must be posted to restrict the gross vehicle weight and/or axle weight when the bridge can no longer safely support the maximum legal vehicle weight. The maximum weight restrictions for vehicles are described in the Indiana Code, Title 9, Article 20 (see Appendix A). INDOT’s policy for load limit posting of bridges is based on a ton rating value. Any bridge that has a capacity of less than 16.0 tons for the H20 rating vehicle at the inventory level shall be posted at the bridge site for the tonnage capacity. Most Indiana counties follow this policy. Any bridge that has an HS-20 operating load capacity rating factor less than 1.00 shall be posted at the bridge site with a load limit sign equal to the H-20 inventory rating, in tons. However, a bridge may also be posted at other load levels if deemed appropriate by the owner. Factors that may influence posting levels include traffic volume, traffic character, and the likelihood of overweight vehicles.

This posting policy is official for state-owned bridges only. However, many local owners also follow these procedures to set posting values. The Load Rating Team Leader notifies the bridge owner of posting requirements. INDOT reserves the right to withhold federal funding if bridge owners are not posting in accordance with this posting policy.
Posting bridges for load limit is a serious matter. Doing so can create a hardship on the motoring public and industry in the vicinity of the bridge. Bridges that rate low using Allowable Stress (AS) should be re-rated using Load Factor (LF) or Load and Resistance Factor Rating (LRFR) to determine if the bridge can accommodate higher loads based on currently accepted code criteria. Similarly, bridges that rate low using LF should be re-rated using LRFR prior to posting. To ensure that posting is justified, an inspection should be conducted by the Inspection Team Leader to visually confirm the condition, measurements, and other properties of the bridge. When appropriate, a more in-depth analysis of live load distribution should be conducted to assure that the capacity is truly valid.

A one-lane alternative may be considered when evaluating for posting. Normally a bridge will be rated for the normal number of traffic lanes it is capable of carrying; however, if the capacity is less than 16 tons, the bridge may be checked for a reduced number of lanes. Reducing the number and locations of loaded lanes, and restricting lanes with barrels or stop lights, can keep a bridge from being posted with a weight restriction. Reference the INDOT Bridge Reporting for Appraisal and Greater Inventory (BRAGI) Coding Guide for coding of this situation.
SECTION 10.2  POSTING PROCEDURE

If posting is required or warranted for state, county, toll road, or other local agency bridges, the signs should conform and be installed in accordance with the INMUTCD. Signs should be legible from a distance of no less than 50 feet. Additional advance signage shall be placed at the intersection with the last state road prior to the bridge. Advance signage shall be located as necessary to provide prohibited vehicles the opportunity to detour.

Signs must be maintained during the life of the bridge or until repairs have been made to remove the restriction. Postings or closings on state routes should be done according to INDOT’s current Bridge Restriction or Closure Protocol (see Appendix B). It is recommended that counties, the toll road, and other local agencies follow a similar protocol. An official posting/closure letter, signed by a designated official, should be added to the bridge file.

The gross vehicle weight and/or axle weight allowed should be indicated on signs at each end of the bridge. Posting of specific load limits should be accomplished using an R12-1 sign, containing the legend “WEIGHT LIMIT” on the top two lines and the applicable weight limit on the bottom two lines. The weight limits shall be shown as “X TONS.” Weight limit signage shall be used to indicate restrictions pertaining to total vehicle weight, including cargo. Failure to post bridges that have capacities less than the posting value can result in a loss of federal bridge funds.

Posting of a bridge closure may be accomplished by the use of an R11-2, “ROAD CLOSED” sign. In addition to signage, significant nonmoveable barriers shall be placed at each end of the closed bridge, restricting crossing. A permanent barricade shall be built across both ends of the bridge to prevent vehicles from crossing.

In order to document proper posting of a bridge, photos of the posting shall be taken at each end of the bridge. Photos shall be submitted when they are installed, and at each inspection. An updated Structure Inventory and Appraisal (SI&A) Report shall be submitted and the Central Database shall be updated immediately following any load rating or posting change. These are major National Bridge Inspection Standards (NBIS) compliance review items and the use of federal bridge funds can be suspended for noncompliance.
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CHAPTER 11 PERMITTING

Except for certain vehicles, which are given a permit exemption, any transport exceeding the maximum legal size and weight limits as established by Indiana law [IC 9-20-3, IC 9-20-4] must obtain a permit prior to moving on Indiana highways. In general, vehicles that exceed these dimensions and weights will require additional efforts and engineering judgment. The Indiana Department of Transportation (INDOT)/Indiana Department of Revenue (IDOR) can only permit vehicles to travel on Interstates and U.S. and State Highways. Local roads, streets, and bridges must be permitted and load-rated through local agencies.

Load ratings shall be done on the individual permitted vehicles for all bridges they will cross, taking into account axle weight, spacing, and impact. Impact effects may be minimized by requiring the vehicle to slow down to five miles per hour (mph) or 10 mph. The trucking company may be required to use a longer trailer with more axles to cross some bridges.

Once the permit vehicle has been analyzed for the intended route, one of four conditions will apply to each individual bridge on the route:

- **NO RESTRICTION** – The bridge may be crossed at the maximum allowable speed with no restrictions.
- **ONE LANE DISTRIBUTION** – The bridge must be crossed at the maximum allowable speed, travelling in the center of the travel lanes while alone on the bridge.
- **SLOWDOWN** – The bridge must be crossed at a reduced speed in the center of the travel lanes while alone on the bridge.
- **FAILURE** – The bridge may not be crossed by this particular vehicle. The trucking company may be required to use a longer trailer with more axles to cross some bridges.

Additional information regarding weight restrictions and oversize limits can be found in IDOR’s Oversize/Overweight Vehicle Permitting Handbook found at: [http://www.in.gov/dor/files/osowhandbook.pdf](http://www.in.gov/dor/files/osowhandbook.pdf).
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<th>Appendix</th>
<th>Title</th>
<th>Page</th>
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<td>APPENDIX A</td>
<td>INDIANA SIZE AND WEIGHT LAWS</td>
<td>2</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>RESTRICTION OR CLOSURE PROTOCOL</td>
<td>11</td>
</tr>
</tbody>
</table>
Summary of Indiana Size and Weight Laws 
under TITLE 9 Article 20

Except for Interstate highway travel, the following vehicles are exempt from size and weight requirements:

1. Machinery or equipment used in highway construction or maintenance by the Indiana department of transportation, counties, or municipalities.
2. A highway construction vehicle when engaged in highway construction and movement is restricted to areas under construction and not open to public is exempt from size and weight.
3. Farm drainage machinery.
4. Implements of husbandry when used during farming operations or when so constructed can be moved without damage to the highway.
5. Firefighting equipment owned or operated by a political subdivision or volunteer fire department.
6. And except for interstate highways does not limit the width or height of a farm vehicle loaded with a farm product, which would include unprocessed leaf tobacco.
7. Recovery vehicles are exempt from size and weight requirements when moving a disabled vehicle or combination of vehicles for a distance not exceeding 50 miles. However, these vehicles must meet requirements of IC 9-20-9-9 and IC 9-20-9-10.

With some exceptions, the maximum legal weights, with load, allowed under the law can be summarized as follows:

- Maximum possible gross weight: 80,000 pounds
- Maximum single axle weight: 20,000 pounds
- Maximum tandem axle weight: 34,000 pounds
- Maximum tri axle weight: 50,000 pounds
- Maximum wheel weight: 800 pounds per inch of tire width measured between the flanges of the rim.

For anything beyond these maximum weights, a permit has to be obtained from the Indiana Department of Revenue and certain requirements have to be met. For further information on permits and other information the Indiana Department of Revenue maintains a website at http://www.state.in.us/dor or at (317) 615-7320.

Vehicle License Plates and Registered Weight
Indiana has a registered weight limit, which is based on the declared gross weight (referred to as registered weight) for a vehicle when it is registered with the Bureau of Motor Vehicles or International Registration Plan (IRP) and only refers to the amount of registration fee paid according to the amount of weight declared on the registration.
Weight limits for vehicles; rules

In 1975, Indiana adopted the “Bridge Formula” as state law as stipulated in IC 9-20-40-1.

The formula is used to calculate the maximum legal gross weight and axle weights allowed for a vehicle or combination of vehicles.

\[ W - 500 \{ [(LN) + (N 1)] + 12N + 36 \} \]

\( W = \) the overall gross weight on any group of two or more consecutive axles, to the nearest 500 pounds.

\( L = \) the distance between the extreme of any group of two or more consecutive axles. (The measurement is taken at center of the wheel hubs).

\( N = \) the number of axles in the group under consideration, except that two consecutive sets of tandem axles may carry a gross load of 34,000 pounds each, providing the first and last axles of the consecutive sets of tandem axles are at least 36 feet apart or more.
### Federal Bridge Formula

Permissible gross loads for vehicles in regular operation, based on weight formula: \( W = 500 \left( \frac{L}{N} + 12 + 36 \right) \)

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<th>Maximum load in pounds carried on any group of 1 or more axles.</th>
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Indiana has a “grandfather law” built into its weight law retaining the weight limits that were in effect on January 4, 1975.

This retention protects vehicles from losing weight capability based upon their configuration when the bridge formula is applied to them.

The maximum gross weight, with load, under this subsection is seventy-three thousand two hundred eighty (73,280) pounds.

The maximum weight on an individual axle of a tandem axle group is sixteen thousand (16,000) pounds for each axle.

And limited to a maximum wheel weight of eight hundred (800) pounds per inch width of the tire measured between the flanges of the rim, or a maximum axle weight of eighteen thousand (18,000) pounds.
Examples of vehicles where the “grandfather law”, applies are:

When the outer bridge measurement is less than 40 feet for total gross weight and the tandem axles or inner bridge measurement between axles 2-5 is less than 36 feet, one set of tandems will get at least thirty four thousand (34,000) pounds, but both sets of tandem axles (axles 2-5) would not be able to gross more than sixty four thousand (64,000) pounds when added together as combination axle weight.

In this example, this vehicle would be penalized for allowable gross weight if the bridge formula were applied; the “grandfather law” allows both axles the potential to weigh twenty thousand (20,000) pounds depending on the size of the rims (tires) and effects potential gross weight.
While this vehicle would be penalized for total gross weight if the bridge formula were applied, under the "grandfather law" it has the potential to have a gross weight of no more than seventy thousand (70,000) pounds. The tri-axle assembly itself can weigh fifty thousand (50,000) pounds. This can be broken down to thirty-four thousand (34,000) pounds on the tandem and sixteen thousand (16,000) pounds on the single axle, or thirty-two thousand (32,000) pounds on the tandem axle and eighteen thousand (18,000) pounds on the single axle. Again, size of the rim determines wheel weight and gross weight.

This vehicle is also penalized for gross weight if the bridge formula was applied to it. Depending on wheel and axle configuration it has the potential to gross no more than seventy three thousand two hundred eighty (73,280) pounds under the "grandfather law". And again rim size determines wheel weight and gross weight.

Exceptions: farm commodities and the weight law.
A vehicle or combination of vehicles transporting farm commodities from the place of production to the first point of delivery where the commodities are weighed and title to the commodities are transferred are allowed ten percent additional weight to the maximum gross weight. For example, if a combination vehicle is allowed a gross weight under the Bridge Formula of eighty thousand (80,000) pounds, with this exception of ten percent, the total gross allowed would be eighty-eight thousand (88,000) pounds.
However, this increase in weight is not applicable when the following apply:
   1. Weight limits imposed for bridges or sections of highways under IC 9-20-1-4.
   2. A vehicle operated on any part of an interstate system.

Axle weights and registered weight is not applicable as long as the two aforementioned instances are not involved, or the vehicle does not exceed the 10 percent tolerance.

Farm commodities include logs, wood chips, bark, sawdust, and bulk milk. In the case of wood chips, bark, and sawdust, the ten percent tolerance is applicable at all times for gross weight and axle weights.

Exceptions: Refuse vehicles and the weight law
Special restrictions apply to a garbage truck, truck-trailer combination, or a truck-wagon combination that is either:

   1. A municipal waste collection and transportation vehicle:
      a. Specially designed and equipped with a self-compactor or detachable container;
      b. Used exclusively for garbage, refuse, or recycling operations; and
      c. Laden with garbage, refuse, or recyclables; or
   2. A disposal plant transporting vehicle certified under IC 15-2.1-16 that is laden with dead animals or animal parts.

Except for Interstate highway travel the maximum allowable gross weight shall not exceed:
   1. Twenty four thousand (24,000) pounds on a single axle; and
   2. Forty two thousand (42,000) pounds on a tandem axle.

This exception does not exempt trucks, laden or unladen, from the limitations on wheel weights imposed by IC 9-20-11-4.

THE BASIC LEGAL DIMENSIONS ALLOWED ARE:
Limitations to height, width and length include vehicle and load.

Generally the maximum width is 8’6” except for width exclusive devices as specified in 23 CFR 658, for example, exterior rear view mirrors.

The following are exceptions to the width requirement:
   1. Machinery or equipment used in utility construction or maintenance if the violation is the result of oversize tires
   2. A recreational vehicle with appurtenances making the vehicle wider than allowed
      a. The appurtenances do not extend more than the factory installed exterior rear view mirrors
      b. And the mirrors only extend to the distance necessary to afford the required field of view.

There is no exemption to the legal height of 13’6”.


Maximum length of a single vehicle operating under its own power is 40 feet, except for length exclusive devises as set forth in 23 CFR 658.13.

Exemptions
1. A recreational vehicle may measure a maximum of 45 feet.
2. A vehicle used by the railroad companies to transport steel rails in connection with a railroad construction, reconstruction or maintenance project may not exceed 40 feet.
3. A bus (9-20-8-2) must meet one of the following length measurements:
   a. An articulating bus used for public transportation can be a maximum of 65 feet.
   b. A conventional school bus can measure 38 feet.
   c. A transit school bus can be 42 feet.
   d. All other buses, 45 feet.
4. A single vehicle equipped with a permanently installed specialized equipment used for lifting, reaching, pumping or spraying, is allowed an additional 5 feet overhang of the equipment as long as it is not used to haul cargo.

A combination of two vehicles coupled together, including load, may not exceed a total length of sixty feet, except for the following:
1. Constructed to transport other vehicle or boats.
2. A combination of two vehicles coupled together being transported in a drive away or tow away service.
3. A pole trailer owned by or operated for a public utility while the pole trailer is being used in connection with the utility services of the public utility.
4. Trailers used in transporting oil field equipment or pipe for the transportation oil or gas.

A combination of three or more vehicles coupled together, including load, may not exceed a total length of sixty-five feet.

Any number of vehicles in a combination coupled together:
1. that are especially constructed to transport other vehicles or boats; and
2. by the tow bar, saddle mount, or full mount methods;
may not exceed a total length of seventy-five feet.

The maximum length of a combination of two vehicles coupled that are commonly referred as “stinger-steered” vehicles and are:
1. especially constructed to transport other vehicles or boats; and
2. a stinger-steered vehicle;
is seventy-five feet.

The maximum length of a trailer used in a truck-tractor-semitrailer-semitrailer combination is twenty-eight feet, six inches.

A maximum overall length limit is not imposed on a truck-tractor-semi trailer-semi trailer combination.
The maximum length of a semi trailer, including the load, in a truck-tractor combination is fifty-three feet.

A maximum overall length limit is not imposed on a truck-tractor-semi trailer or truck-tractor semi trailer-trailer combination.

The maximum length of a semi trailer or trailer operating in a truck-tractor-semi trailer-trailer combination is twenty-eight feet, six inches.

The maximum length of a maxi-cube vehicle combination is sixty-five feet and the maximum length of the separable cargo-carrying unit is thirty-four feet.

Maximum distance between kingpin and rearmost axle of a semi trailer measuring longer than forty-eight feet, six inches, operating on highway that is part of the state highway system is forty-three feet.

Maximum length of truck-trailer or truck-wagon combinations used in refuse operations is limited to sixty-eight feet.

For further information on Title 9 Article 20, and additional information on size and weight requirements the Indiana General Assembly may be referenced at http://www.in.gov/legislative/ic/code/title9/ar20/.
Emergency Bridge Restriction or Closure Protocol
(Effective October 1, 2008)

The protocol details the required actions to restrict/close a bridge structure or roadway below a bridge structure due to an unsafe condition brought about by collision, deterioration or other factor and lists the necessary personnel to be notified of the subsequent intervention.

1.) District is made aware of an unsafe condition; district radio room contacts the District Bridge Inspection Engineer or designee and the appropriate Subdistrict Manager. The Subdistrict coordinates with the District Bridge Inspection Section to determine equipment needs and traffic control requirements to perform the immediate inspection.

2.) The District Bridge Inspection Section informs by telephone and e-mail the Office of Structural Services (George Snyder, Bridge Rehab Unit Supervisor 317-232-5163, 317-370-3603) of the condition. (If determination of an immediate dangerous situation is made by District forces, they should take action as appropriate.)

   a. The Deputy Commissioner of Highway Management, the Deputy Commissioner of Planning Operations, the Division Director of Production Management and the Bridge Inventory Section in the Bridge Programs Section of the Engineer Program Division are notified of the situation by the Bridge Rehab Unit.

3.) If District determines that additional input is required, the District Bridge Inspection Section and the Bridge Rehab Unit inspect the bridge structure as soon as possible to determine the need for restriction/closure and to determine the need for non-INDOT assistance.
a. If no restriction/closure is required, no further protocol activity is required. (Subsequent plan development may be undertaken by a District assigned consultant or the Bridge Rehab Unit)

b. If closure is required, an official detour is determined by the District. Any computations required to justify the closing will be performed/reviewed and maintained by the Office of Structural Services. (Subsequent plan development may be undertaken by a District assigned consultant or the Bridge Rehab Unit)

c. If restriction is required, appropriate action is taken i.e. lane closure, shoulder closure, load restriction, etc. (Subsequent plan development may be undertaken by a District assigned consultant or the Bridge Rehab Unit) In the case of a load restriction, the Office of Structural Services will perform/review any necessary load rating activities and maintain all required computations; the District will develop and sign the appropriate Official Action for the legal weight restriction.

4.) The District will inform the following parties of closure or restriction information:

a. Office of Communications
b. Commissioner and Chief of Staff
c. Bridge Inventory Section
d. Deputy Commissioner of Highway Management
e. Deputy Commissioner of Planning Operations
f. Prod Management Division Director/Office of Str. Services
g. Deputy Commissioner of Highway Operations
h. Permits Section Supervisor of Maintenance Administration
i. Traffic Management Centers Director
5.) A brief written action plan will be prepared within one business day by the District and distributed to all mentioned parties. If requested by the District, the Office of Structural Services will assist in the preparation.

[Signature]
Gary Mruczka, Director
Production Management Division

11/20/08
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CHAPTER 1 GENERAL BRIDGE INFORMATION

This chapter describes the mechanics, components, construction materials, and classifications of bridges. This part of the manual addresses subjects common to fixed and movable bridges. Refer to Part 3 of this manual for a discussion of components unique to movable bridges.

SECTION 1.1 INTRODUCTION

Fixed bridges are the most common structures which carry the traveling public over roadways, railways, waterways, and valleys. Movable bridges are common over navigable waterways where the height of a fixed bridge would otherwise restrict marine traffic. It is the responsibility of the agencies that own both fixed and movable structures to uphold the public’s confidence in the infrastructure by knowing the condition of their structures and by maintaining them in a safe and cost-effective manner.

It is critical to know when a structure or component thereof has deteriorated to such an extent that it is unable to support the loads it is designed to carry. One of the responsibilities of a bridge inspector is to recognize this condition. To make this judgment, as well as to write a meaningful inspection report, an inspector must be knowledgeable about structural mechanics, be able to identify the components of a bridge and know their functions, and understand the behavior of different materials.
SECTION 1.2 OVERVIEW OF BRIDGE MECHANICS

A bridge inspector must know how a bridge functions to recognize and judge how a defect affects the load-carrying ability of a member and, eventually, the entire bridge. This section briefly describes bridge loads and bridge geometric classifications with the associated behavior of each. A more complete discussion may be found in the Bridge Inspector’s Reference Manual (BIRM).

Subsection 1.2.1 Design Loads

Bridge loads can be divided into three general categories: dead, primary live, and secondary.

Dead loads are the permanent self-weight loads of the bridge. Dead loads include the weight of items such as girders, deck, railings, diaphragms, and overlays. Utilities mounted on a bridge are also considered dead loads. Dead loads are gravity loads and exert downward forces on the bridge.

Primary live loads are the temporary gravity loads that act on the structure. These include all moving vehicles (trucks, cars, trains), with their associated impact loads, and pedestrians. Current American Association of State Highway and Transportation Officials (AASHTO) specifications for bridges establish the design live loads for highway bridges. Depending on a bridge’s use, different design trucks are specified. Differences include the design truck’s weight (15 tons up to 36 tons), number of axles (two or three), and axle spacing (14 feet to 30 feet). Major highways designed prior to the current Load and Resistance Factor Design (LRFD) specifications were designed for an alternate military loading vehicle as well. The LRFD specification uses a design tandem with a pair of 25-kip axles in place of the alternate military vehicle which had a pair of 24-kip axles. It should be noted that the design vehicles do not represent actual trucks found on highways, but were developed to represent an approximate live load for consistent design. The maximum pedestrian load on sidewalks or pedestrian bridges is 85 pounds per square foot. Primary live loads are gravity loads and exert downward forces on the bridge. Load rating of bridges is discussed further in Part 1, Chapter 9 of this manual.

Secondary loads are all remaining loads which act on the bridge, many of which act in a lateral direction. These loads include the following:

- Buoyancy – Upward forces on substructures when submerged in water
- Centrifugal forces – Forces transverse to curved bridges due to vehicles traveling around a curve
- Curb loads – Lateral forces due to vehicle wheels
- Earth pressure – Lateral soil pressure on abutments and retaining walls
- Earthquake – Lateral and vertical forces caused by seismic events
- Friction forces – Transferred from bearings
- Ice pressure – Lateral forces caused by river or stream ice flow hitting bridge components
- Longitudinal forces – Forces parallel to the bridge span due to vehicles braking and accelerating
- Railing loads – Lateral forces due to errant vehicles or pedestrians
• Rib shortening – Forces in arches and frames caused by dead load deformations
• Shrinkage – Forces within concrete members caused by member dimensional changes due to curing
• Stream flow pressures – Lateral forces caused by river or stream flow acting on bridge members
• Temperature – Forces within members caused by member dimensional changes due to temperature fluctuations
• Wind load on the primary live loads – Lateral pressures transferred to the bridge due to wind blowing on the sides of vehicles traveling across the bridge
• Wind load on the structure – Pressures due to wind blowing on the sides of bridge members

Subsection 1.2.2 Simply Supported Spans

A simply supported span is the most basic type of bridge and the easiest for an engineer to analyze and design. It forms a stand-alone, single span, with its beams or trusses commonly supported with one fixed end and one movable end. The movable end bearing devices allow the bridge to rotate and expand under load and temperature changes. On some bridges, the beam ends are encased within a concrete diaphragm over the abutments, hiding the bearing devices. Simply supported bridges can be very forgiving structures should one of the supports settle. The bearings act like hinges to allow for unrestrained, free movement. Simply supported bridges can also be very unforgiving structures should the beams ever fail between the supports. A failed beam section may act as a third hinge, causing structural instability.

Figure 4:1-1: Simply Supported Span with Prestressed Concrete Beams
The most common simply supported bridges are single span structures with the beam ends bearing on abutments. Alternatively, a bridge may consist of a series of simply supported spans, with the beam ends supported on abutments or piers. Each pier will therefore support two lines of bearings. To allow for unrestrained rotation of the bridge ends, joints are normally provided in the deck above all abutments and piers with simply supported spans.

When a simply supported span is loaded, it deflects downward between its supports and rotates at its bearings. For a uniformly loaded beam, shear forces (vertical forces within the beam) are maximum at the supports, and zero at midspan. Point loads produce uniform shears of varying magnitudes along the beam. For a simply supported beam with any type of loading, the amount of bending is zero at the supports. Bending is a maximum at midspan for uniform loading or directly under the load for point loading.

Figure 4:1-2: Simply Supported Beam Unloaded (Top) and Loaded (Bottom)
An important mechanical concept to understand is beam bending. Bending is measured in units of length, multiplied by force (defined as a moment). Most commonly in the U.S., moment is measured in foot-kips or foot-pounds. For example, suppose a person wanted to hold, horizontally, a 5-pound hammer with a 1-foot-long handle in one hand. The person’s wrist would need to resist a 5-pound x 1-foot = 5 foot-pound bending moment. If the hammer weighed 10 pounds, a 10-pound x 1-foot = 10 foot-pound bending moment would need to be resisted. Similarly, a 5-pound-hammer with a 2-foot-long handle would produce a 5-pound x 2-foot = 10 foot-pound bending moment.

As it relates to a beam, bending is classified as either a positive or negative. A deflected beam having a concave curve (producing a “smiling face”) will be resisting positive bending moments. A deflected beam having a convex curve (producing a “frowning face”) will be resisting negative bending moments. When a beam is resisting positive bending moments, the fibers at the top surface of the beam are shortened and experience compressive stresses, while the fibers at the bottom surface are stretched and experience tensile stresses. Conversely, when a beam is resisting negative bending moments, the fibers at the bottom surface of the beam are experiencing compressive stresses, while the fibers at the top surface are experiencing tensile stresses. In both situations, there is a point somewhere between the beam’s top and bottom that does not change length. Since there is no length change, there are no stresses generated. This point on the beam’s cross-section is known as the neutral axis. Simply supported bridge spans will always deflect in a concave shaped curve and will, therefore, only experience positive bending moments. As a result, the top fibers, or flanges, of the beams will always be in compression, and the bottom fibers, or bottom flanges, will always be in tension.

Subsection 1.2.3  Continuous Spans

Continuous spans are more complex in their behavior, design, and analysis. Continuous spans are beams or trusses with supports at their ends with one or more intermediate supports. As with simply supported spans, the supports are most commonly pins, rockers, rollers, or bearing pads which allow the bridge to rock, rotate, and expand under load. Continuous bridges can be very forgiving structures should the beams ever fail between the supports. To illustrate this, if the middle span of a three-span bridge fails and creates a hinge, the end spans can act as anchor spans. In doing so, the end spans can prevent a collapse by acting as levers with pivots at the piers to hold up the failed middle span. Conversely, continuous bridges can be unforgiving structures should one of the supports settle. Since continuous spans have no internal hinges, support settlements act like additional loads to the bridge. Depending on which support settles, the settlement load may overstress and possibly fail the beams.
In continuous spans, the beam depths will be smaller, deflections will be less, and spans can be made longer in comparison with multiple simple spans. Also, each pier under a continuous span will have only one line of bearings, saving costs in multi-span structures. Because the beams are continuous over the intermediate supports, deck joints are not required, which is another economic advantage. This also provides a smoother riding surface. Continuous bridges can cost more to design, fabricate, and erect than simple span bridges and are subject to developing transverse deck cracks over the piers.

When a continuous span bridge is uniformly loaded, it deflects downward between the supports and rotates at its supports. Shear forces are at a maximum at the supports and zero at or near midspan. Positive bending moments are at a maximum between supports, while negative bending moments are at a maximum directly over the interior supports. The deflected shape of the bridge will therefore have a concave curve between supports and convex curvature over the supports. Point loads produce more complex patterns of shears and bending moments. Point loads will deflect the beam downward in the loaded span producing uniform shears of varying magnitudes and a maximum bending moment at the point of the load. For any loading type, the bending moment is zero at locations where the curvature changes from concave to convex and at the end supports.
Subsection 1.2.4  Cantilever Spans

A cantilever span has one end that is free to deflect and rotate and one end that is fixed against deflection. The fixed end is idealized as fully fixed against rotation; but, in reality, a small amount of rotation will occur. The deflected shape of a cantilever span will always be convex. Therefore, bending moments are always negative and vary from zero at the free end to a maximum at the fixed end. At the free end, shear forces may be zero, but are usually relatively high since tips of the cantilevers are commonly used to support the end of another span. Shear forces are a maximum at the fixed end. The free ends of cantilever spans are always locations for expansion joints.
Cantilever spans will rarely form an entire bridge, but are typically portions of a structure. Usually, fixed cantilevers are simply extensions of continuous spans, with the continuous spans providing anchorage for the cantilever. Long span bridges frequently employ cantilevers to form part of the main crossing. The tips of two cantilevers sometimes meet in the middle; but, more commonly, an independent simply supported structure is suspended between the tips of each cantilever. On some large girder bridges, short cantilever spans may be used to join a series of independent continuous bridges to form a single, long structure. The cantilever span free end is sometimes called a ship lap joint, since the supported span of one structure laps over the cantilever supporting span. Cantilever spans reduce the positive bending moment in adjacent spans and can eliminate the use of expensive shoring for the main span construction of truss cantilevers.
Subsection 1.2.5 Span Definition Overview

Figure 4:1-7 summarizes the span types discussed above.
There are three basic components common to most fixed bridges. These components are the deck, superstructure, and substructure.

Subsection 1.3.1 Deck

A deck provides a place to drive or walk and transfers the live loads and dead loads to superstructure. Sometimes, the deck acts compositely to become part of the beam’s top compression flange. On concrete slab bridges, the deck itself is the main load-carrying member, delivering all live and dead loads directly to the substructure units.

Subsection 1.3.2 Superstructure

The superstructure supports the deck and all of the live and dead loads applied to it, delivering these loads to the substructure units. There are three main types of bridge superstructures: beam bridges such as slab, beam, girder, and truss bridges; arch bridges; and cable-supported bridges such as cable-stayed and suspension bridges. The difference is in how each type delivers loads to the bridge supports. Beam type superstructures act primarily in bending, arches in compression, and cable-supported in tension.
Subsection 1.3.3 Substructure

Substructure units of a bridge support the superstructure and deliver all of the bridge live and dead loads to the foundation soil or rock. Substructure units include the abutments, wing walls, piers/bents, and, in the case of suspension bridges, the cable anchorages. Abutments provide superstructure support at the ends of the bridge, while piers and bents provide intermediate support. In addition to providing support for vertical loads, other loads must be resisted by the substructure, such as horizontal loads due to lateral pressures (soil, wind, current, and impact) and temperature expansion effects. Substructure components must, therefore, function as both compression and bending elements.
Several materials can be used to construct the various components of a bridge. Each has its own advantages and disadvantages with respect to material properties, weight, durability, cost, and appearance. It is of primary importance for a bridge inspector to understand the material properties, to understand the durability of each material, to recognize the seriousness of the material's deterioration and its causes, and to know the best remedial actions for each material.

Subsection 1.4.1 Concrete

(a) PHYSICAL PROPERTIES

Concrete is a building material used since the ancient Roman Empire. It is a mixture of cement, water, and aggregate (sand and stone). When cement is mixed with water, a chemical reaction takes place that produces a strong, durable construction bonding material. Aggregates, which typically comprise approximately 75 percent of a concrete mix by volume, are used as an inexpensive filler material. In addition, aggregate improves a concrete’s abrasion and weather resistance. Entrained air increases workability while the concrete is being placed and improves its durability against freeze/thaw once the concrete has cured.

Plain concrete weighs about 145 pounds per cubic foot, and concrete reinforced with steel bars weighs approximately 150 pounds per cubic foot. Entrained air within the cement paste allows the absorption and passage of water, making concrete a somewhat porous material. It expands and contracts with increasing and decreasing temperatures, respectively.

(b) MECHANICAL PROPERTIES

Concrete is a material used for its compressive strength, which generally ranges from 2,500 pounds per square inch to 6,000 pounds per square inch. High-performance concrete may develop compression strengths in the 10,000 psi range. Its tensile and shear strengths are poor, being only about 10 percent and 12 percent, respectively, of its compressive strength.

To make concrete ductile and usable, reinforcing steel bars, often referred to as rebar, are cast within the concrete mass to create a heterogeneous material known as reinforced concrete. The reinforcing steel is able to resist the tensile forces that the concrete is unable to withstand. The concrete and reinforcing steel also work together in carrying a member’s shear forces. Reinforcing steel bars that transfer shear forces are placed as vertical stirrups in beams and as horizontal ties in columns. Reinforcing steel resists the tensile forces generated as a member undergoes bending. As an example, a simply supported reinforced concrete beam experiences only positive bending moments, generating compressive stresses near the top of the beam and tensile stresses near the bottom. As the beam is loaded to its ultimate capacity, the concrete’s tensile capacity near the bottom surface will be exceeded, and the concrete will
crack. A simply supported reinforced concrete beam will therefore have its reinforcing steel placed near the bottom surface to resist the tensile load. Concrete near the top surface resists the compressive loads.

Reinforcing steel is “deformed,” or has transverse ribs, to provide a mechanical interlock with the concrete. In prestressed or post-tensioned concrete, high-strength steel strands or bars replace deformed reinforcing steel. For prestressed concrete beams, the strands are pulled into tension and concrete is cast around them. The strands are released (cut) after the concrete is cured. The tensile force of the released strands introduces compressive stresses into the concrete. For post-tensioned concrete beams (usually made in the field), concrete is cast around ducts placed near the beam’s tension surfaces. After curing, post-tensioning strands or rods are placed into the ducts, anchored at one end, and stretched into tension by jacking at the other end of the beam. Locking or anchoring the jacked ends keeps the strands/bars in tension, introducing compression into the concrete. The ducts are grouted after the strands or bars are stressed. Prestressing and post-tensioning minimize or eliminate net tensile stresses in the concrete. With the concrete and steel working together, a strong, ductile, and durable construction material is created.

(c) CONCRETE DETERIORATION

Concrete can experience many types of deterioration and the causes of each can vary. It is important for the inspector to understand these causes so that a proper evaluation and recommendation can be made.

Delamination is the separation of concrete at or near the level of the reinforcing steel, and is mainly caused by reinforcing steel corrosion. Delaminations can also be caused by overstress in the member. Corroded steel has a volume approximately seven to 10 times that of the original steel. Since concrete has only limited tensile strength to counteract this expansive force, it cracks internally in a plane along the layer of reinforcing steel. The presence of delaminations may indicate that chlorides, salts, or other corrosive chemicals have reached the reinforcing steel.
Detection of delaminations is often performed by sounding the surface with a hammer. Chain dragging, a technique similar to hammer sounding, can be used to detect delaminations on the top of a bridge deck. For each method, a popping or hollow sound is generated when the hammer hits or the chain drags over a delaminated area. Thin delaminations are more readily detected than thicker ones since thicker delaminations will begin to sound more like undamaged concrete. Sometimes slight surface discolorations, surface cracks, moisture, or rust stains indicate the presence of a delamination. Delaminated areas should be outlined with a lumber crayon or spray paint to allow for monitoring of the deterioration rate or to mark the area for removal.

One high-tech method for delamination detection is infrared thermography. It is mostly used for large area deck investigations or high-traffic situations. It is discussed further in Part 4, Chapter 4.

If it can be performed safely, removal of small delaminated areas may be done during an inspection. Removing the delaminated concrete allows the base concrete to dry out, slowing down the reinforcing steel corrosion process. Additionally, removing concrete in a controlled manner eliminates the possibility of the delaminated area suddenly falling and causing damage below. Large areas of delaminated concrete should be removed as a maintenance action if there is any possibility that its falling could result in damage.

When delaminated concrete is removed or falls off of the base concrete, the resulting depression is called a spall. Spalls are typically circular or oval in shape, often exposing the surface of the corroded reinforcing steel. Causes of spall formation include freeze/thaw action from trapped water, friction from thermal movement, expansive effects from reinforcing steel corrosion, and impact fractures.
The high alkaline environment of concrete temporarily protects the underlying reinforcing steel from corrosion. As the structure ages, however, chlorides from deicing salts and potentially corrosive atmospheres may reach the steel reinforcement by diffusion through the concrete or cracks in the concrete cover. These chemicals, along with moisture and oxygen, form an electrolytic cell that corrodes the steel. As the corrosion advances, it expands, delaminating and spalling the concrete.

Heavy reinforcement corrosion can lead to a structural capacity loss in a member. As corrosion advances, the cross-sectional area of the reinforcing steel is reduced. Since the reinforcing steel must resist the same load, its stresses increase. Excessive section loss may lead to yielding or fracture during an overload. Fortunately, however, there are usually several reinforcing steel bars carrying the tensile loads in any one member. This results in redundancy and a lesser likelihood that a total member failure will occur.
Cracks are linear fractures in the concrete that may extend partially or completely through a member. Due to the nature of reinforced concrete, it is not possible to prevent crack development. Prestressed concrete should not develop any cracks, other than shrinkage cracks, under normal use. Cracks in the flexural region of beams may indicate a serious structural overload. Cracks are described by their length, width, type, and orientation. Prestressed concrete members may have cracks as a result of fabrication at or near the beam ends. These should be noted in the initial inspection.

The BIRM classifies cracks as hairline, narrow, medium, or wide. On conventionally reinforced structures, hairline cracks less than 1/16 inch wide are visible, but difficult to measure and usually insignificant. Cracks larger than 1/16 inch could be structurally significant and should be monitored and recorded in the inspection notes. Narrow cracks have widths between 1/16 inch and 1/8 inch and may be measured with a finely divided ruler or crack comparator card. Medium cracks are 1/8 inch to 3/16 inch wide. Cracks over 3/16 inch are considered wide. When cracks approach this width, aggregate interlock can be lost, resulting in the loss of shear capacity at the ends of slabs and beams.

On prestressed structures, all cracks are significant and an optical crack gauge is needed to measure the cracks. Hairline cracks have widths less than 0.004 inch. Narrow cracks are 0.004 to 0.009 inch. Medium cracks are 0.01 to 0.03 inch. Wide cracks are over 0.03 inch.
Figure 4:1-12: Map Cracks in a Wingwall

Figure 4:1-13: Medium Longitudinal Crack in a Concrete Deck
Cracks are grouped into two categories: structural and nonstructural.

Structural cracks are caused by dead and live loads and include flexural and shear cracks. Flexural cracks always develop on the tension surface near the point of maximum moment of reinforced concrete members. Flexural cracks are most commonly seen on undersides of beams near midspan, between the piers, but are also found on continuous beam tops and decks above the piers due to negative bending moments. Columns under fixed supports may develop flexural cracks when expansion/shrinkage of the superstructure bends the pier. Flexural cracks are oriented perpendicular to the length of the member. The longest cracks are located in areas of the highest bending moment, sometimes extending up to about 75 percent of the member’s depth. Flexural crack lengths shorten as bending moments are reduced. Shear cracks, if present, will always develop near piers and abutments and are always oriented diagonally. These cracks begin near the bearing and extend up towards midspan at an approximate 45-degree angle. Cracks in prestressed members originating at the prestressing strands and inclined diagonally down towards the center of the beam are related to fabrication and the release of tensioning. These are generally nonstructural cracks.
Structural cracks develop when tensile stresses acting on the member exceed the tensile strength of concrete. Reinforcing steel embedded within the concrete picks up all tensile forces immediately upon cracking. Normal loading generally causes uniformly spaced hairline cracks in reinforced concrete. These are not generally viewed as a problem. Narrow to wide cracks accompanied by excessive deflections, or any flexural cracks found in prestressed beams, suggest that the bridge has been overloaded. Foundation movement or settlement can induce stresses in the superstructure or substructure members which can also cause flexural cracks.

Nonstructural cracks do not generally affect the load-carrying capacity of the member. All concrete develops small, generally shallow, nonstructural cracks due to drying and shrinkage during the curing process. Concrete creep (the increased deflections or shortening under sustained loads) and seasonal temperature changes expand and contract the concrete after it has cured. This causes further random cracks. These long-term effects can have serious consequences if the movable bearings become locked up, restraining concrete movement and increasing the crack widths. A nominal amount of reinforcing steel placed transverse and longitudinal to the member controls widths and lengths of shrinkage and temperature cracks.

Depending on the cause of cracking, cracks can travel in several directions within a structural member. Cracks are generally oriented perpendicular to the stress that caused the crack. Their patterns may be described as follows:

- **Map cracking** – Nonstructural temperature/shrinkage cracks which travel randomly within the member. Several usually occur within any given area, giving the surface an appearance of a road map.
- **Random cracks** – Individual meandering cracks.
- **Transverse cracks** – Cracks oriented perpendicular to the bridge centerline. May be structural flexural cracks on slab bridges or nonstructural temperature/shrinkage cracks on bridge decks. These are commonly found in the deck over floor beams in truss structures.
- **Longitudinal cracks** – Cracks oriented parallel to the bridge centerline or horizontal members such as beams, girders, slabs, decks, or parapets.
- **Horizontal cracks** – Cracks oriented transversely to vertical members such as structural flexural cracks in pier shafts, pier columns, walls, and abutments.
- **Vertical cracks** – Cracks oriented vertically on vertical members such as pier shafts, columns, walls, and abutments.
- **Diagonal cracks** – Cracks angled with respect to the member centerline; commonly structural shear cracks.
D-cracks – Letter “D”-shaped cracks found at the edge of deck or slab joints, especially on skewed decks.

Radial cracks – Cracks oriented in a circular pattern; may indicate a punching shear type of failure in a bridge deck.

Efflorescence, informally referred to as leaching, is a white deposit on the concrete surface caused by the crystallization of soluble salts (calcium chloride, calcium hydroxide) contained within the cement paste. Water traveling through the concrete dissolves these salts and usually deposits them along cracks where the water exits. Efflorescence indicates that water and dissolved chemicals are able to pass through and contaminate the concrete.

Light efflorescence does not affect the compressive strength of the concrete paste. Heavy efflorescence, which is sometimes accompanied with rust stains from reinforcing steel corrosion, indicates a reduction in the compressive strength of the concrete and reduction in the structural member’s overall strength. A corresponding wet look to the concrete on the underside of a concrete deck, slab, or concrete member indicates that the concrete may be unsound and debond from the lower layer of steel reinforcing and fall off the deck, slab, or concrete member.

![Figure 4:1-15: Heavy Efflorescence on an Abutment and Slab](image)

Scaling is the gradual loss of cement paste and surface aggregates caused by freeze/thaw activity or chemical degradation. It is classified by the BIRM as light, medium, heavy, or severe. Light scaling indicates mortar loss of up to 1/4 inch with surface exposure of coarse aggregates. Medium scaling indicates mortar loss from 1/4 inch to 1/2 inch, exposing coarse aggregates. Heavy scaling indicates mortar loss of from 1/2 inch to 1 inch with clear exposure of the coarse aggregates. Severe scaling indicates a loss of coarse aggregate, as well as surface mortar, with depths greater than 1 inch; reinforcing steel may be exposed.
Scaling is typically located along the gutter lines of the deck and is caused by deicing chemicals. Ponded salt water along the gutter, caused by clogged drains or scuppers, is the usual culprit for the chemical attacks. Other bridge components, especially substructure units located in a waterway, can be subjected to scaling by way of sulfate compounds found in soil and water and the freeze/thaw action of the waterway.
Pop-outs are small conical shaped depressions in the concrete surface caused by coarse aggregates which expand during moisture absorption. Shale and chert are common expansive aggregate types. Pop-outs may also be caused by reactive aggregates and high alkali cement. Pop-outs can normally be discerned by seeing the aggregate particle’s fractured surface in the bottom of the depression. Pop-outs themselves are not a structural concern, although the pop-outs may eventually cause a rougher ride or help to speed the rate at which water can reach the underlying reinforcing steel.

Honeycombs are voids within the concrete mass caused by congested reinforcing steel or improper concrete vibration during construction. Small honeycombs are not detrimental to the strength of the member, whereas large honeycombs may be structurally significant. Severe honeycombing may leave some of the reinforcing steel within the member uncovered. Only voids adjacent to the concrete surface are detectable by visual inspection techniques.
Trucks, over-height vehicles, derailed trains, floating debris, and marine traffic may strike and damage concrete piers, abutments, or girders. Stream debris or ice floes may also impact bridge piers or abutments located in the channel. Large sections of concrete may be cracked or chipped off a structural member, exposing reinforcing steel or prestressing strands. If damaged sections are similar to spalls, patching may be used as a repair method. Damaged prestressed beams with exposed or broken strands generally need to be replaced. Serious impacts can result in the failure of pier columns or girders. A bridge may need to be closed until the severity of the damage is assessed. Damage inspections are discussed in Part 1, Section 3.8.

Abrasion causes section loss of concrete members over time. Surface abrasion is often caused by the erosive action of silt or sand found in fast-flowing rivers, streams, or surf zones. It affects piers, pilings, and abutments. Decks, curbs, and parapets are subject to abrasion from snow plows, street sweepers, tire chains, and studded tires.
Though concrete is considered a fire-resistant material, fire can cause deterioration. Surface effects of fire may include deposition of combustible materials and discoloration on the concrete surface. Concrete pop-outs, scaling, delaminations, and spalls may be caused by the intense heat expanding the aggregate and reinforcing steel and the expansion of moisture present in the concrete. Prolonged exposure to fire may cause the deterioration of the concrete matrix. When this is suspected, concrete samples should be obtained for laboratory examination.

**Subsection 1.4.2 Structural Steel**

Carbon steel is often referred to simply as steel and has been a widely used building material since the latter part of the 19th century. Steel is differentiated from iron by the inclusion of carbon and other alloying elements. Many standard cross-sectional steel shapes such as angles, channels, and wide flange sections are produced by rolling mills. Nonstandard shapes may be created by welding, bolting, or riveting together combinations of flat plates and/or smaller rolled sections. In Indiana, all rolled I-shaped members are called rolled beams and all built up I-shaped members are called girders.
(a) PHYSICAL PROPERTIES

Steel weighs approximately 490 pounds per cubic foot. The chemical composition of steel varies widely depending on the type of steel. Steels used for bridge construction are normally classified as low carbon steels, containing less than 0.30 percent carbon. Various alloying elements such as copper, chrome, manganese, silicone, vanadium, and nickel are added for improved mechanical properties, weldability, and corrosion resistance. Steel also contains deleterious elements such as sulphur and phosphorus. Higher-strength steels are produced using higher percentages of alloying elements coupled with heat-treatment. These are known as quenched and tempered alloy steels, and they are not commonly used for bridge structures.

Unprotected structural steel will readily corrode or rust. Painting and galvanizing (the application of a sacrificial coating of zinc) are the most common methods used to protect steel against atmospheric corrosion. Some steels, known as weathering steels, oxidize to produce a dense protective coating of rust which inhibits further corrosion. When used in the proper environment, these steels require no painting and develop an even-textured, dark red-brown appearance.

(b) MECHANICAL PROPERTIES

Steel is a material used for its high tensile and compressive strengths. The yield strength of steel, the greatest stress a material can withstand without being permanently deformed, ranges from approximately 28,000 pounds per square inch to 70,000 pounds per square inch. Tensile and compressive yield strengths are the same. Shear strength is about 60 percent of the steel’s yield strength.

When stressed below its yield point, steel is elastic and a loaded beam will return to its unloaded position once the load is removed. Should high loads or impacts be applied which produce stresses beyond yield, the member will be permanently deformed. Because steel is ductile, it can usually withstand these deformations without failure. However, steel may have reduced ductility or become brittle due to the effects of welding, heat treatment, fatigue, or very low temperatures.

Fatigue is material fracture under cyclic loading at stresses below its yield strength. It affects the part of a member’s cross-section subject to varying tensile stresses or stress reversals. Steel strength is reduced if it is subject to a large number of stress fluctuations or reversals. This strength reduction depends on the number of load cycles, the magnitude of the stress fluctuation, and the type of detail involved. Reductions in allowable stresses may be required when discontinuities such as changes in the cross-section, cuts, tack welds, and rough edges exist. Small discontinuities may be removed or improved by grinding to a smooth profile.

Sudden fracture of a steel member may occur under unique circumstances when a member is being stressed in multiple directions.
Steel can have many types of defects and is subject to many types of damage, including corrosion, fatigue, overload, impact, and fire. Steel’s susceptibility to corrosion and fatigue damage makes reporting these defects all the more critical.

The following information is a brief overview of causes of fatigue cracking in steel. An excellent resource for a more complete discussion of fatigue, as well as for example photographs and diagrams, is the *Manual for Inspecting Bridges for Fatigue Damage Conditions* by Yen, Huang, Lai, and Fisher.

Corrosion, or rust, is the most visible type of steel deterioration. It is a chemical reaction in which the iron in the steel combines with oxygen in the air to form ferric oxide and ferric hydroxide. More specifically, it is an electrochemical process between an area having a tendency to corrode (the anode) and an area with a lower tendency to corrode (the cathode). The anode and cathode may be located on the same piece of steel. A liquid electrolyte (water) must be present to allow for the flow of metal ions, and a conductor (the steel itself) must be present to allow electron flow from the anode to the cathode. Iron in the steel dissolves in the water to form iron ions. These ions react with oxygen in the air to form rust at the anode. Electrons that flow from the anode to the cathode combine with other ions in the water, typically hydrogen ions, to form hydrogen gas. As a result, the cathode is left undamaged.

![Figure 4:1-21: Steel Corrosion at Girder Splice](image-url)
The corrosion process can be stopped by preventing the electrolyte (water) from coming in contact with the base metal. In most steel bridge structures, this is done by the application of a protective paint coating. In lieu of painting, a galvanized coating may be applied. The galvanized zinc provides both a barrier coating and a galvanic protection layer. Since zinc has a greater tendency to corrode than iron, it becomes the anode and the steel becomes the cathode.

Once the base steel is exposed to the atmosphere, there are several causes for corrosion. The most common cause is the environment, and this primarily affects steel in contact with water or soil. Impurities in water, such as deicing chemicals, bird waste, atmospheric pollutants, and acids in the soil, produce ionic solutions which create more efficient electrolytes, increasing the rate of corrosion.

Other less common causes for corrosion include fretting, stress corrosion, bacterial-induced corrosion, and direct currents. Fretting is the rubbing of two closely fitted steel parts. Pitting and a red deposit occur at the interface. Stress corrosion occurs when a metal is loaded in tension. The tensile stress exposes an increased amount of surface area at the metal’s grain boundaries, leading to corrosion and cracking. Waterborne bacteria, heavy clay, and contaminated waters can destroy the steel’s protective coating and sometimes corrode the steel itself. Stray currents from sources such as welding equipment, substations, and railway power or signal systems can also create or speed the rate of the electrochemical process.

The three commonly recognized stages of corrosion are light, moderate, and heavy. Light or surface rust is a loose form of corrosion usually appearing as a dark orange or light brown color. It can also be observed as light pitting or spotting on the paint surface. Its effect is not serious, as it does not oxidize away a measurable amount of the steel. Moderate corrosion has a medium to dark brown color and a scaly appearance. Shallow pits may have formed in the steel surface. There is no paint left to protect the steel, and small amounts of section loss may have occurred. Heavy corrosion is easily recognized by its dark brown to almost black color, flaking, and laminations. These rust laminations may be removed with a chipping hammer, exposing large deep pits in the steel surface. Heavy corrosion causes reductions in plate thickness that can easily be seen with the naked eye or can even cause through-thickness section loss.

Corrosion can occur between two plates that are riveted, bolted, or pinned together, such as field splices, bracing connections, cover plates, hanger bars, or bearings. If the plates are not clamped tightly together or paint does not properly seal the edge of the faying surface, moisture is able to penetrate between the plies. This moisture can remain for extended periods, since it is difficult for this area to dry out. When corrosion begins, it expands to separate the plates, providing increased moisture penetration and creating prying forces on the fasteners. Advanced corrosion will exhibit layered rust, plate bending, and failed rivets or bolts.
If left unchecked, corrosion will remove a significant quantity of a member’s cross-sectional area. Member stresses increase significantly when the area is reduced.

For example, suppose a member has an uncorroded area of three square inches and carries a load of 60,000 pounds. Stress in the original member is 60,000 pounds ÷ 3 square inches, or 20,000 pounds per square inch. If corrosion removes one-third of the original cross-sectional area, leaving only two square inches of steel, the remaining stress is increased by 50 percent to 60,000 pounds ÷ 2 square inches, or 30,000 pounds per square inch.
For a given load, stress is inversely proportional to the cross-sectional area. Continuing with the procedure above, a 50 percent reduction in area will lead to a stress of 40,000 pounds per square inch. If steel with a yield strength of 36,000 pounds per square inch were used for the member, an overstress and possible failure may occur.

Corrosion causes surface discontinuities in the form of rough edges and surface pits. Discontinuities act as notches. When stress “flow” is forced to bend around a notch, local stresses in the immediate vicinity are greatly amplified. Under repeated loading, the notch may act as a crack initiation point, and the high-stress concentrations, coupled with repeated loading, will eventually tear the steel apart. As a result, a corroded member is more prone to fatigue damage than members with smooth, uncorroded surfaces.

Corrosion that forms at expansion devices such as pins and hangers, sliding plate bearings, and pinned bearings can become so excessive that these devices stop allowing movement. When this occurs, unintended loads are introduced into the structure which could cause overstresses and possible component failure.

Fatigue is material failure or fracture at stress levels below the yield point under cyclic loading. Stress fluctuations are caused by repeated member loading, such as trucks driving over a bridge. Each load cycle causes member stresses to increase and then decrease. The fatigue stress range is the algebraic sum of the minimum and maximum stress at the location. Bending a paper clip back and forth until it breaks is an example of a fatigue failure.

Fatigue cracks are of primary concern since their growth can lead to sudden catastrophic failures. It is extremely important for an inspector to understand where fatigue cracks are likely to occur and be able to identify a fatigue crack. Fatigue crack development depends on several factors. These factors include load frequency, stress type, stress range, and type of detail. Fatigue is discussed in detail in Part 4, Chapter 11.
Steel is more likely to develop fatigue cracks under a high number of load applications. Bridges that experience multiple truck loadings on a daily basis are more prone to fatigue damage than rural or local bridges that carry minimal truck traffic. Older bridges have probably seen a greater number of truckload applications than recently built structures.

Load frequency is generally a concern for highway and railroad bridges where heavy vehicles commonly use the structure. It is generally not a concern for pedestrian bridges, or where the frequency of design loads is relatively low.

Fatigue is most often a concern when the stress during each load cycle is from repeated tension or compression-tension load reversals. Susceptible components include the tension chords, diagonals, and verticals of truss bridges; the tension flanges of beam/girder bridges; and the hangers of suspended girders or trusses. Beam webs can also be subject to fatigue cracking when cross-frames or diaphragms create out-of-plane distortion in the web. Fatigue-prone details are shown in Part 4, Appendix B.

Cyclic compression stresses can also produce fatigue cracks, but any cracking in locations subject to cyclic compression stress is usually due to residual tensile stresses in the steel from welding or uneven cooling after rolling. Cyclic compressive stress is rarely a concern for bridges.

Another factor for steel’s susceptibility to fatigue is the stress range. Steel is more likely to crack when the stress range during each load cycle is high.

Resistance to fatigue cracking is not dependant on the yield strength of the steel. Steel toughness, the ability of steel to resist fracture, has an impact on resistance to fatigue, especially at colder temperatures.
Secondary member attachments such as welded cover plate ends, bolt holes, or tack welds create a material discontinuity and introduce an interruption in the stress flow. Each discontinuity acts as a notch in the steel member, creating a sudden rise in the stress level. Smooth transitions are less susceptible to cracking; whereas sharp transitions, such as transverse welds at the end of a cover plate or gouges in the flange, are very susceptible.
Notches force the stress flow to suddenly “bend” around a corner. This sudden direction change produces a rise in the stress which may, on the microscopic level, reach yield. Repeated loading to yield will eventually fracture the steel, creating a crack (similar to the repeated bending of a paper clip mentioned above). Once a crack forms, the cross-sectional area of the member is reduced, and the crack tip acts as a stress riser, leading to higher stresses and further crack growth. If the crack is left unarrested and occurs within a tension or stress reversal zone, the member could eventually tear itself apart.

The AASHTO bridge specifications have categorized several steel bridge details with respect to their susceptibility to fatigue cracking. All were categorized with respect to beam or girder in-plane bending and axial loading of members or member components. See Part 4, Appendix C for these details.

Several inspection techniques are used to detect fatigue cracks. The most common and most important method is visual examination, as this is usually how cracks are found. While it would be ideal to examine every square inch of every element experiencing tensile stress variations or stress reversals, this is unnecessary and expensive. Since fatigue cracks develop at discontinuities, it is reasonable to inspect local suspect details only. Telltale, visual signs suggesting a crack include rust drips (bleeding), rust powder (due to rubbing along the crack), and small, usually rusty cracks. Some cracks can be very large, and in extreme situations they may even open and close under traffic loading. Another sign is a fine line of discoloration in the paint at the toe of a connecting weld or on the surface of a weld. The Manual for Inspecting Bridges for Fatigue Damage Conditions contains several photos and diagrams illustrating these signs. Suspected cracks may be more easily confirmed by using a magnifying glass. All suspect cracks should be reported, and their location marked directly on the member with a permanent felt tipped marker or paint stick.

After visual detection, some small cracks may require confirmation through the use of nondestructive testing techniques. Most commonly, magnetic particle or liquid (dye) penetrant testing is used because these methods are easy to administer, inexpensive, quick, and require fairly low-tech equipment. Since magnetic particle and dye penetrant testing will only reveal the size of the crack at the metal’s surface, more advanced nondestructive techniques may need to be used to establish the extent of a crack within the base metal. The most common advanced method of examination is ultrasonic testing. Generally, more expensive methods include acoustics, eddy current, and radiography (x-ray).
Confirmed cracks should be re-examined during subsequent inspections until the cracks are eliminated or repaired. Shallow cracks may be ground or drilled out. Holes (sometimes referred to as "mouse holes") may be drilled at the tips of long cracks to eliminate the sharp rise in stress in this area. Longer cracks typically require the drilling of mouse holes plus bolting splice plates to the member. These holes must be properly sized in relation to the length of the crack, the stress range, and the fatigue detail in order to ensure that the crack does not continue past the drilled hole. The plug from the drilled hole and the edges of the hole must be examined to ensure that the end of the crack was correctly identified.

Although the base metal away from component details is generally not a fatigue concern (such as tension flange areas located between diaphragm connections), crack initiation points may still exist in the form of tack welds, welded flange splices not ground smooth, and notches resulting from traffic impact or fabrication carelessness. These flaws should be examined closely and reported. The flaws should also be re-examined during subsequent inspections until they are eliminated or repaired. Tack welds or butt welds with the reinforcement left in place can generally be ground smooth, eliminating the defect. Notches are typically ground smooth to form a smooth, tapering transition in the plate.
A detail contributing to the cracking of many fabricated girders is the web-gap. A web-gap is created when a horizontal gusset plate is notched to fit around a transverse, vertical connection plate. The horizontal gusset plate, used to connect lateral bracing, is then welded directly to the girder web. The small space created between the transverse connection plate and horizontal gusset plate notch is called the web-gap. Web cracking is not related to the in-plane bending details indicated in the AASHTO stress categories. Web-gap cracking is produced by out-of-plane, or sideways, web bending. Forces in the lateral bracing/horizontal gusset plate push and pull on the girder web, causing it to bend sideways (out-of-plane). This bending is restrained due to the stiffness created by the transverse connection plate. As a result, the web is forced to deflect and bend over the very short gap distance, generating extremely high, local stresses. After numerous load cycles, a vertical web crack within the web-gap region will develop, creating a material discontinuity and notch with respect to in-plane bending. This effect is shown in Figure 4:1-28. Left unarrested, this crack can grow into the tension flange to create a critical situation.

![Figure 4:1-28: Girder Web Gap Fatigue Crack](image)

(Note the drilled crack arrest holes at crack tips and the outline of the lower lateral shelf plate located on the opposite side of the web in Figure 4:1-28.)

An overload occurs when live loads crossing the bridge are so great that the structural members are stressed beyond their design strength, causing permanent deformation. In tension components, a permanently elongated member, a reduced cross-section, or fracture are all signs that an overload has occurred. Compression members or components may become unstable when overloaded. Symptoms of compression overloading include buckled members that form either a single, curved bow, or a double, curved “S” shape. Bucking or waviness in plates or outstanding beam flanges or the legs of angles also indicates compression stress overloads. Separations or wrinkling in paint coatings in the absence of corrosion may also indicate member overloads.
Impact damage, most often caused by vehicular collisions, normally occurs above the roadway or waterway on the fascia girder. Stream debris or ice floes may also impact bridge piers or abutments located in the channel. Indications include dislocated and distorted members and scrape marks on the flange undersides. Distorted portions of members or components may act as stress risers, making a normally sound component a fatigue-prone detail. A bridge may need to be closed until the severity of the damage is assessed. Damage inspections are discussed in Part 1, Section 3.8.

Unprotected steel has poor resistance to extended heat exposure. Although it is incombustible, both the yield strength and the modulus of elasticity are reduced at elevated temperatures. Yield strengths of steels normally used in bridge construction are reduced by about 23 percent at 800 degrees Fahrenheit, 37 percent at 1,000 degrees Fahrenheit, and 63 percent at 1,200 degrees Fahrenheit. Melting points of different steel alloys vary, but the melting temperature of pure iron, about 2,800 degrees Fahrenheit, is a good approximation. Thermal expansion can produce high axial forces and steel properties may be adversely affected by rapid quenching in efforts to extinguish a fire.
Subsection 1.4.3 Timber

Timber has been a widely used building material for all of recorded history. Timber has many advantages as a bridge material, including excellent resistance to fatigue and impact loading, resistance to deicing chemicals and freeze/thaw effects, a favorable strength to weight ratio, and ease of construction. Timber bridges can be aesthetically pleasing. Timber is a readily available, renewable resource. Traditionally, solid sawn lumber was used for all bridge components due to the abundance of large, old growth trees. Current manufacturing processes allow very large timber members to be created by glue-laminating several smaller pieces together. These members can be assembled into many types of structures including slabs, beams, trusses, arches, trestles, and even suspension bridges. Timber bridges are generally inefficient for long spans and are subject to insect and biological attack.

(a) PHYSICAL PROPERTIES

Wood used for bridge construction weighs about 50 pounds per cubic foot, although this value can vary widely, depending upon the wood species and moisture content. It is a hygroscopic material that absorbs and loses moisture as the humidity of the air changes. These moisture content fluctuations cause the wood to expand and shrink. Wood is an orthotropic material, meaning that its physical properties parallel to the grain are different than those perpendicular to the grain. It is resistant to many chemicals. Heavy wood members resist continued fire damage by the forming of a char layer that acts to insulate the underlying sound wood.

Features related to tree growth, such as knots, splits, checks, and shakes, can adversely affect a member’s strength. High moisture content can also negatively affect the wood’s strength, and wood without a preservative treatment has limited resistance to decay or insect attack. Fungi, termites, carpenter ants, powder-post beetles, marine borers, and caddisflies are the most common sources for timber deterioration.

(b) MECHANICAL PROPERTIES

Wood is a material used for its tension, compression, and bending capabilities. Its mechanical properties vary greatly from species to species. Because wood is an orthotropic material, the mechanical properties also vary depending on its principal axes of anatomical symmetry. Ultimate strengths for the most common properties used in design range from 6,600 to 17,500 pounds per square inch for tension parallel to the grain, 1,700 to 10,100 pounds per square inch for compression parallel to the grain, 3,900 to 20,200 pounds per square inch for bending, and 500 to 2,600 pounds per square inch for shear parallel to the grain. Similar properties in wood’s other two orthogonal directions (perpendicular to the grain in the radial and tangential directions) will have different ultimate strength values.
For most engineering applications, wood behaves elastically, and a beam stressed below its ultimate strength will return to its unstressed shape once the load is removed. Recovery from its deformed loaded shape may not be immediate. If the load had been in place long-term, recovery will take a longer period of time. Wood is susceptible to creep. Creep is a gradual deformation under a sustained load. Over a period of years, the initial deflection of a wood beam can eventually double under high, permanent loading.

Should high-dynamic impact loads be applied, wood is a very resilient material. It can sustain dynamic loads up to approximately twice the amount that would produce failures if applied statically.

(c) TIMBER DETERIORATION

Timber is susceptible to deterioration and damage. Untreated wood can suffer structural deterioration due to insect or biological attack. Treated or untreated wood is susceptible to structural damage from mechanical or atmospheric sources such as fire, vehicle impact, overloads, and drying.

Biological damage to wood is caused by living organisms. The main defense against such attacks is to treat the wood with chemical preservatives. Decay caused by fungi is the primary reason for timber bridge replacement. Brown rot and white rot are the two fungi most responsible for structural damage. They feed on the cellulose and lignin that make up the wood’s cell wall configuration and give it its strength. Brown rot makes the wood dark brown and crumbly. Because its enzymes can diffuse into the wood far from their source, brown rot can weaken the wood substantially in the early stages of its attack. White rot makes the wood white and stringy. Though the enzymes do not migrate into the wood as with brown rot, white rot uses more of the wood cell wall as a food source, causing more severe, localized decay. Other fungi may be present on a timber member, but do not cause any serious structural damage. However, their presence indicates that conditions are right for the growth of brown or white rot. These indicator fungi include molds, which have cottony or powdery appearances and vary from white to black in color. Stains may appear as specks, spots, streaks, or patches of varying color on the wood surface. Soft rot attacks the wood, but only to just below the surface. It makes the wood soft and spongy.

For fungi to survive, there must be sufficient oxygen and over 26 percent moisture present in the wood. Fungi must have a food source, and this is the wood itself. Temperatures must range between 32 degrees and 90 degrees Fahrenheit, with the rate of biological activity higher at warmer temperatures. Areas that trap moisture promote fungi growth. These commonly exist at connections, supports, splices, and the ground line. The natural decay due to fungi can be stopped using wood preservatives, which poison the fungi food source, or by reducing the moisture content.
Wood parasites include insects, mollusks, or crustaceans that live within or feed upon the timber member. Termites feed on damp wood, usually in contact with the ground. Their tunnels contain no exit holes, so a termite-damaged timber may look sound. A sharp tap on a timber’s surface, however, will easily punch a hole into a termite-damaged interior. Mud tubes that run from the ground to the wood member are a sign of termite activity. Timber damage due to termites on frequently used bridges is rare. It is suspected that they may be intolerant of the frequent vibrations.

Carpenter ants tunnel through a timber’s interior for shelter. As with termites, they damage the interior of a timber so that infestation is not readily apparent. They will, however, leave a pile of sawdust at the entrance tunnel, signaling their presence.

The larvae of powder-post beetles feed on the interior of timbers, creating tunnels and many exit holes. A powdery residue is often packed into these exit holes, indicating their presence.

Caddisflies are insects found in fresh or brackish water. Caddisfly larvae use timber piles for protection by boring holes into the sides of the timber. They are attracted to timber with fungal decay. Since they do not eat the wood, they can also be found in piles treated with creosote.

Mechanical damage is usually caused by the live loads acting on the bridge. Overload damage occurs when live loads acting on the bridge are so great that the structural members are stressed beyond their ultimate strength. Compression members may buckle into a single, curved bow; double, curved “S” shape; crack; or even break. Tension and bending members will crack or fracture. Cracks due to overloads will generally be perpendicular to the grain, splintering the wood. Overloads may be caused by traffic or by foundation settlements.

Impact damage, most commonly caused by vehicular collisions, normally occurs above the roadway or navigable channel on the fascia girder. It can also occur on the main load-carrying members of through trusses and arches. Stream debris or ice floes may also impact bridge piers or abutments located in the channel. Indications of impacts include damaged timbers and scrape marks.

Abrasion is most often seen on timber bridge decks and is caused by vehicle tires and snow plows. These forces can cause ruts in the deck that hold water, further weakening the wood. Mechanical wear occurs from fasteners rubbing against their holes at loose connections.

The weathering effects of moisture, light, and heat can adversely affect the physical properties of wood. Moisture loss in wood can cause dimensional instabilities of a timber, resulting in warps, cracks, and shrinkage. Warping of a wood member is caused by uneven drying, allowing one side of the timber to shrink at a different rate than the other. As a result, the member may bow, twist, or cup.
Moisture loss in a timber will often cause the member to shrink, causing cracks. Cracks create openings into a timber’s untreated interior, allowing biological agents to enter and begin the decay process. Cracks may also reduce the timber’s strength. Checks are cracks oriented parallel to the grain and perpendicular to the annual growth rings. Splits are similar to checks, but these extend completely through the member. Some cracks, called shakes, may form before a tree has been felled. Shakes are oriented parallel to both the grain and annual growth rings.

Improperly dried wood may shrink during service, resulting in loose connections. Loose connections may allow biological agents to enter the untreated timber interior. Mechanical wear due to the fastener rubbing against the wood may also take place under live load.

Though fire can completely consume a small timber member, large timber members offer some resistance to fire. Fire consumes wood at a rate of about 0.05 inch of thickness per minute for the first 30 minutes, and about 0.021 inch per minute thereafter. As wood burns, a black char layer is formed. This char helps to insulate the underlying unburned wood, slowing the consumption rate. Large timbers have enough volume to develop this protective char layer, leaving a core of undamaged wood. Though the remaining wood core does not have the strength of the original undamaged timber, it is often enough to prevent a total collapse.

Subsection 1.4.4 Other Materials

(a) STONE MASONRY

Stone masonry is rarely used in modern construction as a structural material for bridges. However, it was used extensively for abutments and piers in the 1800s and early 1900s. It was also used during this time to build arch superstructures and culvert structures. Different types of stone were used, depending on local availability. These are most commonly limestone, sandstone, and granite.

Stone masonry is classified as rubble masonry, square-stone masonry, or ashlar. Rubble masonry is rough-cut stones used for random-coursed or roughly coursed construction. Square-stone masonry is roughly squared and dressed and may be laid in random or coursed construction. Ashlar masonry is precisely squared and finely dressed and may be laid in random or coursed construction.

Stone masonry weighs between 135 pounds per cubic foot (sandstones) to 165 pounds per cubic foot (granites). It expands and contracts with increasing and decreasing temperatures, respectively. It may be porous and, therefore, absorbs moisture. Limestone, common in Indiana, tends to be more absorptive than most other stones. Stone is a durable material, and different stone types will have different durabilities.
Stone masonry is a material used for its compressive strength. Depending on the material type and where it had been quarried, compressive strengths generally range from 6,000 pounds per square inch (limestones and sandstones) up to 36,000 pounds per square inch (granites). Its tensile strengths are poor, ranging from about two to 13 percent of its compressive strength. Mortar is used to form a bedding material for each masonry unit, bond individual stone units together, seal joints against moisture penetration, and seal irregularities on the masonry unit’s surface.

Figure 4:1-30: Masonry Deterioration/Spalls at an Arch Bearing

The three main causes of stone masonry deterioration are splitting, spalling, and weathering.

Splitting refers to the seams or cracks that may form in rocks. This common type of deterioration may occur due to freezing water within small seams and pores, due to volume changes from seasonal temperature fluctuations, and due to the wedging force of plant roots growing into crevices and joints. Structural overloads may also cause the stone masonry units to split. Small pieces of rock which break out or chip off of the stone masonry unit are called spalls. Sources of spalling are the same as those that produce splits. Vehicle impacts may also produce spalls. Weathering is the degeneration of the rock surface into small granules. Causes that chemically attack the stone include lichens and ivy, acid rain, and gasses and solids dissolved in water. Windborne or waterborne particles can cause abrasion. Freeze/thaw cycles may also produce weathering.
CAST IRON

Cast iron is a material not used in modern construction as a structural material for bridges. However, it was used for the compression members and bearing castings of bridges built in the 1800’s and early 1900’s. Cast iron is produced by pouring molten iron into a mold and letting the metal solidify.
Cast iron has a gray color due to the presence of graphite particles distributed throughout the metal. It weighs approximately 450 pounds per cubic foot. The chemical composition of cast iron varies widely depending on the type. However, the most common gray cast iron is composed mainly of iron, carbon (2.0 percent to 4.0 percent of carbon by weight), and silicone (up to 2.8 percent). Other elements include sulphur, phosphorus, and manganese. Unprotected cast iron will corrode, but tends to be more corrosion-resistant than steel. It is usually painted to protect against atmospheric corrosion.

Cast iron is a material used for its high compressive strength. The tensile yield strength of gray cast iron is about the same as its ultimate tensile strength of 20,000 to 30,000 pounds per square inch. Its compressive yield strength varies from approximately 80,000 to 100,000 pounds per square inch.

The free carbon, slag, and other impurities in cast iron make it a brittle material and difficult to weld. These impurities act as discontinuities in the crystal structure, restricting the movement of dislocations and acting as nucleation points for cracks. This ultimately results in decreased ductility. It has poor resistance to shock, impacts, and fatigue loading, but has good damping properties and is easy to machine. Types of cast iron deterioration are similar to those found on steel (see Subsection 1.4.2[c]).

(c) WROUGHT IRON

Wrought iron is a material that is not used in modern construction as a structural material for bridges. It is, however, still found on many old bridges as tension members. Wrought iron is produced by mechanically rolling or working relatively pure iron into a desired shape, producing a fibrous material with properties in the worked direction similar to steel.

Wrought iron weighs about 480 pounds per cubic foot. The chemical composition of wrought iron is mainly of iron, slag (iron silicate, up to 3.0 percent by weight), and phosphorous (approximately 1.2 percent). Other elements include sulphur, manganese, and carbon.

Unprotected wrought iron will corrode, but tends to be more corrosion-resistant than steel. Its fibrous nature produces a tight rust that is less likely to flake and scale than structural steels.

Wrought iron is a material used for its high tensile strength. Its yield strength is about 30,000 pounds per square inch. When wrought iron is worked or rolled, the slag distributed throughout the metal is elongated into fibers. Because of this, it is an anisotropic material, having different mechanical properties with respect to the direction of the slag fibers.

The slag fibers give wrought iron many desirable properties. It surpasses steel in its ductility, fatigue strength, and corrosion resistance. It has good machinability properties and good impact and shock resistance. Wrought iron is also weldable.

Types of wrought iron deterioration are similar to those found on steel (see Subsection 1.4.2[c]).
(d) CAST STEEL

Cast steel is a material not normally used in fixed bridge construction, but it has been used for tracks in movable bridges. Cast steel is produced by pouring molten metal into a casting mold directly from the steel-making furnace.

Several types of cast steel exist, including carbon steel, low-alloy steel, alloy steel, and stainless steel. Cast steel weighs about 490 pounds per cubic foot. The chemical composition of cast steel varies widely depending on the type. However, carbon steel castings are composed of iron and carbon (0.2 percent to over 0.5 percent of carbon by weight). Unprotected cast steel will corrode.

Cast steel is a material used for its machinability qualities. The yield strengths of carbon steel castings commonly used for bridges range from 35,000 to 95,000 pounds per square inch, and tensile strengths range from 60,000 to 120,000 pounds per square inch. Low-alloy and alloy bridge castings are stronger, and can have yield and tensile strengths up to 135,000 pounds per square inch and 140,000 pounds per square inch, respectively.

Types of cast steel deterioration are similar to those found on steel (see Subsection 1.4.2[c]).

![Fatigue Cracks on a Steel Casting](image)

Figure 4:1-33: Fatigue Cracks on a Steel Casting

(e) ALUMINUM

Aluminum is not normally a material used as a structural material for vehicular bridges except for some underfill structures. However, it may be found as part of the deck, superstructure, or substructure on pedestrian bridges where fatigue is not a concern.
Aluminum weighs about 175 pounds per cubic foot. The chemical composition of aluminum varies widely depending on the type. However, the most common aluminum used for structural applications is composed mainly of aluminum, magnesium, silicon, copper, and chromium. Aluminum is more corrosion-resistant than steel. Because of this, painting is usually unnecessary to protect it from the atmosphere.

Aluminum is a material used for its high tensile and compressive strengths. Depending on the aluminum type, yield strengths range from 40,000 to 48,000 pounds per square inch, giving it a high strength-to-weight ratio. Tensile and compressive yield strengths are the same. Shear strength is about 60 percent of its yield strength. The modulus of elasticity values of aluminum are approximately one-third that of steel. Modulus of elasticity is a material property relating material stress to elongation. Since modulus of elasticity values are inversely proportional to elongations, an aluminum beam will deflect three times as much as a similarly shaped steel beam carrying the same load. In addition, aluminum's fatigue strength is approximately one-third that of steel, making it less desirable when fatigue is a concern.

When stressed below its yield point, aluminum is elastic, and a loaded beam will readily spring back into shape once the load is removed. Should high loads or impacts be applied which produce stresses beyond yield, aluminum is ductile and can withstand excessive deformations without failure. Although weldable, aluminum experiences significant base metal strength reductions of up to one-half the yield strength in the vicinity of welds.

With the exception of atmospheric corrosion, types of aluminum deterioration are similar to those found on steel (see Subsection 1.4.2[c]).

(f) COMPOSITES

Composites are plastics/resins reinforced with carbon, glass, or other fibers. Their use as main load-carrying members for bridges is limited. Although composites can have a high strength-to-weight ratio, can attain strengths similar to steel, and have excellent corrosion and impact resistance, there are several reasons why structural engineers do not generally specify composites. The main reason is that design standards do not currently exist. There are numerous types of plastics available, but their properties lack consistency from producer to producer. Also, costs are generally high.

Composites often exhibit viscoelastic (nonlinear) behavior. This means that at any given strain magnitude, temperature changes can produce marked changes in strength and deflection. Similarly, load duration and magnitude affect a composite’s strength and deflection. Viscoelastic behavior is less pronounced in composites than in plain, unreinforced plastics/resins. Though fatigue data does exist for some of the composites, no method is currently available to characterize the fatigue strengths of composites.
Bridges are classified according to their superstructure type. The use of each type generally depends on the distance the bridge must span, although more than one type can be used for the same span length. Other factors include the depth of the channel or ravine to be crossed, required underpass clearance, horizontal curvature, economics, and aesthetics.

Subsection 1.5.1 Slab

Slab bridges are the simplest bridge structures, constructed using reinforced concrete or timber for short spans. Typically concrete slab bridges are cast-in-place; however, some slabs are pre-cast. Long spans are usually continuous, often constructed with a thickened slab over the piers. These are called variable depth slabs. Longer span concrete slab bridges often utilize prestressed or post-tensioned slabs. Slab superstructures act like a very wide beam spanning between substructure elements. For slab bridges, including flat slabs, haunched slabs, and rigid frames, the superstructure is also the deck.

Figure 4:1-34: Deteriorated Single Span Concrete Slab
Subsection 1.5.2  Beam/Girder

Beam/girder bridges rely on the use of two or more primary elements acting in bending to support the deck and traffic. Beam/girder bridges are usually constructed of steel or concrete, although timber is also sometimes used.

The shortest steel bridges are typically constructed using standard hot-rolled “I” shapes, referred to as beams. Longer steel spans require deeper sections that are not produced by rolling mills. For these situations, welded, bolted, or riveted “I” shapes fabricated from plates are used. In Indiana, a shape built-up by welding, bolting, or riveting together plates and structural shape is called a girder. Longer spans also utilize steel plates built-up into a four-sided rectangular or trapezoidal closed shape, known as a box girder. Due to the box girder’s inherent resistance to the effects of torsion, box girders are commonly used for horizontally curved spans.
Many types of concrete beam bridges exist since concrete can be cast into many different shapes. The earliest examples are cast-in-place structures, usually of single spans. The rectangular beams and deck were typically cast simultaneously, forming “T” beams with the deck acting as the top flange. In Indiana, these cast-in-place “T” beams are called “Reinforced Concrete Girders.” On some older bridges, the fascia beams protruded above the deck and acted as bridge parapets, as well as superstructure elements. In Indiana, these are classified as “Concrete Through Girder” bridges if there are no girders except the two fascia girders.
In Indiana, most prestressed, pre-cast members are called beams. Prestressed concrete beams, cast at an off-site plant and delivered to the site, gained acceptance in the 1950s. By pre-compressing the beam with steel tendons, internal tensile stresses in the concrete are greatly reduced or eliminated. Prestressed beams/girders come in a variety of geometric cross-sections, including I, C, T, Bulb-T, modified or hybrid Bulb T, U, and closed-box shapes.

For longer spans or horizontally curved structures, post-tensioned concrete box girders may be used. Rather than being prestressed at a plant, the girders are either cast-in-place, or segments are precast at a plant and joined on-site to form a girder. Both contain ducts through which post-tensioning rods or tendons are passed. The rods or tendons are then pulled into tension, compressing the girder.

Rectangular timber beams may be either sawn or glue-laminated and are used for fairly short span bridges. Solid sawn beams are most often associated with older structures built when large timber members were plentiful. Currently, multiple strips of wood are glued together to build up large, laminated, or glulam, members.

**Subsection 1.5.3  Truss**

A truss is a structure whose members are arranged to form triangles. Each member is classified as either a top chord, bottom chord, vertical, or diagonal. Most trusses have vertical members. The mechanics of this arrangement is such that each member is acting as either a pure tension or pure compression member. Generally, two parallel trusses form the main load-carrying system of a bridge superstructure. Each may be thought of as a very deep beam with holes cut into the web. The top chord acts as the top flange, and the bottom chord acts as the bottom flange. Thus, under positive bending, the top chord is in compression, and the bottom chord is in tension. The reverse is true if the truss undergoes negative bending. Truss diagonal members deliver the shear loads of the imaginary deep beam to the supports by means of tension or compression, depending on their orientation within the truss.

Most truss bridges are constructed using steel members, while very old trusses used timber and wrought iron. Loads are delivered to trusses by way of the deck, supported on stringers (longitudinal beams), which in turn bear on floor beams (transverse beams). The floor beams frame into the sides of the trusses, usually at the panel points. Timber trusses are used only for fairly short spans. Simply supported steel trusses are used for spans up to approximately 800 feet long. Cantilevered and continuous spans often range from 500 to 1,500 feet long.
Figure 4:1-38: Parker Truss Bridge

Figure 4:1-39: King Post Truss Bridge
Subsection 1.5.4  Arch

Arch bridges generally transmit their loads to the ground by diagonally pushing on their supports rather than bearing vertically as with slabs, beams, or trusses. To resist this push, or thrust, buttresses are built at the arch ends, or the ends are tied together with a tension member in a manner similar to an archer’s bow. Arches resist a combination of compression, bending, and shear. The relative magnitude of each depends upon the shape of the arch. True arches are parabolic in shape and are subjected only to compressive forces. For practical reasons, most arches are not designed or built as true parabolas and, therefore, must transmit bending and shear in addition to compression.

Arches have been used for a wide range of bridge spans. Almost all types of construction materials have been used to build arches, including stone masonry, wood, cast iron, steel, and concrete. They may be comprised of two or more parallel ribs, or of a single curved member called a barrel. Arch ribs can be constructed with steel, concrete, or wood. Usually, only stone masonry and concrete are used to form barrel arches.

The space between the flat deck and curved arch is called the spandrel. Open spandrel arches use columns placed within the spandrel to transfer the live loads and deck dead loads to the arch ribs. Closed spandrel arches usually use earth fill retained by spandrel walls to transfer the live loads and deck dead loads to barrels. Other closed spandrels do not use earth fill, but leave the spandrel unfilled or vaulted. Deck live and dead loads are delivered to the barrel by way of the spandrel and interior walls.
Subsection 1.5.5  Rigid Frame

Rigid frames are similar to arches in that they transmit their loads to the ground by diagonally pushing on their supports. However, since they consist of horizontal members rigidly connected to the tops of inclined or vertical members, they have the advantage of reducing span length while allowing more head clearance for traffic traveling underneath. Rigid frames primarily resist bending and shear forces, with compression loads occurring mostly in the vertical or slanted legs.
Only steel and concrete are used for rigid frame bridge construction. Steel rigid frames are usually multi-span structures, known as K-frames, with main spans ranging from 50 feet to 200 feet. They are built of welded plate girder construction and require a minimum of two frames placed parallel to the roadway to carry the deck and live loads. Concrete rigid frames can be built as single or multi-span structures with a main span of each typically in the range of 50 feet in length. Single-span concrete rigid frames are commonly slab-type structures, similar to barrel arches. Multi-span bridges are usually built of multiple frames similar to steel rigid frames.

Subsection 1.5.6 Cable-Stayed

Cable-stayed bridges have superstructures supported by diagonal cable tension members. Each cable stay is connected to a pylon (tower) located at the main pier. Superstructures may be built of steel or concrete.
The cable stays act as spring supports, causing the superstructure to act as a multi-span bending member. Since the cables are sloped relative to the roadway, the cable stays also introduce compressive forces into the superstructure. Compression forces are also introduced into the pylon at each cable stay connection point. Because of the possible unequal live loading from span to span, variable cable stay forces also cause the pylon to bend. Back-stay cables, either anchored to the approach spans or to an anchorage block on land, help to balance the forces of the main span cables, thereby minimizing pylon bending. When used for highway bridges, they can be used for spans from 200 to 2,000 feet.

**Subsection 1.5.7 Suspension**

Suspension bridges can span distances in excess of 1,800 feet when used for highway bridges. They use vertical cable hangers to suspend the superstructure from two or more main cables. The main cables are draped over towers and terminate at heavy anchor blocks. The main suspension cables often have diameters exceeding 3 feet for long roadway spans. The main cables exert large compressive loads on the tops of the towers and may introduce some bending due to unequal live loading from span to span.

The horizontal distance between adjacent hanger cables is relatively small and, therefore, only a relatively shallow superstructure is required for strength. However, this results in a very flexible structure, giving rise to large deflections. Because of this, deep stiffening trusses, girders, or box girders are normally used to more evenly distribute the live loads among the hangers, thereby reducing deflections. Stiffening trusses and girders for highway suspension bridges are normally built of steel.
Figure 4:1-45: Pedestrian Suspension Bridge
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CHAPTER 2  CONDITION EVALUATION

SECTION 2.1  INTRODUCTION

The biggest challenge in any bridge inspection program is to relate the material distress found on a bridge to its effect on the structure’s strength and safety. Another challenge is to create uniformity between all bridge inspectors for evaluating and rating the structural condition of a bridge.

All qualified bridge inspectors must have a basic understanding of bridge mechanics and of how deterioration of a certain bridge component will affect the bridge’s performance and public safety.

Indiana uses the National Bridge Inspection Standards (NBIS), as outlined in the Federal Highway Administration’s (FHWA’s) Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation’s Bridges (FHWA Coding Guide) as the basis for all inspections. The information gathered is supplemented with data on the condition of various elements in each bridge.

Figure 4:2-1: Damaged Girder
SECTION 2.2 NBI INSPECTION

The FHWA Coding Guide is the basis for the National Bridge Inventory (NBI) condition ratings. It has been used as the basis for bridge inspections since 1971 and its primary objective is to monitor the safety of the nation’s bridges. The FHWA Coding Guide provides guidance for rating the condition of a bridge’s deck, superstructure, substructure, and channel, if it exists. It also provides condition rating guidance for underfill structures.

In addition to establishing a component’s physical condition, rating data is used in a variety of analyses and decisions performed by the bridge owners and FHWA. The data helps to determine the sufficiency of a bridge to remain in service and its eligibility for rehabilitation or replacement.

NBI inspection results rate the major bridge components without being specific as to where, how much, or what type of deterioration exists. Each bridge component is assigned a numeric rating code ranging from 9 to 0, with 9 being excellent condition and 0 being failed condition. The ratings represent the overall physical condition of the component as compared to the day it was built. It provides an evaluation of the bridge component’s material and its state of deterioration, and not an evaluation of its ability to carry current legal loads.
SECTION 2.3 SUPPLEMENTAL INSPECTION DATA

Indiana collects information about various bridge elements in addition to the data required in the Coding Guide. This helps to identify problems and actions that need to be taken to ensure the safety and longevity of a bridge. The supplemental information required for each bridge owner is identified in the Bridge Reporting for Appraisal and Greater Inventory (BRAGI) Coding Guide.

An estimate of the remaining life of the wearing surface, deck, joints, superstructure, substructure, approach features, channel features, and culvert or underfill features is required for all bridges.

For state-owned bridges, this supplemental inspection data breaks out various bridge components, such as the railings, girders, diaphragms, abutments, and pier columns. Each component is inspected and assigned a numeric rating code, based upon its state of deterioration. Rating codes generally follow rating guidelines in the FHWA Coding Guide.

Figure 4:2-2: Cable Tower
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SECTION 3.1 INTRODUCTION

Decks are structural components of a bridge, and serve several functions. The wearing surface of a deck provides a smooth riding surface for traffic. The deck distributes the bridge live loads such as vehicle wheel loads to the girders, stringers, and floor beams. Reinforced concrete decks also serve as the top flange of reinforced concrete T-beam bridges, and reinforced concrete decks may function as part of the top flange of steel open girder, steel box girder, prestressed concrete, and concrete box girder bridges. For concrete slab bridges, the deck is also the superstructure.

Decks receive a considerable amount of abuse from truck overloads; corrosive deicing chemicals; freeze/thaw weathering; and parasites/fungi and other sources that cause wear and abrasion, such as wheels, snow plow blades, and road debris. Decks can deteriorate rapidly and must be monitored diligently.
Concrete decks are the most common type of deck an inspector will encounter. The inspector should review the bridge history to confirm the construction details for each deck. The history should include information about any overlays, the year each overlay was constructed, the design load, if the steel is coated with epoxy, and whether or not the deck is composite with the superstructure. There are several types of concrete decks:

- Concrete decks that are cast on the superstructure on-site are referred to as cast-in-place. Forms are used to contain reinforcing bars and wet concrete so that after curing, the deck components will be in the correct position and shape. Bar chairs are used to support reinforcement in the proper location during casting. Removable forms are usually wood planking or plywood, but can also be fiberglass reinforced plastic. These forms are removed from the deck after the concrete has cured. Corrugated metal sheets, fiber reinforced precast concrete, and polymers are common materials used for stay-in-place forms.

- Precast deck panels are cast and cured off-site. Precast deck panels are typically reinforced with conventional mild reinforcement. The panels are transported to the bridge site, placed on the superstructure, leveled, and attached to the superstructure/floor system. The panels are either bolted to the stringers with mechanical clips, or attached using grout or concrete filled block-out holes as shear connectors.

- Pre-cast, prestressed deck slabs are cured off-site. They are reinforced with prestressing steel in addition to some mild reinforcement. The prestressing tendons or bars are tensioned prior to placing the slab (pretensioned) or after the slab is cured (post-tensioned). This creates compressive forces in the slab, which reduce the amount of tension cracking in the cured concrete.
Concrete deterioration normally starts in the wearing surface and along the copings, joints, or curb lines and progresses downward and inward until the entire slab is involved. Therefore, when deterioration is observed on the bottom of a slab, there is a good chance that the deterioration is worse above this point and the deck should be rated accordingly.

A bituminous overlay can accelerate the deterioration of the deck, as well as hide patches, spalls, delaminations, and repairs in the original deck or debonding of an overlay from the deck. Repaired and distressed areas which are known to exist through historical documentation or previous inspection reports need to be taken into account when assigning a rating to the deck. Inspectors should state the source of any information beyond visual inspection of the wearing surface. Chain dragging or other soundings may provide knowledge about distress under an overlay and should be used when deterioration is suspected.

Technically advanced means of evaluating a wearing surface or concrete deck include ground-penetrating radar and infrared thermography. These are seldom used due to cost and effort limitations, but it may be appropriate to utilize these tools for large bridges with high average daily traffic (ADT).

The inspection of concrete decks should include a thorough evaluation of the wearing surface, copings, curb lines, and the underside of the deck for the following items:
Check for cracks, note their location, orientation, length, maximum width, and type. The extent of cracking gives an indication of how much water is able to penetrate the deck. Cracks to note include:

- Longitudinal flexural cracks caused by deck positive bending between the girders or stringers. Wide cracks may indicate a serious structural overload.
- Longitudinal flexural cracks in areas of negative moment bending over the girders or stringers in the deck.
- Transverse flexural cracks adjacent to and over piers, where reinforcement bars end, and over floor beams.
- Diagonal or transverse temperature/shrinkage cracks. These will be found on most concrete decks and can provide a means for chlorides to reach steel reinforcement.

Check for pop-outs, scaling, abrasion, and rutting. This may be most evident in the gutters and around the drains.

Look for spalls and note any large individual spalls.

Look for signs of corroding reinforcing steel, such as rust stains.

Note exposed reinforcing steel, corrosion, or loss of section.

Check for efflorescence. Note if it is stained with rust, since this condition suggests reinforcing steel corrosion.

Check for areas of delaminations. Loose concrete can fall and cause serious damage or injury.

Note all collision damage.

Check for sagging.

Note distressed repair areas.

Check for water leakage. Frequently, water leakage appears on support structures, under drains, or under expansion joints.

Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

Check stay-in-place forms for corrosion and other signs of leakage through the deck. Stay in place forms may trap moisture and hide the condition of a deck.

Check the deck at the railing and/or light standard connections.
Steel decks are sometimes used on bridges because they weigh less than concrete decks. They are often used on movable bridges to reduce the required counterweight needed to balance the span. Steel decks have been used to replace concrete decks on older bridges when an increased live load capacity is desired, or when existing superstructure or substructure elements do not have enough strength to support the heavier dead load of a concrete deck.

Subsection 3.3.1 Steel Grid Deck

Steel grid decks are the most common type of steel deck. Steel grid decks contain several components that are either welded or riveted together, including bearing bars, cross bars, and supplementary bars. Openings between these bars may be filled with concrete to improve the durability of a steel grid deck. Exodermic decks are a type of steel grid system utilizing a reinforced concrete slab placed on top of the steel grid. The concrete acts compositely with the grid.

Steel open grid decks are strong and lightweight. Open grids are prefabricated using rectangular bars and delivered to the bridge site in several panels, which are then connected to the superstructure. The tops of the bars may be serrated to provide a skid-resistant riding surface.

Steel open grid decks are constantly exposed to the elements. Even though they are often galvanized or painted, traffic wear quickly exposes the deck top surface, leaving the deck vulnerable to corrosion. Open grids also leave the superstructure exposed to roadway debris, rain, and deicing chemicals.

On concrete and bituminous concrete-filled steel grid decks, the steel grid serves as the deck’s structural component. The material between the bar openings offers better corrosion protection and a more durable riding surface than an open deck. The deck system provides some protection for the superstructure below from rain, deicing chemicals, and roadway debris. Filled steel grid decks are heavier than open grid decks, but lighter than traditional concrete decks. The fill of these elements may be placed flush with the top layer of bars or preferably overfilled 1 to 2 inches. The bottom of the fill may be flush with the bottom of the grid or at mid-depth of the main bars.
The inspection of steel grid decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

- Examine the bearing bars in the bearing areas at stringers/girders for cracked welds or broken fasteners. Special attention should be paid to the tension areas of the bars.
- Examine welds attaching the deck to the stringers or girders to ensure cracks are not developing.
- Look for twisted, cracked, broken, or missing bars, particularly at bearing bars.
- Check for corrosion and related section loss.
- Look for worn serrations or excessive wear causing section loss or broken welds between the bars.
- Listen for any rattling as traffic passes over the deck. Rattling suggests loose, broken, or missing fasteners.
- Look for broken fasteners on bolted or riveted steel grid decks.
- Check any repair plates placed over the grid to make sure they are still securely fastened.
- Check for grid expansion at the joints and bridge ends. This is often caused by corrosion.
- Check for bowing of the deck panels.
• Look for filler that is cracked, broken, leaking, or missing altogether.

• Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

Subsection 3.3.2 Steel Orthotropic Decks

Steel orthotropic decks are often used on long span bridges for their light weight. An orthotropic deck consists of a flat steel plate with longitudinal stiffeners welded to the underside of the plate. The floor beams of the bridge act to stiffen the deck perpendicular to the length of the bridge. Orthotropic decks may act as the top flange of the superstructure primary members, reducing the total bridge dead load. The deck surface usually includes a manufacturer-applied coating.

The inspection of steel orthotropic decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

• Check for corrosion of the steel plate or stiffeners.

• Check for leakage.

• Check for proper support.

• Look for cracked or broken stiffeners, welds, and connectors.

• Listen for rattling as traffic passes over the deck. Rattling suggests loose, broken, or missing fasteners.

• Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

• Check for failure of the wearing surface coating.

Subsection 3.3.3 Steel Railroad Car Decks

When reclaimed railroad cars are used as bridges, the bridge deck is the floor of the original rail car. They may be overlaid with an asphaltic wearing surface or timber decking. These reclaimed structures were likely exposed to many load cycles before being re-used as bridges and should be carefully inspected.

The inspection of steel railroad car decks should include a thorough evaluation of all visible portions of the top, bottom, and sides of the deck for the following items:

• Check for corrosion of the steel flooring or stiffeners.

• Check for leakage.

• Check for proper support.
• Look for cracked or broken stiffeners, welds, and connectors.

• Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

Subsection 3.3.4  Steel Corrugated Flooring

This deck type uses corrugated steel plates spanning transversely between the girders or stringers. After the flooring is fastened to the superstructure, the corrugations are filled with asphalt. This deck system can trap and hold water that passes through the topping, making it very susceptible to corrosion. The corrosion often cannot be seen until the corrosion extends through the thickness of the corrugated plate.

The inspection of steel corrugated decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

• Check for corrosion of the steel plate.

• Check for cracked or broken-up areas of asphalt that would allow water penetration.

• Check for areas of asphalt that look “settled.” This may indicate that the steel plates below are deforming or sagging.

• Check for leakage.

• Check for proper support.

• Look for cracked or broken welds and connectors.

• Examine the welds attaching the deck to the stringers or girders to ensure cracks are not developing.

• Listen for rattling as traffic passes over the deck. Rattling suggests loose, broken, or missing fasteners.

• Check the wearing surface for rutting or spalls and note any large individual spalls.

• Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
Timber decks are normally used for timber superstructures, although they are occasionally found on other steel superstructures. Timber decks may also be referred to as decking or timber flooring. There are several types of timber decks:

- **Plank decks** – These are the most common type of timber deck. Deck planks are sawn timber planks laid flat across the tops of the timber beams or steel stringers. They span transversely between the beams/stringers and are fastened to the superstructure with nails or bolt clamps. Common planks are three-to-six inches thick and 10-to-12 inches wide.

- **Nail laminated decks** – This deck type uses sawn planks laid on edge across the tops of the timber beams or steel stringers, creating a very stiff deck. Each plank is placed tight against and nailed to the adjacent one. When used in conjunction with timber superstructures, each plank is toe-nailed to the beam. When used in conjunction with steel superstructures, the deck is attached with clamps at regular intervals.

- **Glued laminated decks** – These decks are similar to nail laminated decks, but the planks are glued together in a factory and shipped to the job site in three-to-five-foot wide planks. After setting the planks on top of the superstructure, the planks are clamped together for the full length of the bridge by way of tie rods. The deck is then fastened to the beams/stringers using nails, bolts, clip angles, or nailers. Glued laminated decks are generally stronger, stiffer, and more water-resistant than plank or nail-laminated timber decks.

- **Prestressed laminated deck** – These decks use laminated timbers similar to nail and glued laminated decks. They are different in that external prestressing is used to clamp the laminations together. The individual laminations work together as a unit due to the large frictional forces generated by the prestressing. Normally, steel rods passing through the laminations are used to deliver the prestressing forces at approximately two-foot centers.

Because of timber’s low resistance to abrasion, wearing surfaces are often used. These may be timber or steel running boards or a bituminous overlay. Running boards are placed longitudinal to traffic, usually along the wheel paths. They are easily replaced when worn. Bituminous wearing surfaces may be placed on any type of timber deck, although this can trap water against the timber. Bituminous surfaces tend to crack and deteriorate quickly on plank decks due to plank flexibility and differential deflection.
Figure 4.3-3: Timber Plank Deck

Figure 4.3-4: Steel Running Boards on a Timber Deck
The inspection of timber decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

- Look for signs of wear and abrasion, weathering, splitting, crushing, and decay.
- Look for loose, missing, or damp members.
- Check all bearing areas for decay and crushing. Crushing can be caused by decay or by overloads.
- Check for corroded, loose, or missing fasteners.
- Check tension areas for excessive deflections, fractures, and transverse cracks. These are typically signs of excessive flexural stresses and overloads.
- Hammer tap random and suspect areas to evaluate the wood’s soundness.
- Perform probe tests where decay is suspected. Using an awl, ice pick, or pocketknife, lift a small sliver of wood from the surface. Wood that lifts up and splinters is sound, while wood that breaks up upon lifting the tool is decaying.
- Drill or bore suspect planks to estimate the extent of decay.
- Examine any overlay for signs of wear and abrasion, cracks, potholes, or impending potholes.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Check for fire damage.
- Note the presence and condition of any insecticides, preservatives, or protective flashings or coverings.
SECTION 3.5   NBI DECK RATING

Deck condition ratings assess the current structural condition of the deck as compared to its original, as-built condition. Postings or original design capacities less than current legal loads will not influence the rating. Because only a single number is used to rate the deck, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, but widespread deterioration would influence the rating. The rating must consider the extent and severity of the deterioration.

Temporary deck supports, bituminous overlays, partial concrete overlays, patching, and temporary strengthening methods do not improve the condition of the deck material or influence the deck rating.

On slab bridges, the deck is also the superstructure, so the ratings of the deck and superstructure must be the same.

Decks integral with the superstructure (rigid frame, box girder, etc.) will be rated as a deck only, and not how they may influence the superstructure rating. Similarly, the superstructure of an integral deck-type bridge will not influence the deck rating.

For some decks integral with the superstructure, such as adjacent box beams, you cannot see the underside of the deck and must rate the deck based on the top surface alone. If the bridge has an overlay, the deck rating will be based on an assessment of the condition of the overlay and any documented history of the concrete below the overlay.

Ratings of 9 to 7 apply to decks in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests critical condition, and 1 to 0 suggest a condition where the bridge must be closed to traffic. It is important to note that there is a significant change from a deck in condition rating 5 to condition rating 4. If the load-carrying capacity is reduced, the deck rating must be less than 5.

The condition of the wearing surface, protective systems, joints, expansion devices, curbs, sidewalks, parapets, fascias, bridge rail, and scuppers shall not be considered in the overall deck evaluation of National Bridge Inspection Standards (NBIS) Item 58, Decks. However, these items should be evaluated and reported as described in Subsection 3.5.2.

The general condition ratings and Indiana supplemental rating guidelines for decks are as follows.
## Decks

### Part 4: Bridge Inspection

#### NBI Deck Rating

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
<th>Supplemental Rating Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE</td>
<td>Used for structures without decks such as underfill structures or filled arch bridges.</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION</td>
<td>Generally used on properly constructed new bridges.</td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Deck</strong> – There are no spalls, delaminations, cracks, or scaling present.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Steel Deck</strong> – There are no deficiencies which affect the deck condition.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Timber Deck</strong> – There are no deficiencies which affect the deck condition.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – No problems noted.</td>
<td>Generally used on properly rehabilitated bridges or bridges in nearly new condition.</td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Deck</strong> – There are no spalls, delaminations, cracks, or scaling present. Minor transverse cracks may be present in the deck surface or the underside of the deck.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Steel Deck</strong> – There is no damage to the primary or secondary bars other than surface corrosion on uncoated decks. Any deck coating system is sound. The grid deck is securely fastened to the floor system and any filler present is sound.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Timber Deck</strong> – There is no crushing, rotting, or splitting. The deck is tightly secured to the floor system.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>GOOD CONDITION – Some minor problems.</td>
<td>Insignificant cracks which can be sealed with tar or epoxy are present. There are few transverse cracks and only light scaling of the deck surface. No exposed reinforcing steel is present. There is no leaking or corrosion of stay-in-place forms.</td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Deck</strong> – There may be minor damage to the primary or secondary bars, such as small twists or bends. There may be surface corrosion on uncoated decks, or minor isolated areas of corrosion of coated decks. Any filler present is sound.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Timber Deck</strong> – There is minor checking or splitting with a few loose planks.</td>
<td></td>
</tr>
</tbody>
</table>
6 Satisfactory Condition – Structural elements show some minor deterioration.

Supplemental Rating Guidelines:

Concrete Deck – Spalls and delaminations may be present on up to five percent of the deck surface or soffit area. Up to 10 percent of the deck surface or soffit area may have map cracking. Transverse cracking at greater than five-foot spacing may be present. Moderate scaling of the deck surface may also be present.

Steel Deck – There may be some twisted, bent, or cracked bars. There may be some isolated broken welds or loose/broken fasteners. Filler may have broken out at a few localized areas. There is surface corrosion on uncoated decks, and surface or freckle corrosion of coated decks.

Timber Deck – Less than 10 percent of the planks are checked or split, but they are sound. There may be some loose or moderately worn planks. Some areas of wetness are present.

5 Fair Condition – All primary structural elements are sound, but some may have minor section loss, cracking, or spalling.

Supplemental Rating Guidelines:

Concrete Deck – Up to 10 percent of the deck surface or soffit area is spalled or delaminated. Up to 25 percent of the deck surface or soffit area may have map cracking. Transverse cracking on the underside at less than five-foot intervals in the majority of the deck, with or without efflorescence, may be present. The underside of the deck has spalls with exposed reinforcing bars with up to 10 percent section loss in isolated areas. Heavy scaling of the deck surface may also be present.

Steel Deck – There are some twisted, bent, or cracked bars and possibly a few broken or missing bars. There are some broken welds or loose/broken fasteners. Filler may have broken out at a few scattered locations. Some section loss may be occurring due to corrosion, but the section loss is not measurable. Section loss due to wear may be noticed in the wheel lines.

Timber Deck – Ten percent to 40 percent of the planks are checked, split, rotted, or crushed. Many planks are loose. Fire damage is limited to surface charring with minor, measurable section loss. Less than 10 percent of the planks are in need of replacement.
4 POOR CONDITION – Advanced section loss, deterioration, or spalling is present.

Supplemental Rating Guidelines:

Concrete Deck – Longitudinal cracks exist over the majority of the deck. Up to 25 percent of the deck surface or soffit area is spalled or delaminated. Up to 50 percent of the deck surface or soffit area may have map cracking. The underside of the deck has wet-looking areas. Stay-in-place forms are corroded in numerous areas. Full-depth failures are imminent. Significant efflorescence is present. The underside of the deck has spalls with exposed reinforcing bars with up to 30 percent section loss in isolated areas. Loose delaminations are in danger of falling on traffic or pedestrians below.

Steel Deck – There are numerous cracked, broken, or missing bars. There are numerous broken welds or loose/broken fasteners. Filler has broken out at many locations. Measurable surface pitting and/or section loss is occurring due to corrosion. The coating system has failed. Measurable section loss due to wear has occurred in the wheel lines.

Timber Deck – Over 40 percent of the planks are rotted, crushed, or split. Fire damage with significant section loss, possibly reducing the load-carrying capacity, may be present. Over 10 percent of the planks are in need of replacement.

3 SERIOUS CONDITION – Loss of section, deterioration, or spalling has seriously affected the components. Local failures are possible. Flexure and shear cracks in concrete may be present.

Supplemental Rating Guidelines:

Concrete Deck – Full-depth failures are present or imminent. Greater than 25 percent of the deck surface or soffit area is spalled or delaminated. Excessive efflorescence is present. Large areas on the underside of the deck look wet. Large areas of stay-in-place forms are corroded. Significant exposed reinforcing bars, with greater than 30 percent section loss, are present.

Steel Deck – There are numerous broken or missing bars. There are widespread broken welds or broken fasteners. Much of the filler is missing. Serious section loss and measurable section loss in the wheel lines is present.

Timber Deck – Severe signs of distress are visible. Extensive plank damage is evident with reduced deck load-carrying capacity.
2  CRITICAL CONDITION – Advanced deterioration of primary components is present. Fatigue cracks in steel or shear cracks in concrete may be present. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

**Supplemental Rating Guidelines:**

**All Decks** – There are deficiencies in the deck that would likely cause a driver to lose control of his/her vehicle. Local deflections exist.

**Concrete Deck** – Full-depth failures exist over much of the deck. The deck is grossly compromised.

**Steel Deck** – There are widespread broken or missing bars accompanied with partial deck failures. There are widespread broken welds or broken fasteners. Most of the filler is missing. Excessive section loss is evident.

**Timber Deck** – There is advanced deterioration with partial deck failure. There are broken or missing planks.

1  “IMMINENT” FAILURE CONDITION – Major deterioration or section loss is present. The bridge is closed to traffic, but corrective action may put it back in light service.

0  FAILED CONDITION – The bridge is out of service, beyond corrective action.
Indiana requires the deck wearing surface to be rated for all bridges. Additional items to be rated for state-owned bridges are shown in Figure 4:3-5. Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 58, the NBIS deck condition rating. Each item shall be rated as follows unless noted:

- **N** Not Applicable
- **9** Excellent Condition – new
- **8** Very Good Condition – no problems noted
- **7** Good Condition – some minor problems
- **6** Satisfactory Condition – structural elements show some minor deterioration
- **5** Fair Condition – minor section loss, cracking, or spalling
- **4** Poor Condition – advanced section loss, deterioration, or spalling
- **3** Serious Condition – loss of section, deterioration, or spalling has seriously affected components
- **2** Critical Condition – advanced deterioration of primary elements
- **1** Imminent Failure Condition – bridge closed to traffic, but corrective action may put bridge back in light service
- **0** Failed Condition – beyond corrective action

![Figure 4:3-5: Additional Deck Items](image-url)

June 2010 Page 4-3-20
ITEM 58.01 – WEARING SURFACE

The wearing surface is the portion of the top of the deck used for vehicle traffic. This rating is used for all decks, whether they are monolithic, or have an added wearing surface. The rating of wearing surface can be significantly different than the rating of the deck. The rating should be determined using the following guidelines:

N NOT APPLICABLE:

Supplemental Rating Guidelines: Used for structures without decks such as underfill structures or filled arch bridges.

9 EXCELLENT CONDITION:

Supplemental Rating Guidelines: Generally used on properly constructed, new bridge wearing surfaces.

Concrete Wearing Surface – There are no noticeable deficiencies.

Steel Wearing Surface – There are no noticeable deficiencies.

Timber Wearing Surface – There are no noticeable deficiencies.

Bituminous Wearing Surface – There are no noticeable deficiencies.

8 VERY GOOD CONDITION:

Supplemental Rating Guidelines: Generally used on properly constructed, new bridge wearing surfaces.

Concrete Wearing Surface – There are no spalls, delaminations, or scaling present. Minor transverse cracks may be present in the wearing surface.

Steel Wearing Surface – There is no damage to the primary or secondary bars other than surface corrosion on uncoated decks. Any deck-coating system is sound. Any concrete filler present is sound.

Timber Wearing Surface – There is no crushing, rotting, or splitting.

Bituminous Wearing Surface – There are no spalls or delaminations present. Minor transverse cracks may be present in the wearing surface.
**GOOD CONDITION:**

**Concrete Wearing Surface** – There are no spalls or delaminations. Cracks which can be sealed with tar or epoxy exist, or light scaling may be present.

**Steel Wearing Surface** – There may be minor damage to the primary or secondary bars, such as small twists or bends. There may be surface corrosion on uncoated decks, or minor isolated areas of corrosion of coated decks. Any filler present is sound.

**Timber Wearing Surface** – There is minor checking or splitting with a few loose planks.

**Bituminous Wearing Surface** – There are no spalls or delaminations. Sealed cracks are present.

**SATISFACTORY CONDITION:**

**Concrete Wearing Surface** – Up to five percent of the wearing surface area is spalled or delaminated. Up to 15 percent is patched. The patching is in good condition. Minor open cracking in the wearing surface (five-foot maximum spacing) or moderate scaling may be present.

**Steel Wearing Surface** – There may be some twisted, bent, or cracked bars. There may be some isolated broken welds or loose/broken fasteners. Filler may have broken out at a few localized areas. There is surface corrosion on uncoated decks, and surface or freckle corrosion of coated decks.

**Timber Wearing Surface** – Less than 10 percent of the planks are checked or split, but they are sound. There may be some loose or moderately worn planks.

**Bituminous Wearing Surface** – Up to five percent of the surface area is unsound (potholes, spalls, etc.). Up to 15 percent is patched. The patching is in good condition. Minor open cracking in the wearing surface (five-foot maximum spacing) may be present.

**FAIR CONDITION:**

**Concrete Wearing Surface** – Up to 15 percent of the wearing surface area is spalled or delaminated. Fifteen percent to 30 percent is patched. The patching is in fair condition. Less than 20 percent of the wearing surface is delaminated with no spalls or patching. Excessive open cracks or heavy scaling may be present.

**Steel Wearing Surface** – There are some twisted, bent, or cracked bars, and possibly a few broken or missing bars. Filler may have broken out at a few scattered locations.
Timber Wearing Surface – Ten percent to 40 percent of the planks are checked, split, rotted, or crushed. Many planks are loose. Fire damage is limited to surface charring with minor, measurable section loss. Less than 10 percent of the planks are in need of replacement.

Bituminous Wearing Surface – Five percent to 15 percent of the wearing surface area is unsound (potholes, spalls, etc.). Fifteen percent to 30 percent is patched. The patching is in fair condition. Excessive open cracks may exist in the wearing surface. Minor raveling may be present.

4 POOR CONDITION:

Concrete Wearing Surface – Up to 25 percent of the wearing surface area is spalled or delaminated. Thirty percent to 50 percent is patched and the patching is in poor condition.

Steel Wearing Surface – There are numerous cracked, broken, or missing bars. There are numerous broken welds or loose/broken fasteners. Filler has broken out at scattered locations. Measurable surface pitting and/or section loss is occurring due to corrosion. The coating system has failed. Measurable section loss due to wear in the wheel lines may be present.

Timber Wearing Surface – Over 40 percent of the planks are rotted, crushed, or split. Fire damage exists that has significant section loss. Over 10 percent of the planks are in need of replacement.

Bituminous Wearing Surface – Fifteen percent to 25 percent of the wearing surface area is unsound (potholes, spalls, etc.). Thirty percent to 50 percent is patched and the patching is in poor condition. Visible rutting or raveling may be present.

3 SERIOUS CONDITION:

Concrete Wearing Surface – Full-depth failures are present or imminent. Greater than 25 percent of the wearing surface area is spalled or delaminated. Over 50 percent of the surface is patched.

Steel Wearing Surface – There are numerous broken or missing bars. There are widespread broken welds or broken fasteners. Several areas of filler are missing. Serious section loss and measurable section loss due to wear in the wheel lines may be present.
Timber Wearing Surface – Extensive plank damage is evident.

Bituminous Wearing Surface – Greater than 20 percent of the wearing surface area is unsound (potholes, spalls, etc.). Over 50 percent is patched. Serious rutting or raveling may be present.

2 CRITICAL CONDITION:

All Wearing Surfaces – There are deficiencies in the deck that would likely cause a driver to lose control of his/her vehicle. Local deflections exist.

Concrete Wearing Surface – Full-depth failures exist over much of the wearing surface.

Steel Wearing Surface – There are widespread broken or missing bars accompanied with partial deck failures. There are widespread broken welds or broken fasteners. Much of the filler is missing. Excessive section loss is present.

Timber Wearing Surface – There are broken or missing planks.

Bituminous Wearing Surface – Full-depth failures exist over much of the wearing surface.

1 FAILURE CONDITION – Major deterioration in the wearing surface exists. The bridge is closed to traffic, but corrective action may put it back in light service.

0 FAILED CONDITION – The bridge is out-of-service, beyond corrective action.
Figure 4:3-7: Concrete Wearing Surface With Patches and Spalls

Figure 4:3-8: Timber Plank Wearing Surface
Figure 4:3-9: Concrete Wearing Surface With Spalls and Patching

Figure 4:3-10: Bituminous Wearing Surface With Spalls and Patching
ITEM 58.02 – DECK UNDERSIDE

This item rates the underside of the deck as described as NBI Item 58, above. The ratings follow those outlined above for Item 58 and, because the underside of the deck generally reflects the structural condition of the deck, Item 58.02 will usually match Item 58.

Figure 4:3-12: Deck Underside With Shrinkage Cracking
ITEM 58.03 – CURBS

Curbs are vertical concrete surfaces designed to keep traffic on the wearing surface and off of the bridge sidewalks or railings. Curbs keep water from draining over the bridge coping.

Inspection of concrete curbs should include the following items:

- Check the curb for delaminations, spalls, and exposed reinforcing steel.
- Inspect the curb for both vertical and transverse cracks.
- Inspect the curb for scaling or efflorescence. Note if it is stained with rust, since this condition suggests reinforcing steel corrosion.
- Check the curb for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
- Check previously repaired areas for soundness by hammer tapping.
Rate the physical condition of the curb and its ability to function as designed according to the following criteria:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition – new</td>
</tr>
<tr>
<td>8</td>
<td>Very Good Condition – no problems noted</td>
</tr>
<tr>
<td>7</td>
<td>Good Condition – some minor cracking or scaling</td>
</tr>
</tbody>
</table>

Figure 4:3-14: Curb

Figure 4:3-15: Spalled and Crumbling Curb

Rate the physical condition of the curb and its ability to function as designed according to the following criteria:
### ITEM 58.04 – COPINGS

Copings are the outside, vertical faces of the bridge deck. Inspection of copings should include the following:

- Check for delaminations, spalls, and exposed reinforcing steel.
- Inspect for cracks, scaling, or efflorescence. Note if the efflorescence is stained with rust, since this condition suggests reinforcing steel corrosion.
- Check for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
- Check previously repaired areas for soundness by hammer tapping.

Rate the physical condition of the copings according to the following criteria:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition – new</td>
</tr>
<tr>
<td>8</td>
<td>Very Good Condition – no problems noted</td>
</tr>
<tr>
<td>7</td>
<td>Good Condition – some minor cracking, or scaling.</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition – some cracking, scaling, or delaminations</td>
</tr>
<tr>
<td>5</td>
<td>Fair Condition – general cracking, scaling, or delaminations</td>
</tr>
<tr>
<td>4</td>
<td>Poor Condition – up to 10 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition – ten to 30 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition – thirty to 50 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>1</td>
<td>Failure Condition – greater than 50 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition – crumbling</td>
</tr>
</tbody>
</table>
1 Failure Condition – greater than 50 percent of coping is spalled, patched, or delaminated

0 Failed Condition – crumbling

Figure 4:3-16: Coping

ITEM 58.05 – MEDIAN

Medians are areas of raised concrete or steel located between opposing travel lanes to keep traffic separated. Inspection of the median should include the following:

- Check for delaminations, spalls, and exposed reinforcing steel.
- Inspect for cracks, scaling, and efflorescence.
- Check the curb for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
- Check previously repaired areas for soundness by hammer tapping.

Note the type of median and rate the physical condition of the median and its ability to function as designed according to the following criteria:

N Not Applicable
9 Excellent Condition – new
8 Very Good Condition – no problems noted
7 Good Condition – some minor cracking or scaling
6 **Satisfactory Condition** – some cracking, scaling, or delaminations
5 **Fair Condition** – general cracking, scaling, or delaminations
4 **Poor Condition** – up to 10 percent of median is spalled, patched, or delaminated
3 **Serious Condition** – ten to 30 percent of median is spalled, patched, or delaminated
2 **Critical Condition** – thirty to 50 percent of median is spalled, patched, or delaminated
1 **Failure Condition** – greater than 50 percent of median is spalled, patched, or delaminated
0 **Failed Condition** – crumbling

**Figure 4:3-17: Concrete Median**

**Figure 4:3-18: Concrete Median Barrier Wall**
ITEM 58.06 – SIDEWALKS

Sidewalks are areas designated for pedestrian traffic. They are generally raised to provide separation from vehicular traffic. Any hazard that could potentially result in harm to the public should be noted on the inspection form and reported to the structure owner. Inspection of concrete sidewalks should include the following:

- Checking the sidewalk for delaminations, spalls, pop-outs, and exposed reinforcing steel. Large spalls or exposed rebar can pose tripping hazards to pedestrians.
- Note any loose or misaligned expansion joint plates that pose a tripping hazard to pedestrians.
- Inspect the sidewalk for cracks.
- Check the sidewalk for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
- Check previously repaired areas for soundness by hammer tapping.
- Notify the owners of any sidewalks that pose a tripping hazard.

Figure 4:3-19: Sidewalk With Minor Pop-Outs
Rate sidewalks for the walking surface quality and accessibility according to the following criteria:

- **N** Not Applicable
- **9** Excellent Condition – new
- **8** Very Good Condition – no problems noted
- **7** Good Condition – some minor cracking or scaling
- **6** Satisfactory Condition – some cracking, scaling, or delaminations; accessible; and no hazard to pedestrians or motorists
- **5** Fair Condition – general cracking, scaling, or delaminations and minor hazards or barriers to accessibility
- **4** Poor Condition – not accessible and hazards to pedestrians or motorists present; up to 10 percent of sidewalk is spalled, patched, or delaminated
- **3** Serious Condition – not accessible and hazards to pedestrians or motorists present; 10 to 30 percent of sidewalk is spalled, patched, or delaminated
- **2** Critical Condition – not accessible and hazards to pedestrians or motorists present; 30 to 50 percent of the sidewalk is spalled, patched, or delaminated
- **1** Failure Condition – not accessible and hazards to pedestrians or motorists present; greater than 50 percent of the sidewalk is spalled, patched, or delaminated
- **0** Failed Condition – sidewalk is unusable

*Figure 4:3-20: Sidewalk With Rust Stains and Minor Spalling*
ITEM 58.07 – PARAPET

Parapets are concrete railings or concrete barriers. The primary function of a parapet is to keep errant vehicles on the bridge. Additionally, if there is foot traffic, the parapet should keep pedestrians and bicycles on the bridge and provide a minimum level of comfort while crossing. They can also protect the main load-carrying elements of certain superstructure types, such as through trusses and arches, from damage due to vehicular impacts. Inspection of parapets should include the following:

- Look for signs of impact damage such as spalls and localized heavy cracking. The location, severity, and size of the damage should be documented.
- Check for delaminations, spalls, exposed reinforcing steel, and scaling.
- Inspect the parapet for both vertical and transverse cracks.
- Check the entire member for signs of corroding reinforcing steel as indicated by rust stains or exposed reinforcement.
- Look for efflorescence and note if it is stained with rust, since this condition suggests reinforcing steel corrosion.
- Check previously repaired areas for soundness by hammer tapping.
- Check that any anchorage is sound.
Rate the parapet according to the following criteria:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition – new</td>
</tr>
<tr>
<td>8</td>
<td>Very Good Condition – no problems noted</td>
</tr>
<tr>
<td>7</td>
<td>Good Condition – some minor cracking or scaling</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition – some cracking, scaling, or delaminations</td>
</tr>
<tr>
<td>5</td>
<td>Fair Condition – general cracking, scaling, or delaminations</td>
</tr>
<tr>
<td>4</td>
<td>Poor Condition – up to 10 percent of parapet is cracked or spalled; hazards to pedestrians or motorists present</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition – ten to 30 percent of parapet is cracked or spalled; hazards to pedestrians or motorists present; anchorage deficiencies present; and moderate efflorescence present</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition – thirty to 50 percent of parapet is spalled, patched, or delaminated; hazards to pedestrians or motorists and significant efflorescence present</td>
</tr>
<tr>
<td>1</td>
<td>Failure Condition – greater than 50 percent of parapet is spalled, patched, or delaminated; hazards to pedestrians or motorists and significant efflorescence present.</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition – crumbling</td>
</tr>
</tbody>
</table>
ITEM 58.08 – RAILING/POST

Railings/posts are the wood or metal components of bridge railings. Rate railings and posts for cracks and section loss in metal components, and for splitting, rot, and insect attack in timber components. Note any impact damage. Special attention must be given to the size, type, and spacing of fasteners and the anchorage. Inspection of railings and posts should include the following items:

- Look for damage caused by vehicular collisions.
- Report any loose connections or anchorage.
- Check the horizontal and vertical alignments.
- Examine timber members for splits, checks, and decay.
- Check metal members for corrosion and section loss.
- Notify owner of any damaged railing that would be unable to redirect an errant vehicle.
- Check that railing meets current design criteria.

Rate the railing/post according to the following criteria:

N  Not Applicable
9  Excellent Condition – new; meets current design criteria
8  Very Good Condition – no problems noted; meets current design criteria
7  Good Condition – some minor problems; meets current design criteria
### Additional Deck Ratings

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td><strong>Satisfactory Condition</strong> – elements show some minor deterioration; no hazard to pedestrians or motorists; meets current design criteria</td>
</tr>
<tr>
<td>5</td>
<td><strong>Fair Condition</strong> – structurally sound; does not meet current design criteria</td>
</tr>
<tr>
<td>4</td>
<td><strong>Poor Condition</strong> – any hazard to pedestrians or motorists; does not meet current design criteria; up to five percent of sections are missing, corroded through, or broken; horizontal or vertical misalignment; up to five percent loose connections or anchorage</td>
</tr>
<tr>
<td>3</td>
<td><strong>Serious Condition</strong> – any hazard to pedestrians or motorists; does not meet current design criteria; five percent to 10 percent of sections are missing, corroded through, or broken; less than five percent to 10 percent loose connections or anchorage</td>
</tr>
<tr>
<td>2</td>
<td><strong>Critical Condition</strong> – any hazard to pedestrians or motorists; does not meet current design criteria; 10 percent to 20 percent of sections are missing, corroded through, or broken; 10 percent to 20 percent loose connections or anchorage</td>
</tr>
<tr>
<td>1</td>
<td><strong>Failure Condition</strong> – any hazard to pedestrians or motorists; does not meet current design criteria; more than 20 percent of sections are missing, corroded through, or broken</td>
</tr>
<tr>
<td>0</td>
<td><strong>Failed Condition</strong> – any hazard to pedestrians or motorists; does not meet current design criteria; not providing value as a railing or post</td>
</tr>
</tbody>
</table>

Figure 4.3-24: Guardrail With Collision Damage
Figure 4:3-25: Steel Railing/Post

Figure 4:3-26: Steel Railing/Post

Figure 4:3-27: Steel Railing/Post With Minor Corrosion
Figure 4:3-28: Timber Railing/Post With Minor Checks

Figure 4:3-29: Railing/Post Does Not Meet Design Criteria
Figure 4:3-30: Railing/Post With Missing Section

Figure 4:3-31: Steel Railing on Concrete Parapet
Figure 4:3-32: Metal Railing

Figure 4:3-33: Metal Railing With Missing Support
ITEM 58.09 – PAINTED LINES

Rate the overall condition of lines painted on the wearing surface, considering visibility, reflectivity, and coverage.
ITEM 58.10 – DRAINS

A drainage system should remove water from the structure as quickly and completely as possible without causing erosion below the structure. Poor or insufficient drainage can cause a range of problems. Deck drains are receptacles to receive water. Deck drains include simple holes through the deck, slots at the base of a concrete parapet, and inlet boxes (scuppers).
Inspection of deck drains should include the following items:

- Check the deck drains for debris accumulation (plant growth, sand, gravel, and trash).
- Note any inlets or inlet grates that are deteriorated, broken, or missing. Broken grates that are hazards to traffic or pedestrians should be reported immediately.
- Look for evidence of ponding on the deck, such as debris accumulation in the gutters or low spots. Try to determine why roadway water is not getting to drains, and note these reasons on the inspection form. Notify the owner of any drains that allow ponding on the bridge deck.
- Examine the embankments and slopes for evidence of erosion. Clogged drainage systems force more runoff water onto these areas, increasing the erosion potential.

Rate the condition of the deck drains, as seen from the deck, including alignment, using the following criteria:

- **N**  Not Applicable
- **9**  Excellent Condition – new
- **8**  Very Good Condition – no problems noted
- **7**  Good Condition – some minor problems
- **6**  Satisfactory Condition – some minor deterioration or clogging; operating properly
- **5**  Fair Condition – partially clogged; minor misalignment
- **4**  Poor Condition – clogged; misalignment interferes with function; any hazard to pedestrians or motorists
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<th>Condition Description</th>
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<tbody>
<tr>
<td>3</td>
<td>Serious Condition – inoperable drainage</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken</td>
</tr>
<tr>
<td>1</td>
<td>Failure Condition – bridge closed to traffic, but corrective action may put it back in light service</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition – bridge closed to traffic; beyond corrective action</td>
</tr>
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**Figure 4:3-39: Clogged Deck Drain**

**ITEM 58.11 – DOWN SPOUTS/DRAIN PIPES**

Down spouts and drainage pipes carry runoff away from the drain and off of the superstructure and substructure. Runoff water that drains directly onto the superstructure or substructure may corrode structural steel, deteriorate concrete piers, and contribute to erosion of earthen abutment slopes.

Inspection of down spouts and drain pipes should include the following:

- Check for clogging and debris accumulation.
- Examine down spouts and drain pipes and their fittings for splits, breaks, or disconnected pipes.
- Check to see that clean outs are in place and operating.
- Look for any missing or broken pipe brackets and check to see that all components are supported properly.
• Check the condition of any rubber down spout boots. Rubber boots connect a fixed rigid pipe (such as a pipe attached to a pier) to a movable rigid pipe (such as an outlet pipe) at expansion joints. These flexible boots allow superstructure expansion and contraction without breaking the downspout.

• Check that drains do not allow water to run onto superstructure or substructure elements.

Rate the overall condition of the down spouts or drain pipes, as seen from under the deck, according to the following criteria. Note any clogs.

- N Not Applicable
- 9 Excellent Condition – new
- 8 Very Good Condition – no problems noted
- 7 Good Condition – minor problems
- 6 Satisfactory Condition – some minor deterioration; operating properly
- 5 Fair Condition – partially clogged; minor misalignment; some erosion of embankment
- 4 Poor Condition – clogged; misalignment interferes with function; any hazard to pedestrians; channels water onto superstructure or substructure, causing damage; erosion of embankment
- 3 Severe Condition – severe erosion of embankment; channels water onto superstructure or substructure elements
- 2 Critical Condition – inoperable
- 1 Failure Condition – inoperable
- 0 Failed Condition – missing
Figure 4:3-40: Down Spout With Crushed Section

Figure 4:3-41: Down Spout
ITEM 58.12 – LIGHTS

Rate the overall condition of any lighting or lighting supports on the bridge. On concrete supports, look for spalls and cracks. On steel supports, check for corrosion and cracks. On aluminum supports, check for fatigue cracks, particularly on roadway lights. On timber supports, check for rotting, insect attack, and splitting. Check all supports for loose connections, vandalism, alignment, and collision damage.
Rate the overall condition of the lights according to the following criteria:

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor problems
6  Satisfactory Condition – elements show some minor deterioration
5  Fair Condition – structurally sound, but some deterioration such as corrosion, rot, or splitting of lighting units; lights functioning properly; no hazard to pedestrians or motorists
4  Poor Condition – structural condition of the lighting units is deteriorated; lights not operating as designed; hazard to pedestrians or motorists
3  Serious Condition – possibility of structural failure; lights not operating as designed
2  Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken
1  Failure Condition – bridge closed to traffic, but corrective action may put it back in light service
0  Failed Condition – bridge closed to traffic; beyond corrective action

Figure 4:3-44: Lighting Support With Deteriorated Grout Pad
ITEM 58.13 – SIGNS

Signs are critical to the public safety. Signs must be posted at each bridge approach in a location that is near the bridge, but will also allow vehicles to change direction if the signs restrict the bridge.

Common signs found on bridges include the following:

- **Object markers**: Used at most highway bridges to warn the traveling public of the approaching crossing. This is most often a Type 3 object marker, mounted at the ends of the bridge rail. These are rectangular, vertically oriented signs with diagonal black and yellow stripes.

- **Narrow bridge**: Used when the bridge horizontal clearance of a two-way road is between 16 feet and 18 feet, or when the bridge roadway clearance is less than the width of the approach travel lanes.

- **One-lane bridge**: Used when the bridge horizontal clearance of a two-way road is less than 16 feet. If commercial vehicles constitute a high proportion of the traffic, or if the approach sight distance is limited, the bridge would be considered one-lane if the horizontal clearance is less than 18 feet.

- **Vertical clearance**: Used when the vertical clearance of the traveled way under the bridge is less than 14 feet, six inches. The clearance in feet and inches is always printed on this sign.
• **Weight limit posting:** Used to indicate a weight restriction on the bridge. The allowable load is always printed on this sign. See Part 1, Chapter 9 for Load Posting Information.

• **Other:** Posted signs related to the bridge, such as curve warning signs, high water signs, “Watch for Ice on Bridge” signs, or “Bridge Out” signs.

![Figure 4:3-46: Vandalized Object Marker Sign](image)

Rate the condition of the bridge’s signage. Items that must be considered include the following:

- Look at visual items such as legibility, reflectivity, faded paint, and obstructing vegetation or dirt.
- Look at message effectiveness and clarity.
- Examine support structural condition and deterioration.
- Evaluate the physical condition of the sign board and post, such as traffic impacts, loss of foundation material, or lateral support.
- Watch for vandalism such as graffiti, damage, or a missing sign.

Rate the overall condition of any signs or sign supports on the bridge in accordance with the following criteria:

- **N** Not Applicable – no signs
- **9** Excellent Condition – new signs
- **8** Very Good Condition – no problems noted
- **7** Good Condition – some minor problems
- **6** Satisfactory Condition – elements show some minor deterioration
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<tr>
<td>5</td>
<td>Fair Condition</td>
<td>deterioration such as corrosion, rot, or splitting on sign supports; signs’ messages applicable and readable; no hazard to pedestrians or motorists</td>
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<tr>
<td>4</td>
<td>Poor Condition</td>
<td>structural condition of signs is deteriorated; signs are incorrect, inapplicable, or unreadable; any hazard to pedestrians or motorists</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition</td>
<td>possibility of structural failure; signs are incorrect, inapplicable, or unreadable; any hazard to pedestrians or motorists</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition</td>
<td>unless closely monitored, may be necessary to close the bridge until corrective action is taken</td>
</tr>
<tr>
<td>1</td>
<td>Failure Condition</td>
<td>bridge closed to traffic, but corrective action may put it back in light service</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition</td>
<td>bridge closed to traffic; beyond corrective action</td>
</tr>
</tbody>
</table>

Figure 4:3-47: Cracked Sign Support
ITEM 58.14 – UTILITIES

Utility companies are often given permission to mount their services on a bridge. These could include gas lines, telephone lines, or sewer line. The utility owner is responsible for the adjustments, repairs, or restoration of their attachments to the bridge. Utilities are mounted on bridges by permit. Utility owners must be notified of problems. Failure of the utility owner to act promptly to eliminate hazards or utilities in poor condition is reason to rescind the permit.

Inspection of utilities should include the following:

- Note any utilities on the bridge, the location of the utilities, and any visible problems with their condition, supports, or hangers.
- Report any hazards to motorists or pedestrians posed by the utility to the utility and to the bridge owner.
- Look for leaks, breaks, corrosion, loose wires, or bad insulation.
- Check that utilities are not reducing the vertical clearance or freeboard.

Rate the overall condition of any utilities or their supports on the bridge and note the type of utility. Utilities that are close to the bridge and that may affect the bridge function should be noted. Describe any unknown utilities in the notes.
ITEM 58.15 – LONGITUDINAL JOINTS

Longitudinal joints are joints parallel to the direction of travel. In addition to the condition rating of each joint, the joint type needs to be identified. Inspection of longitudinal joints should include the following:

- Check for horizontal or vertical displacements or misalignments of the joint or its elements.
- Check for debris in the joint and deterioration of the joint materials or anchorage of the joint.
- Check for leaking or discoloration of the underside of the deck in the vicinity of the joint.
- Record the approximate air temperature (Fahrenheit) and the width of the joint opening, in inches, on each end of each joint.

Rate the overall condition of longitudinal joints on the bridge in accordance with the following:

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<td>8</td>
<td>Very Good Condition – no problems noted</td>
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<td>7</td>
<td>Good Condition – some minor problems</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition – some minor deterioration</td>
</tr>
<tr>
<td>5</td>
<td>Fair Condition – deterioration or misalignment, minor leaking, or minor debris</td>
</tr>
</tbody>
</table>
4 Poor Condition – damaged and/or misaligned; horizontal or vertical displacement, creating a hazard; significant debris; significant leaking

3 Serious Condition – advanced damage, misalignment, and/or displacement; hazardous

2 Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken

1 Failure Condition – bridge closed to traffic, but corrective action may put it back in light service

0 Failed Condition – bridge closed to traffic; beyond corrective action

ITEM 58.16 – TRANSVERSE JOINTS

Expansion joints provide for thermal expansion and contraction of the deck and superstructure. The clear opening of the joint should provide adequate space for movement of the adjacent superstructure elements. Joints also fill the gap between deck and abutment backwall to provide a smooth ride for vehicles transitioning onto and off the bridge. They must also be durable enough to withstand the abuse from traffic wheel loads, snow plow blades, road debris, sunlight, freezing, and deicing chemicals.

Transverse joints are joints perpendicular to the direction of travel. In addition to the condition rating of each joint, the location of each joint and the joint type needs to be identified.

Inspection of transverse joints should include the following:

- Check that there are no horizontal or vertical displacements or misalignments of the joint or its elements.
- Check for debris in the joint.
- Check for deterioration of the joint materials and anchorage of the joint.
- Check for leaking or discoloration of the underside of the deck in the vicinity of the joint.
- Note any overlays placed over the joint.
- Listen for any rattles or indications of component looseness as traffic drives over the joint.
- Check the support condition from below the deck. Look for broken welds and corrosion.
- Record the approximate air temperature (Fahrenheit) and the width of the joint opening, in inches, on each end of each joint.
Rate the overall condition of any transverse joints on the bridge according to the criteria below. Record the type of joint. Estimate the length of the joints using National Bridge Inventory (NBI) Item 51 or 52. If more than one type of transverse joint is used on the bridge, enter the data for the most critical type. List other joint types in the notes.

- **N** Not Applicable
- **9** Excellent Condition – new
- **8** Very Good Condition – no problems noted
- **7** Good Condition – some minor problems
- **6** Satisfactory Condition – some minor deterioration
- **5** Fair Condition – deterioration and/or misalignment; minor leaking; minor debris
- **4** Poor Condition – damaged and/or misaligned; horizontal or vertical displacement, creating a hazard; significant debris; significant leaking
- **3** Serious Condition – advanced damage, misalignment, or displacement; hazardous
- **2** Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken
- **1** Failure Condition – bridge closed to traffic, but corrective action may put it back in light service
- **0** Failed Condition – bridge closed to traffic; beyond corrective action
Figure 4:3-50: Transverse Joint

Figure 4:3-51: Transverse Joint with Debris
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SECTION 4.1 INTRODUCTION

For bridge inspection purposes, superstructure refers to all structural members, other than the deck, that distribute loads to the substructure units. One exception to this definition is a reinforced concrete slab, where the deck and superstructure are one and the same. Figure 4:4-1 shows cross sections for many common superstructure types:

- (A) Reinforced Concrete Slab
- (B) Reinforced Concrete Voided Slab
- (C) Timber Slab
- (D) Steel Multi-Beam
- (E) Steel Through Girder
- (F) Steel Girder/Floor Beam/Stringer
- (G) Reinforced Concrete Girder (T-Beam)
- (H) Prestressed Concrete I-Beam
- (I) Precast Concrete Channel Beam
- (J) Prestressed Concrete Box Beam
- (K) Steel Box Girder
- (L) Post-Tensioned Concrete Box Girder
- (M) Reinforced Concrete Through Girder
- (N) Timber Multi-Beam
- (O) Steel Truss
- (P) Timber Truss

Figure 4:4-1: Common Superstructure Types
Superstructure members are categorized into two groups: primary and secondary. Primary superstructure members are those that directly carry the deck dead loads and live loads to the substructure. Primary superstructure members include girders, beams, stringers, arches, trusses, cables, bearings, and bearing stiffeners. Primary superstructure members must carry repetitive live loads, as well as repeatedly applied impact loads.

Secondary superstructure members provide lateral stability for the primary members and help laterally distribute the live loads so that the primary members act together as a unit. Secondary members include diaphragms, cross-frames, sway bracing, lateral bracing, transverse web stiffeners, and longitudinal web stiffeners.

Depending on the type of superstructure, the members may need to deliver these loads to the substructure by way of bending, tension, compression, or a combination of these. To handle this type of demand, it is critical that the members be sound, as any failure of a member could be catastrophic. This chapter provides guidelines for the bridge inspector on which parts of the superstructure are critical to inspect and what defects may cause future problems.

Figure 4:4-2: Through Arch Truss Bridge
SECTION 4.2 STEEL SUPERSTRUCTURES

Since the late 1800s, steel has been one of the most commonly used materials for the construction of bridge superstructures. It can be designed to carry tension, compression, and bending loads. Steel can be configured in many different ways and can be used to create virtually any bridge type, including multi-beam bridges, two-girder bridges, arches, rigid frame bridges, trusses, and box girder bridges.

The most common defect found on steel superstructures is corrosion, and the worst corrosion is generally found where the steel is subjected to cycles of moisture. Corrosion reduces the section of a member, leading to an increase in stress. Corrosion can also affect how a structure operates. For example, unintended bending stresses may be introduced to a member when corroded pins restrict movement. In order to check for corrosion, inspectors must remove local areas of debris accumulation. Dirt and debris on members trap moisture and road salts and increase corrosion. Bird waste is acidic and traps moisture and road salts, accelerating corrosion. Figure 4:4-3 shows corrosion on a girder flange.

![Figure 4:4-3: Pitting Caused by Corrosion on Girder Bottom Flange](image)

Pack rust is corrosion occurring between two pieces of lapped steel, such as between the vertical leg of a flange angle and the girder web. These details trap moisture and do not allow for quick water evaporation; so, pack rust most often occurs under leaking drains or expansion joints, at fascia girders, and on trusses and arches. The expansive force of pack rust can be great enough to bend thick plates and to pry and fracture rivets and bolts. Details prone to pack rust include girder flange and web splices, gusset plates, riveted cover plates, and back-to-back angles. Figure 4:4-4 shows corrosion on a girder flange.
Bridges constructed with weathering steel are also susceptible to corrosion. The signs of corrosion on weathering steel include deep pitting, laminar rust, flaking, or a rough surface.

Steel structures are also susceptible to developing fatigue cracks. Fatigue failure is of special concern because fatigue failures can be brittle, giving no warning as to imminent collapse. When steel is welded, the stress from the weld can create a crack. Certain details, especially those where welds intersect or where the steel is constrained in more than one direction, are especially prone to cracking. Appendix A shows several illustrative examples of fatigue-prone details. All welds must be carefully examined because poor welding may have left flaws within the weld metal even where fatigue cracks are not normally expected to be found. Fatigue cracks usually show up as rust stains or rusty breaks in the paint, propagating perpendicular to the direction of stress. Detection of fatigue cracks will most often occur during arm’s length inspections. See Part 4, Chapter 11 for more information on Fatigue and Fracture Critical Inspections.

Subsection 4.2.1 Beam and Girder Bridges

Beam and girder bridges are constructed using hot rolled steel beams or fabricated girders including fabricated box girders. These shapes can be used to construct multi-beam bridges, two-girder bridges, or single-girder bridges when using box beam construction.
• **Rolled Multi-Beam Bridges:** Rolled multi-beam bridges are constructed using three or more hot-rolled steel beams as the primary members. Beam depths are usually no more than 36 inches, which limits spans to about 90 feet. Transverse diaphragm secondary members, using C-shaped channel sections or I-shaped members, may be bolted, riveted, or welded with intermittent welds to the beam webs. To increase a beam’s bending capacity, cover plates may be riveted, bolted, or welded to the tension and/or compression flanges.

![Rolled Steel Multi-Beam Bridge](image)

**Figure 4:4-5: Rolled Steel Multi-Beam Bridge**

• **Fabricated Multi-Girder Bridges:** Fabricated multi-girder bridges are constructed using three or more built-up steel girders as the primary members. The girders are fabricated by either riveting or bolting steel plates and sections, or by welding steel plates. Greater economy is typically achieved by varying flange thickness/width or the number of plates in a flange to accommodate the bending moment. Web depths may also be deepened (haunched) over the piers to accommodate the bending moment. Girder depths are usually greater than 36 inches, allowing for spans up to about 500 feet. Due to their greater web depths, transverse cross-frames using angles or T-shapes are usually used as secondary members. In addition, vertical and longitudinal stiffeners may be welded or riveted to the web to prevent web buckling. Older structures may use lateral bracing placed at the level of the bottom or top girder flanges to connect adjacent girders. Larger spans may be built with a floor system consisting of stringers and floor beams as additional primary members. Floor beams are transverse members that frame into the girder webs. The stringers bear on or are framed into the floor beams. Stringers are usually rolled beams placed between, and running parallel to, the girders.
• **Fabricated Two-Girder Bridges:** Two-girder system bridges are constructed using only two built-up steel girders as primary members. These bridges have floor systems that use floor beams and sometimes stringers. As in fabricated multi-girder bridges, the girders are fabricated by either riveting/bolting together steel plates and angles, or by welding steel plates together. Two-girder systems do not have load path redundancy and are classified as fracture critical bridges.
- **Steel Through Girder Bridges**: Through girder bridges are fabricated two-girder bridges with the deck placed between the girders rather than on top of them. Many older short- to medium-span highway and railroad bridges use this configuration. Through girder bridges lack redundancy and are fracture critical.

![Figure 4:4-8: Steel Through Girder Bridge](image)

Figure 4:4-8: Steel Through Girder Bridge

![Figure 4:4-9: Steel Railroad Flatcar Bridge](image)

Figure 4:4-9: Steel Railroad Flatcar Bridge
• **Railroad Flatcar Bridges:** Railroad flatcar bridges are steel girder bridges constructed from salvaged railroad flatcars. They are available in many configurations. The design and installation of a railroad flatcar bridge should be overseen by an engineer registered in the state of Indiana. Special attention must be given to the selection of the flatcar, the design of the longitudinal connections between flatcars, and load transfer. Most railroad flatcars should be supported on the bolsters and the design engineer should ensure that the support is adequate. Welded connections should be visually inspected to ensure that fatigue cracks are not present when a flatcar is selected for use as a bridge. Box cars and gondola cars should not be used in the construction of bridges.

• **Steel Box Girder Bridges:** Box girder bridges have one or more girders fabricated from plates welded into a rectangular or trapezoidal closed shape. Because closed shapes are more torsionally stiff than open I-shaped girders, box girders are commonly used for curved spans. Closed shapes also help protect the steel from corrosion since only half the plate area is exposed to the elements. The vertical plates form the webs and the bottom plate forms the bottom flange. The top flange is formed by the top plate, if present, or the concrete deck. Both the web and flange plates are normally strengthened with transverse and longitudinal stiffeners to prevent buckling. Box girders can usually be entered through access hatches to allow inspection of their interiors. Bridges using one box girder do not have load path redundancy and are classified as fracture critical bridges. Most two-box girder bridges are also classified as fracture critical. However, some two-box girder bridges have been designed with substantial bracing between the boxes so that one of them can support the entire bridge should the other fail. Steel box girder bridges are considered complex in Indiana. The steel box girders constructed in the 1960s and 1970s often developed cracks due to torsion from improper shipping and erection. These cracks were often found at the web gaps.

![Figure 4:4-10: Steel Box Girders](image)
The inspection of steel girder bridges should include the following:

- View down the member's length to check vertical and horizontal alignments and check for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.

- Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to the areas below the deck expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This situation should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

- Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note any deformation of plates.

- Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

- Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

- Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

- Look for overload damage in the form of compression flange buckling and tension flange elongation or fracture.

- Look for web crippling, a permanent wrinkling or buckling of the web due to overloads.

- Look for torsion-related damage on curved box girders at the diaphragms/cross-frames, webs, and flanges as evidenced by plate or member distortions.
• Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel. Impact damage is usually most prominent on the fascia girders, although damage can occur across the entire cross section of the superstructure due to impact and recoil of all members after impact.

• Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

• Inspect cables and rods in accordance with Part 4, 4.2.7.2.

• Inspect pins at eyebars, bearings, hangers (U-bolts), or other devices holding up the floor beams in older trusses.

• Examine the connections between railroad flatcars.

• Note where railroad flatcars are supported. If not supported at the bolsters, recommend that the members be checked for adequate strength and stability in the bearing area.

• Note any pre-installation damage on railroad flatcars and check damaged areas for cracks.

• For railroad flatcar bridges, note areas where original equipment such as mounting brackets and braking equipment have been removed and check for stress risers.

• For railroad flatcar bridges, note if any primary structural components have been modified and check that the load rating reflects the modifications.

Figure 4:4-11: Damaged Steel Flatcar Bridge
Subsection 4.2.2 Steel Truss Bridges

Steel truss bridges are structures with two or more parallel trusses supporting the deck. The deck may be placed on top of the trusses (deck truss) or between the trusses (through truss when there is overhead lateral bracing, or pony truss when there is no overhead lateral bracing). Through or pony trusses are most often constructed using two trusses, and are considered fracture critical structures. Two-truss deck trusses are also fracture critical structures.

Truss chord, diagonal, and vertical members may be fabricated from eyebars, rolled shapes, or built-up members. Connections are made with rivets, bolts, welding, or pin connections in some older trusses. All truss bridges have floor systems similar to two-girder systems. To keep the two trusses in line longitudinally, secondary lateral bracing members diagonally connect the bottom chords. For deck and through trusses, the top chords are laterally braced in a similar way. Sway bracing keeps the two trusses in line laterally. On deck and through trusses, sway bracing transversely frames between the truss verticals. On pony trusses, sway bracing is usually placed as a transverse diagonal on the outside of the trusses. It connects the top chord to transverse outrigger floor beam extensions and prevents buckling of the top chord. Typical components are labeled in Figure 4:4-12.

![Figure 4:4-12: Truss Components](image)

Truss members are theoretically loaded in either pure tension or compression and are considered to be axially loaded. Members carrying tensile loads are fracture critical members. Though each of these members may contain internal redundancy (multiple eyebars or built-up riveted shapes), each member is inspected as a fracture critical member. Steel through trusses and trusses with pin and eyebar connections are considered complex bridges in Indiana.
Tension members must be identified prior to performing a Fracture Critical Inspection. It is also advantageous to identify tension members for a Routine Inspection. On simply supported trusses, the bottom chords will always be in tension and the vertical member closest to each support will always be in tension. On continuous trusses, the top chord will be in tension over the piers, and the bottom chord will be in tension between supports; the bottom chord will be in compression over the piers, and the top chord will be in compression between supports. On simply supported trusses, diagonals that point upward and away from mid-span are tension members, as well as any counters which form an “X” pattern at or near mid-span. There is no easy method to determine which diagonals are in tension for continuously supported trusses and for vertical members of any truss.

Visual methods are not always capable of adequately evaluating the condition of gusset plates with section loss due to corrosion in tightly configured connections, or those where the members framing into the gusset plate are closely spaced. Trusses with these fracture critical connections may require special documentation and nondestructive testing (NDT) to quantify the gusset plate thickness. This is further discussed in detail in Part 4, Chapter 11, Section 11.3.
Inspection of steel truss bridges should include the following:

- View down the member’s length to check vertical and horizontal alignments, and check for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.
• Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas below expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

• Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note any deformation of plates.

• Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, or re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and/or photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

• Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

• Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

• Closely examine eyebar heads for cracks, corrosion, and lack of movement. Check any forged areas on eyebars for cracks or separations.

• Check to make sure all eyebars in a multiple eyebar member are parallel to one another.

• Check for bowed or buckled tension members. Unintended bending and compressive stresses may be introduced into a tension member from substructure settlement or heavily rusted/frozen pinned joints. Look for overloads on other members when this situation is encountered, since loads previously carried by the tension member must be redistributed somewhere else within the bridge.

• Document the primary truss gusset plates where limited access prevents section loss from being adequately quantified.
• Look for compression overload damage in the form of local member buckling or waviness. Global buckling will take the form of a bowed member or a member bowed into an “S” shape if support is provided between its ends.

• Check all pins for excessive wear.

• Check to see if pin spacers are keeping the eyebars or loop rods properly aligned and symmetric about the truss plane.

• Examine the condition of threaded members such as truss rods at turnbuckles.

• Check for heavily corroded pins that may have locked-up eyebar or loop rod movement. Transverse cracks may appear in the member body away from the forge zone or in the eyebar head.

• Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on member edges or corners. Particularly strong collisions may tear the steel. Cracks can develop in the connections at each end of any member that has been hit.

• Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

• Inspect cables and rods in accordance with Part 4, 4.2.7.2.

Subsection 4.2.3 Steel Arch Bridges

Arches resist axial compressive loads and bending moments. Because they are not tension members, arches are not considered fracture critical even though most steel arches have only two main members. Tied arches are the exception and are considered fracture critical. Arch members are classified as solid-ribbed, braced-ribbed (trussed arch), spandrel-braced, or tied. The Bridge Inspector’s Reference Manual (BIRM) has several photographs in Chapter 8 illustrating some of these arch styles.

Solid-ribbed steel arches are fabricated into I-girders or box shapes. Braced-rib arches have two curves (usually fabricated boxes) defining the arch shape, braced with truss webbing between the curves. These are usually used for longer spans or where better control of live load deflections is required. Spandrel-braced arches are similar to solid-ribbed arches, but have diagonal bracing between the spandrel bents above the arch. Tied arches have their ends connected with a tension tie girder as a means to remove the arch’s horizontal thrust from its bearing. These tension ties are fracture critical components of the arch superstructure. The ties and arches are usually fabricated box members.
Arch ribs carry compressive loads and bending moments. Compressive forces are fairly constant throughout the arch. Bending moments will be variable and depend on the location of arch hinges. Moments are zero at the hinges. Arches may have three hinges (one at the crown and two at the bases), two hinges (at the bases), or no hinges (fixed). Columns or shafts on arch bridges may carry a combination of compressive loads and bending moments (spandrel columns), tensile loads (hangers or longitudinal bracing members), or compressive loads (longitudinal bracing). Hangers, arch braces, and spandrel braces are tension members.

- **Steel Deck Arch Bridges**: Steel deck arch bridges are structures with the deck placed on top of two or more riveted, bolted, or welded arches. The arches are the main load-carrying members and their ends bear on foundations at grade. Their bearing ends are usually pinned. The end reactions have a vertical component due to the dead and live gravity loads and a horizontal component due to the arch’s outward thrust. A pin may also be present at the arch crown, forming a three-hinged arch. The area between the deck and arch is known as the spandrel. Deck arches use vertical compression members, called spandrel columns, to deliver the deck loads to the arch ribs. The spandrel columns may be rolled or built-up shapes. Each arch rib may be fabricated into an “I” or box shape (solid-ribbed arch) or into a truss shape (braced-rib arch). When diagonal braces connect the spandrel columns above the rib, the bridge is classified as a spandrel-braced arch. The floor system will contain floor beams, spandrel girders, and sometimes stringers. Secondary members include the upper and lower lateral bracing which brace the floor system and arch ribs, respectively. Transverse sway bracing keeps the ribs and spandrels in line laterally. Although many deck arch bridges have only two arch ribs, the bridges are not considered fracture critical since arches resist a combination of compression loads and bending moments, not tension. Open spandrel deck arch bridges are considered complex in Indiana.

![Figure 4:4-16: Steel Deck Arch Bridge With Spandrel Bent Columns](image)
• **Steel Through Arch Bridges:** Steel through arch bridges are structures with the deck placed below the crown of, and between, two riveted, bolted, or welded arches. As with deck arches, the arches are the main load-carrying members and are usually pinned, with the ends bearing on foundations at grade. A pin may also be present at the arch crown to form a three-hinged arch. Through arches use vertical tension members to suspend the deck under the arch ribs. The tension members may be steel cables, wire rope, or solid steel hangers. Each arch rib may be fabricated into a box shape (solid-ribbed arch) or more commonly into a truss shape (braced-rib arch). The floor system will contain floor beams, girders, and sometimes stringers. Secondary members include lateral bracing for the arch ribs and floor system, and transverse sway bracing to keep the ribs in line laterally. As with deck arches, most through arches are not fracture critical bridges.

![Figure 4:4-17: Through Arch Bridge](image)

• **Steel Tied Arch Bridges:** Steel tied arch bridges are special types of through arches. The ends of tied arches bear on piers and are tied together with a tie girder. The tie girder is in tension to resist the large horizontal thrusts of the arch rib. It functions in a similar manner to the string on an archer’s bow. Because tied arch bridges have only two arches and two tie girders, tied arch bridges are considered fracture critical since a failure of one tie girder will directly lead to a failure of its associated arch. The tie girder may also behave as a bending member, in conjunction with the ribs, to deliver dead and live gravity loads to the pier. Primary and secondary members of tied arches are similar to those of through arches, although the arch ribs are typically solid box-shaped members. Floor beams frame directly into the webs of the tie girders, and cables or hangers (solid or hollow) directly support the tie girder. The hangers may be oriented vertically or diagonally.
The inspection of steel arch bridges should include the following items:

- View down the member’s length to check vertical and horizontal alignments, as well as for any canting (lateral bending or twisting). This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.

- Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas under deck joints and details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

- Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note and measure any deformation of plates.
Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

Look for local compression overload damage in the form of local member component buckling, plate waviness, or crippling.

Look for global buckling which will take the form of longitudinal rib misalignment.

Inspect the longitudinal bracing members of braced rib arches. These members should be inspected in a manner similar to truss members (see Subsection 4.2.2). They are designed to take compressive loads, tensile loads, or both.

Examine the rib splice plates for loose fasteners and excessive corrosion.
- Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel.

- Inspect the hinge pins for corrosion and excessive wear.

- Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

- Inspect cables and rods in accordance with Part 4, 4.2.7.2.

Subsection 4.2.4 Steel Rigid Frame Bridges

Steel rigid frame bridges are structures in which the structure’s inclined supporting “legs” are integrated with the girders to form a rigid frame. Rigid frames are usually constructed using welded plate girders and legs to form a “K” shape or triangular delta shape. Though the legs are used as bridge piers, the legs are actually part of the superstructure because of their rigid connection to the girders. This rigid intersection of the leg and girder is referred to as the knee and allows both the girders and legs to resist bending moments. Large moments and shear forces are resisted by the knee, resulting in a complex arrangement of stiffeners in this area. The legs are pinned at grade, and the girder ends supported by conventional abutments. Rigid frame bridges may use two or more frames to support the deck. The girders, legs, and bearings are all primary members on multi-rigid frame bridges. The diaphragms, cross-frames, longitudinal stiffeners, transverse stiffeners, and radial stiffeners are all secondary members. On two-frame bridges, the girders, legs, stringers, floor beams, and bearings are all primary members. Secondary members include the lateral bracing, longitudinal stiffeners, transverse stiffeners, and radial stiffeners. Spans of 50 to 200 feet are attainable using rigid frames.

Two-frame bridges are considered fracture critical. The curvature of the deck should be checked periodically to monitor for flattening and to check for sag. Check for uplift of the ends of short-end spans when the center span is loaded.

Figure 4:4-20: Steel Rigid Frame Bridge
The inspection of steel rigid frame bridges should include the following:

- View down the member’s length to check vertical and horizontal alignments, as well as for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.

- Periodically survey the curvature of the deck to monitor flattening.

- Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas under the deck expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

- Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note and measure any deformation of plates.

- Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

- Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

- Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

- Look for overload damage in the form of compression flange buckling and tension flange elongation or fracture.

- Look for web crippling, a permanent wrinkling or buckling of the web due to overloads.
• Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel.

• Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

• Inspect cables and rods in accordance with Part 4, 4.2.7.2.

• Look for uplift of the girders at the abutments and for misaligned bearings due to uplift.

Subsection 4.2.5 Steel Cable-Stayed and Suspension Bridges

• **Steel Cable-Stayed Bridges**: Steel cable-stayed bridges are typically long span structures that use one or two planes of inclined stay cables as their main means of support. The stay’s opposite ends are attached to, or carried over, pylons, which deliver the cable forces to the foundation. The cables are tension members. Cable-stayed bridges are always considered complex bridges in Indiana and may be fracture critical.

• **Basket Handle, Cable-Stayed Arch Bridges**: Indiana has one basket handle, cable-stayed steel arch bridge carrying I-65 over State Route 46. On a basket handle cable-stayed bridge, the arches supporting the cable are connected at the top.

![Figure 4:4-21: Basket Handle, Cable-Stayed Arch Bridge](image)
Suspension Bridges: Suspension bridges are typically long span structures that support the deck from vertical cable hangers attached to two or more catenary main suspension cables. The main suspension cables are draped over towers and their ends are fixed to gravity anchors. Suspension bridges are always fracture critical and are considered complex bridges in Indiana.
As complex bridges, steel cable-stayed and suspension bridges will have their own operation and maintenance manuals to guide the inspector during routine evaluations. The reader is referred to the Federal Highway Administration (FHWA) publication HI-94-033, *Safety Inspection of In-Service Bridges Participant Notebook, Volume 3* for additional guidance.

**Subsection 4.2.6 Moveable Steel Bridges**

Movable steel bridges are discussed in detail in Part 5 of this manual.

**Subsection 4.2.7 Inspection of Special Details in Steel Superstructures**

*4.2.7.1 Pins or Pin-and-Hanger Assemblies*

Pins and pin-and-hanger assemblies are primary load-carrying connection assemblies found in many steel superstructures. Individual bridge pins are located on multi-span girders where it is necessary to locate a non-expansion hinge away from a pier. Pin-and-hanger assemblies, consisting of two pins and two hangers, are found on multi-span girder bridges where it is necessary to locate the expansion hinge away from a pier. The assemblies are placed at the tip of a girder’s cantilever span and are used to suspend an adjacent span. Cantilevered trusses also use pin-and-hanger assemblies. On two-girder system bridges, pin-and-hanger assemblies are fracture critical members. All bridges with pin-and-hanger details and all trusses with pin and eyebar details are considered complex bridges in Indiana.

Hangers are designed to act as links and are consequently intended to be tension-only members. At least two are used per connection, one on each side of the girder web. Hangers may be shaped as simple flat plates or as eyebars.

Hanger plates are susceptible to damage when corrosion freezes the pins and prevents free rotation. When this occurs the assembly ceases to behave as a hinge and begins to carry bending moments. These moments introduce bending stresses in the hangers in addition to the tensile stress for which the hangers were designed. Torsional forces in the pin can cause cracks and pin failure. Out-of-plane bending stresses may also be generated from girder misalignment or pack rust. As a result, overstress cracks may develop in the hanger plate(s).

On trusses, pins are normally employed to connect the ends of eyebars or loop rods, although large pins can connect the ends of modern built-up members. On girders, pins pass through web plates to form a non-expansion hinge. Pins are intended to be frictionless connections that allow for member rotation, but are not designed to carry any torsion. They are fabricated in a variety of sizes. The smallest are solid and use cotter pins to prevent the pin from walking out of the connection under vibratory loads. Medium diameter pins are also solid, but their ends are threaded so that self-locking nuts can be used to prevent the pin from walking out. Sometimes holes are drilled through the center axis of medium-sized pins. The largest pins have holes drilled through their center axis, through which passes a threaded rod. The rods also pass through pin end cap plates. Nuts are threaded onto the rod to retain the cap plates and the pin.
The inspection of pins and pin-and-hanger assemblies should include the following items:

- Carefully check all edges and surfaces of all hangers, especially the ends beyond the pin centerlines, and the forged areas of any eyebars for cracks or corrosion. Forged areas will usually be near the eyebar head and body junction.

- Check both sides of the hanger for cracks, if possible. A flashlight and inspection mirror can help.

- Use NDT methods (dye penetrant, magnetic particle, ultrasonic, etc.) to look for cracks. NDT should be performed as part of an In-Depth Inspection.

- Immediately report any cracks or section loss greater than 10 percent to the District Engineer or the Inspection Consultant. The nature of pin-and-hanger assemblies is such that a failure of one assembly may cause a domino effect failure on multi-girder bridges.

Figure 4:4-24: Crack in Hinge Girder
Tap the pin or threaded rod nut with a hammer to check for looseness. If the pins are excessively loose, notify the District Engineer or the Inspection Consultant immediately. A bridge inspector should never unscrew a pin nut or remove a cap plate to get a better look at the pin. Disassembly is not part of a Routine Inspection. Doing so could be catastrophic if pack rust between the girder web and hanger has placed the assembly on the verge of failure. Disassembly is only undertaken as part of an In-Depth Inspection program and only after proper auxiliary joint support is in place.

Examine all pins for signs of the desired member rotation about the pin, such as powdery orange or red rust (fretting rust) near surfaces that rub or bear, cracked paint between the pin and member, or physical movement as traffic crosses the bridge.
• Measure the amount of pin wear on truss or girder hanger expansion hinge assemblies. Since access may be difficult due to closely spaced members or cap plates, creative measurements must be made. Two measurements must be taken at each pin to obtain adequate information of pin or member wear. Measure the distance from the centerline of the pin to the end of the hanger, (shown as Dimension 1 in Figure 4:4-27) and measure from the center of the pin to the inside flange surface of the girder through which the pin passes (shown as Dimension 2 in Figure 4:4-27). These readings will give measurements for wear at the pin/hanger interface and pin/web interface, respectively. Make these measurements from the centerline of the threaded rod on pins using cap plates.

• Measure the amount of pin wear on non-expansion hinges. Measure from the center of the pin to the inside surface of the girder's top and bottom flanges. These readings will give measurements for wear at the bottom of pin/web interfaces and top of pin/web interfaces, respectively (shown as Dimensions 3 and 4 in Figure 4:4-27). Make these measurements from the centerline of the threaded rod on pins using cap plates.

• Compare these measurements to the distances shown on the original design drawings, accounting for the pinhole tolerance (usually 1/32 inch). Wear of 1/8 inch or greater should be brought to the attention of the District Engineer or the Inspection Consultant. If the original design drawings are not available, record the measurement for comparison to measurements taken on future inspections. If possible, a wire or stiff steel rule should be used to probe between the plies of plates to measure the distance from the pin surface to the surfaces described above.

• Look for fretting corrosion between the hanger and girder web, which will be evident by dusty-looking reddish rust around the plates' interface. Fretting corrosion is caused by two tightly fitting plates rubbing against each other.

• Check for ratcheting. On new structures, rotations are accommodated by the girder web sliding on the pin surface. Fretting corrosion between the web hole and pin surface will advance, eventually “locking up” the web/pin movement. After this occurs, rotations take place by the hanger sliding on the pin surface. This is known as ratcheting, and is evidenced by a broken paint film, wear marks, and corrosion between the pin nut and hanger plate.
- Look for pack rust between the girder web and hanger. Pins connecting plate hangers or tightly packed eyebars are difficult to access and often do not receive proper cleaning or painting during maintenance operations. Excessive corrosion may lock up the joint, introducing unintended bending stresses into the pin-and-hanger or superstructure member. Note any deformation of plates.

- Check the cap plates for flatness.

- Check to make sure adjacent girder flanges and webs are in alignment.

- Measure the distance between the hanger and girder web at several locations. A variation of 1/8 inch or more could mean hanger twist or lateral movement.
• Bridges with pin-and-hanger type connections should be clearly identified in the Central Database. Currently, the Indiana Department of Transportation (INDOT) hires a consultant to inspect and perform NDT on all pin-and-hanger connections on all state- and county-owned bridges that carry vehicular traffic on a five-year cycle. The Indiana Toll Road hires a separate consultant to perform the same level of inspection for bridges under its jurisdiction on a four-year cycle.

4.2.7.2 Cables and Rods

Cables and rods are tension-only members used in suspension, cable-stayed, post-tensioned concrete, tied arch, and some timber bridges.

Cables may be used as vertical suspenders, angled cable stays, catenaries, or post-tensioning strands. Unlike solid rods, many individual wires are helically spun together and placed parallel to each other, or spun into rope to build up the size of the cable. End anchorages are usually made by brooming or spreading apart the cable wires inside a steel fitting. The conical-shaped steel fitting is then filled with a socketing medium, such as molten zinc, to lock the wires in place. For smaller diameter cables or individual strands, jaws (wedges) can be placed around the strand to provide anchorage. These jaws grip and anchor the strand as the strand is pulled and seated into a conical-shaped anchor block.

Rods are most often used to longitudinally post-tension concrete box girders and to transversely post-tension timber slab bridges. Normally, only the ends of the rods are visible for inspection, although early examples of post-tensioned concrete box girders left the entire rod exposed within the cells.
Corrosion is the primary enemy to any steel cable or rod. Note that corrosion has a more profound structural effect on cables than it does on solid members. Because cables have a much greater surface area than a solid rod with the same cross-sectional area, surface corrosion on the wires will reduce a cable’s cross-sectional area more than on a similarly sized solid member.

Inspection of rods and cables should include the following:

- Look for broken wires. Broken wires may be caused by fatigue due to bending near the anchorages and excessive section loss due to corrosion or abrasion against the cable guide.
- Look for corrosion and document its extent. Severe corrosion may also form pack rust between individual wires or between the wires and end fittings.
- Inspect the end fittings, especially lower end fittings, where water would tend to accumulate. Check for any cracks in the end casting.
- Note if any rods or cables are vibrating excessively due to wind or traffic loads and note the amplitude, the wind speed, and the wind direction.
- Check for cable loosening or slippage at the end fittings. Signs of this condition may be wire abrasion and/or corrosion.
- Note any slipping or unraveling of the main cable banding on suspension bridges.
Figure 4:4-30: Cable Anchorage for a Tied Arch Bridge
Concrete has been used to construct bridges in the United States since 1889. With the exception of arches, conventional reinforced concrete was initially limited to use for short, single-span bridges. The development of prestressed concrete in the middle part of the 1900s, with the subsequent development of post-tensioned concrete boxes, allowed concrete to gain acceptance for use on medium- and long-span bridges. Concrete superstructures can be configured in many different ways, including slab bridges, reinforced girder bridges, concrete arch bridges, and box beam bridges.

Subsection 4.3.1 Cast-in-Place Slab Bridges

Cast-in-place slab bridges are the simplest type of concrete bridge. The slab acts as a single, wide beam spanning from substructure unit to substructure unit. There are no individual beams with this type of bridge, and the slab also acts as the deck. Slabs are used for simple spans up to approximately 45 feet. Continuous slab bridges can be built with slightly longer span lengths. To attain greater negative bending strength on continuous bridges, the slab may be thickened (haunched) over the piers. The main reinforcing steel is placed parallel to traffic and located near the bottom of the slab in positive bending regions, and towards the top of the slab in negative bending regions. On older and more complex structures, continuous cast-in-place slabs may contain voids to lighten the dead load of the bridge.

Figure 4:4-31: Single Span, Reinforced Concrete Slab Bridge
Inspection of a concrete slab superstructure should include the following:

- Check for cracks and note their location, orientation, length, maximum width, and type. Cracks to note include:
  - Transverse flexural cracks on the top side of the slab adjacent to, and over, piers and where reinforcement bars end. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.
  - Diagonal or transverse temperature/shrinkage cracks. These will be found on most concrete decks and can provide a means for chlorides to reach steel reinforcement.
  - Diagonal shear cracks on the copings over or near the bearing areas at piers/abutments.
- Check for pop-outs, scaling, abrasion, and rutting. This may be most evident in the gutters and around the drains.
- Look for spalls and note any large individual spalls.
- Look for signs of corroding reinforcing steel, such as rust stains.
- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, or exposed reinforcement.
- Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.
- Check for areas of delaminations. Loose concrete can fall and cause serious damage or injury.
- Check for excessive dead load deflection.
- Note the condition of repaired areas.
- Check for water leakage. Water leakage frequently appears on support structures, under drains, or under expansion joints.
- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.
- Check for missing tie rods, bolts, or nuts.
Subsection 4.3.2: Reinforced Concrete Girder Bridges

Reinforced concrete girder bridges (sometimes called Tee Beam bridges in other states) were commonly constructed in the early half of the 20th century. They are cast-in-place structures, with the deck cast monolithic with the beams. The "T" shape is created by the rectangular beam stem below the deck, with the deck forming the top flange. Because the deck acts as the top flange, deterioration will affect the superstructure rating. The fascia beams on some reinforced concrete girder bridges are upturned, doubling as parapets. Reinforced concrete girder bridges are most commonly used for simple spans, although they may be made continuous by haunching the beam stems over the piers. Individual spans may reach 50 feet in length, with the beams spaced from about three to eight feet. Common beam depths range from 18 to 24 inches. The main reinforcing steel is placed longitudinally near the bottom of the beam in positive-bending regions and longitudinally within the deck in negative-bending regions. Vertical stirrups placed along the beams serve as shear reinforcing.
The inspection of a reinforced concrete girder bridge superstructure should include the following:

- Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each. Look for transverse flexural cracks on the underside of the beams between supports and on top of the deck over the piers on continuously supported bridges. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.
• Check for deteriorated concrete in the flexural zones that is causing debonding of the reinforcing steel. This is critical near the ends of the reinforcing steel bars since a certain length of the bar must be embedded within sound concrete to fully develop its strength. Delaminations, spalls, and longitudinal cracks can all cause debonding.

• Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member may be supported by the reinforcing stirrups.

• Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, delaminations, or exposed reinforcement.

• Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.

• Investigate the bearing areas for spalled concrete due to friction from thermal movement or crushed concrete due to bearing pressure overloads.

• Check the member under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

• Check previously repaired areas for soundness by hammer tapping.

• Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

• Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions will expose several reinforcing bars.

Subsection 4.3.3 Concrete Through Girder Bridges

Concrete through girder bridges were constructed in the early half of the 20th century. They are cast-in-place structures, with the deck cast monolithic with the girders. Two deep girders are normally used and also serve as the bridge parapets. Through girder bridges are used for short simple spans. The deck is connected to the lower portion of the girders. Because the deck must span between the girders, through girder bridge widths rarely exceed 24 feet. The girders themselves are fairly large, usually 18 to 30 inches wide, and four to six feet deep. The main reinforcing steel is placed longitudinally near the bottom of the girders, while the main deck reinforcing steel is placed transversely in the deck bottom. Vertical stirrups placed along the girders serve as shear reinforcing.
The inspection of a reinforced concrete through girder bridge should include the following:

- Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each.

- Look for transverse flexural cracks on the underside of the girder between supports. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks wider than 1/8 inch on a primary concrete member.

- Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed as this may indicate permanent deformation of the stirrups.

- Check for deteriorated concrete in the flexural zones that is causing debonding of the reinforcing steel. This is especially critical near the ends of the reinforcing steel bars since a certain length of the bar must be embedded within sound concrete to fully develop its strength. The deterioration causing the debonding may be delaminations, spalls, or longitudinal cracks.

- Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be supported by the reinforcing stirrups.

- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, or exposed reinforcement.

- Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.

- Investigate the bearing areas for spalled concrete due to friction from thermal movement, or crushed concrete due to bearing pressure overloads.

- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

- Check the member under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

- Check previously repaired areas for soundness by hammer tapping.

- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.
Subsection 4.3.4 Precast Concrete Channel Beam Bridges

Channel beam bridges use precast channel beams as the primary load-carrying members. Channel beam bridges can be designed using standard reinforcing steel or as prestressed members, although most channel beam bridges in Indiana were constructed using standard reinforcing steel. The channels are placed on the substructure units so that they form an upside down "U," with the vertical legs forming the beams and the horizontal top slab forming the deck. The channels are placed tightly side-by-side and should be transversely connected by tie rods or bolts so that the beams act as a unit under live loads. Grouted shear keys also help the beams to act together. Channel beam bridges are used for simple spans up to about 50 feet. Widths of the individual beams usually range from three to four feet. The main reinforcing steel is placed longitudinally near the bottom of the channel legs, while the main deck reinforcing steel is placed transversely in the top slab. Generally, this reinforcing is hooked at the end, but sometimes straight bars were used. Inspectors should note any evidence of hooks. Vertical stirrups may be placed along the channel legs to serve as shear reinforcing.
Inspection of precast concrete channel beam bridges should include the following:

- Sight down each beam and check for excessive or differential deflections, or leaking and efflorescence between channel beams. This may indicate a beam is losing its prestressing force and is unable to carry the loads for which it was designed. This may also indicate failed shear keys. Once the shear keys have failed, live loads cannot be shared between adjacent beams.

- Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each.

- Look for transverse flexural cracks on the beam underside in the positive moment regions. Their presence indicates a serious structural overload. Measure the crack widths and lengths and document their location. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.

- Examine the beam ends for evidence of cracked or spalled concrete, sometimes accompanied by corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing steel.

- Look for diagonal shear cracks on the beam sides near the abutments and piers.

- Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting beam movement.

- Examine the underside of each beam for parallel longitudinal cracks. These usually occur along the reinforcing and may occur due to corrosion or inadequate concrete cover. Rust stains that accompany the cracks suggest that the reinforcing is corroding and debonding.
• Check the beams, especially the fascias, for traffic impact damage. Severe impacts that expose several reinforcing bars or prestressing strands may justify replacement of the beam.

• Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

• Verify that any drains are open.

• Document delaminations, spalls, and exposed reinforcing steel.

• Measure and record the diameter of exposed reinforcing.

• Check for missing tie rods, bolts, or nuts.

**Subsection 4.3.5 Reinforced Concrete Arch Bridges**

Reinforced concrete arch bridges are constructed in either open-spandrel or closed-spandrel configurations.

Open-spandrel arch bridges use either cast-in-place arch ribs, or a single arch ring as the primary load-carrying members. The arches resist a combination of axial compression and bending moments. The deck and floor system are placed above the arches, and spandrel columns and caps (bents) deliver these loads to the arch. The space between the deck and arch, called the spandrel, is left open. Since the arch acts primarily as a compression member, longitudinal steel is uniformly distributed around its perimeter, contained by transverse ties. The spandrel bent columns are reinforced in a similar manner. Spandrel bent caps act as fixed end beams, so reinforcing steel is placed near the bottom, between the columns, and near the top, above the columns. Vertical stirrups placed along the cap serve as shear reinforcing. The deck and floor system loading the spandrel arches are designed and reinforced similar to other reinforced concrete beams. Arch components are shown in Figure 4:4-38.
Closed-spandrel arch bridges use a single, cast-in-place arch ring or barrel as the primary load-carrying member, with the arch resisting a combination of axial compression and bending moments. The spandrel area is enclosed by solid walls, usually built above the arch ring edges. Some spandrel walls are set outside of the arch ring and are tied to the arch ring with reinforcing bars. Over time, this reinforcing corrodes and the spandrel wall can be pushed out and away from the arch ring, accelerating deterioration and loss of fill. See Figure 4:4-40 below.
Closed spandrel arches are considered underfill structures when the level of soil or fill is higher than the level of the copings or headwall/spandrel walls. Underfill structures are discussed in Part 4, Chapter 9.

The deck/roadway is always placed above the arches, and the spandrel area may be filled or vaulted (open). In filled spandrels, the roadway pavement bears on fill material that occupies the spandrel area. This fill is contained by solid spandrel walls built above the barrel edges. Main reinforcing steel for solid spandrel walls retaining fill is placed at the back or fill side of the wall and cannot be inspected. The fill makes it impossible to inspect the top of the arch. In vaulted (open) spandrels, the structural deck and floor system transfers loads to the arch by way of transverse spandrel walls or spandrel bents. In this configuration, the spandrel walls are nonstructural. The spandrel bents, deck, and floor system are reinforced similar to open spandrel arches. Arch barrels are reinforced with longitudinal steel distributed around the perimeter, contained by transverse ties. The top side of the barrel cannot be inspected, unless access is provided in vaulted, closed-spandrel arch bridges. Most arches have construction joints three to four feet in from the copings. These areas are subjected to cracks, delamination, spalls, leaching, and leakage.
Inspection of reinforced concrete arch bridges should include the following:

- Inspect all concrete for cracks, noting the location, orientation, length, maximum width, and type of each. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.

- Examine the bearing areas for signs of concrete crushing, since the highest compressive forces experienced by an arch are found at the spring line. Crushing results in a loss of arch cross-sectional area, increasing the axial stresses.

- Look for longitudinal cracking along the arch axis. Longitudinal cracks indicate a possible structural overload or differential settlements.

- Check the entire arch and spandrel wall for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.

- Check the entire arch for transverse cracks. These are the result of excessive bending moments or arch support settlements.

- Look for leaching and rust stains along the entire arch and spandrel wall.

- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

- Check areas exposed to drainage and roadway runoff. The runoff may cause scaling, spalling, and concrete contamination.

- Check to make sure weep holes in closed-spandrel arch structures are functioning.
Check to make sure surface drains are functioning properly so that water does not penetrate the fill. This is especially important in closed-spandrel arch bridges.

Examine previous repair areas for soundness by hammer tapping.

Check the arch/spandrel column interface for transverse flexural cracks. These cracks may extend up several feet above the arch rib. They are an indication of excessive column bending due to overloads or differential arch deflection.

Check the spandrel bent cap/spandrel column interface for horizontal or diagonal flexural cracks. These cracks will originate at the inside corner of the cap/column junction and are another sign of excessive bending due to overloads or differential arch deflection.

Check the mid-height of the column for flexural cracks, as this is another sign of structural overloads or differential arch deflection.

Examine the entire column for longitudinal cracks and crushed concrete. This indicates a serious structural overload.

Check columns for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.

Check for traffic impact damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member.

Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

Subsection 4.3.6  Prestressed Concrete Arch Bridges

Prestressed concrete arch bridges are not common in Indiana. Arches carry axial compressive stresses, as well as bending, tension, and compressive stresses. Normally, the axial loads are great enough on an arch that there are no net tensile stresses due to bending. When bending stresses are large enough to produce net tension, post-tensioning is used to pre-compress the arch cross section. This keeps the entire cross section in compression, eliminating any net tensile stress.
Inspection of prestressed arch bridges should include the following:

- Inspect all concrete for cracks, noting the location, orientation, length, maximum width, and type of each.

- Look for transverse flexure cracks along the arch. Their presence indicates a serious structural overload, loss of prestressing/post-tensioning force, or arch support settlements.

- Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.

- Examine the bearing areas for signs of concrete crushing since the highest compressive forces experienced by an arch are found at the spring line. Crushing results in a loss of arch cross-sectional area, increasing the axial stresses.

- Look for longitudinal cracking along the arch axis. Longitudinal cracks indicate a structural overload.

- Check the entire arch for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.

- Look for leaching and rust stains along the entire arch. These defects can grow into larger problems such as delaminations and spalls.

- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
• Check for impact damage, including scrapes, chips, cracks, spalls, or missing concrete.

• Check areas exposed to drainage and roadway runoff. The runoff may cause scaling, spalling, and concrete contamination.

• Examine previous repair areas for soundness.

Subsection 4.3.7 Concrete Rigid Frame Bridges

Rigid frame bridges are structures in which the vertical or inclined supporting “legs” are cast monolithically with the girders or slab to form a rigid frame. These bridges are usually single-span structures constructed to form an inverted channel, usually of a slab design. Multiple span bridges may also be constructed by forming a rectangular shape, a “K” shape, or a triangular delta shape. Though the legs are used as bridge piers, the vertical or inclined legs are actually part of the superstructure because of their rigid connection to the horizontal slab or girders. This rigid intersection of the leg and horizontal member is referred to as the knee and allows both members to resist bending moments. Main reinforcing steel in the horizontal members is placed longitudinally near the bottom of the slab or girder between the abutments and legs. At the knees, it is placed longitudinally near the top on continuous bridges and around the outside or the corner on single-span bridges. Main reinforcing steel is placed vertically on both frame leg faces on continuous bridges and only on the traffic face of single-span bridges. Vertical stirrups placed along the horizontal member of beam frames serve as shear reinforcing, while transverse ties are placed along the legs. Spans of 50 to 200 feet are attainable using rigid frames. Figure 4:4-43 shows a concrete rigid frame bridge.

![Figure 4:4-43: Concrete Rigid Frame Bridge](image-url)
Inspection of rigid frame bridges should include the following items:

- Inspect all members for cracks, noting the location, orientation, length, maximum width, and type of each.

- Look for transverse flexural cracks in members carrying moments. Cracks over 1/8-inch wide in the flexural region may indicate a serious structural overload.

- Check for deteriorated concrete in the flexural zones that may be causing debonding of the reinforcing steel. This is especially critical near the ends of the reinforcing steel bars, since a certain length of the bar must be embedded within sound concrete to fully develop its strength. The deterioration causing the debonding may be delaminations, spalls, or longitudinal cracks.

- Check for shear cracks. Shear cracks will be diagonal, located near the end of a span, and inclined towards the center top. Shear cracks may also occur in the knee area angled down into the legs. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be supported by the reinforcing stirrups.

- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.

- Look for efflorescence, and note if it is stained with rust since this condition suggests reinforcing steel corrosion.

- Check the bearing areas for spalled concrete due to friction from thermal movement, or crushed concrete due to bearing pressure overloads.

- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

- Check members under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

- Check previously repaired areas for soundness by hammer tapping.

- Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.
Subsection 4.3.8  Precast Concrete Slab and Box Beam Bridges

In precast, concrete, voided slab bridges, each slab acts as a single, wide beam spanning from substructure unit to substructure unit. Precast slabs will generally have two or three elliptical or circular voids to reduce material weight, although solid slabs may be used for shorter spans. The precast slab may act as the superstructure and the deck. Precast voided slabs are manufactured in a plant and pre-tensioned. Each slab or plank is usually three or four feet wide, with depths ranging from about 15 to 26 inches. Slabs are placed tightly side-by-side and transversely clamped together so that the individual planks act as a unit under live loads. Grouted vertical shear keys also help the beams to act together. Precast voided slabs are used for spans up to 100 feet. The main steel prestressing strands are placed parallel to traffic and located near the bottom of the slab.

Prestressed box beam bridges are similar to precast voided slabs. However, precast box beams contain only a single void. In early applications, the top flange of the box beam acted as the deck. Asphalt overlays were also common. These were generally placed directly on the beams, but were sometimes placed over a membrane.

INDOT has not allowed asphalt overlays on box beam bridges on state routes since 1980, except for short-term repairs. Any box beam bridge with an asphalt overlay on a state route is considered as a temporary bridge and is coded as such in the National Bridge Inventory (NBI) database.

Sometimes a concrete deck is placed on top of box beams. These concrete decks often act compositely with the box beams.

Each beam is usually three or four feet wide, and 12 to 60 inches deep. The beams may be placed tightly side-by-side and transversely clamped together so that the individual beams act as a unit under live loads. Grouted shear keys also help the beams to act together. The beams may also be spaced two to six feet apart to form a bridge similar in appearance to a reinforced concrete girder bridge. In this configuration, a structural deck is constructed on top of the beams.
Precast box beam bridges are used for simple spans up to 130 feet in length. The main steel prestressing strands are placed parallel to traffic and located in the bottom flange of the box. Conventional reinforcing steel ties are placed transversely along the beam for shear reinforcement.

Inspection of precast slab and box beam bridges should include the following:

- Sight down the length of the slabs or box beams to check for sagging. Sagging is a sign that the beam is losing its prestressing force and may be unable to carry the loads for which it was designed.

- Check for differential deflection between slabs or beams placed next to each other. This is a sign that the slabs or boxes are not acting as a unit and may be unable to carry the design loads. It may also indicate failed shear keys. Once these keys have failed, live loads cannot be shared between adjacent beams.

- Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each.

- Examine the beam underside for parallel longitudinal cracks. These usually occur along the prestressing strands and may occur due to inadequate concrete cover. Rust stains that accompany the cracks suggest that the prestressing strands are corroding and debonding. Document any exposed strands.
• Document any prestressing strand corrosion. Visual evidence of prestressing strand corrosion includes rust staining, delaminations, and spalls exposing corroded reinforcement. NDT allows detection before visual signs are present. Refer to Part 6 for a discussion of relevant NDT techniques.

• Look for longitudinal cracks at the interface of the web and top flange of a box beam that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.

• Look for transverse flexural cracks on the slab or box beam underside in the positive moment regions. Their presence indicates a serious structural overload or loss of prestressing/post-tensioning force. Measure and document the crack widths and lengths and document their location.

• Look for diagonal shear cracks on the beam sides near the abutments and piers.

• Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting beam movement.

• Document box beam top flange transverse flexural cracks and any leaching and rust staining that may accompany them. This will usually be performed during a Special Inspection, as the underside of a box beam’s top flange can only be seen from inside the cell.

![Figure 4:4-45: Longitudinal Cracking in Precast Box Beam](image)

• Evaluate barrier and utility connections. These connections can act as entry points for water and chlorides, thereby creating a corrosive environment deep inside the beam.
- Check for any super elevation irregularities on curved box beam bridges. This is a sign that torsional distress has occurred.

- Examine the slab or beam ends for evidence of cracked or spalled concrete, sometimes accompanied by corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing or prestressing steel. It may also be the result of a lack of non-prestressed reinforcement in the zone of prestressing force transfer.

- Check the slabs and beams, especially the fascias, for traffic impact damage. Severe impacts that expose several prestressing strands may justify replacement of the beam.

- Check for leakage and efflorescence between the longitudinal joints of slabs or box beams placed next to each other. This condition, along with reflective longitudinal cracking on the deck surface, suggests that the grouted shear keys between the members have failed. Leakage may indicate an increased likelihood of prestressing strand corrosion.

- Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

- Verify that the drain holes are present and open. Recommend clearing clogged drain holes. Trapped water may cause strand corrosion and longitudinal cracking as the water freezes and thaws.

- Look for delaminations, spalls, and exposed reinforcing steel. Identify areas of delaminated concrete by sounding.

- On slabs or box beams with no additional wearing surface, document the condition of the concrete on the top of the slab or box as part of the superstructure.

- Verify that tie rods are present and functioning properly.
Subsection 4.3.9  Prestressed Concrete Beam Bridges

Prestressed I-beams, T-beams, modified T-beams, and U-beams are commonly used as precast members. They use material efficiently by concentrating the concrete away from the beam's neutral axis where it is needed most for stiffness and strength. Concrete decks are often designed to act compositely with the beams, using shear connectors in the top flanges of the beams. They are used for simple spans up to about 150 feet in length. They may also be made continuous over piers. This is done by placing conventional reinforcing steel longitudinally in the deck over the piers to resist negative bending. The main steel prestressing strands are placed parallel to traffic and are located in the bottom flange of the beam, though some strands can be inclined upwards toward the beam ends. These are called draped or harped strands. Conventional reinforcing steel ties are placed transversely along the beam for shear reinforcement. Prestressed beam bridges generally include concrete diaphragms at the abutments and piers and either steel or concrete diaphragms within the spans.
Figure 4:4-47: Prestressed Beams and Concrete Diaphragms

Figure 4:4-48: Shear Cracks on Precast Concrete Girders
Inspection of prestressed concrete beam bridges should include the following:

- Sight down the length of the beams to check for sagging. Sagging is a sign that the beam is losing its prestressing force and may be unable to carry the loads for which it was designed.

- Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.

- Look for transverse flexural cracks on the beam underside in the positive moment regions. Their presence indicates a serious structural overload or loss of prestressing/post-tensioning force. Measure the crack widths and lengths and document their location.

- Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.

- Examine the beam underside for parallel longitudinal cracks. These usually occur along the prestressing strands and may occur due to inadequate concrete cover. Rust stains that accompany the cracks suggest that the prestressing strands are corroding and debonding.

- Examine the beam ends for evidence of cracked or spalled concrete, sometimes accompanied with corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing or prestressing steel. It may also be the result of a lack of non-prestressed reinforcement in the zone of prestressing force transfer.

- Look for diagonal shear cracks on the beam sides near the abutments and piers.

- Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting girder movement.

- Check the beams, especially the fascias, for traffic impact damage. Severe impacts that expose several prestressing strands may justify replacement of the beam.

- Look for delaminations, spalls, and exposed reinforcing steel.

**Subsection 4.3.10 Concrete Box Girder Bridges**

Box girder bridges are used for very long structures and curved spans. The sections are very large, and a single box can be used to carry an entire roadway. The inside of each box is usually large enough for an inspector to enter.

Traditional box girders are cast-in-place and may be conventionally reinforced or post-tensioned. Cast-in-place box girders will often contain several internal vertical webs and are referred to as multi-cell box girders.
The main reinforcement of post-tensioned box girders is a combination of conventional steel reinforcement and post-tensioning tendons. The post-tensioning tendons may be placed in the bottom flange, in the web walls, in both the bottom flange and the web walls, or not in the concrete at all. The post-tensioning tendons are normally placed within galvanized steel ducts that are filled with grout after stressing. Conventional reinforcing steel ties are placed transversely along the beam for shear and torsion reinforcement. In newer design, the deck is also post-tensioned, especially if there are wide cantilevers of the deck past the girder web walls.

Figure 4:4-49: Concrete Box Girder Under Construction

Segmental box girder bridges are similar to traditional box girders. However, the segments of segmental box girders are manufactured at a precast plant or on-site and erected individually. They commonly have a trapezoidal shape, with the top flange cantilevering over inclined webs. They normally contain only one cell and all are post-tensioned.

Figure 4:4-50: Crack in Box Girder Top Flange
Inspection of reinforced concrete box girders should include the following:

- Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each. Document the location, length, and width of all cracks on sketches or prepared templates.

- All cracks should be checked to see if they are full-depth. Ultrasonic V-meter testing can be used to check for full-depth cracking, or the location of cracks inside and outside the box can be compared from the sketches or templates.

- Mark crack locations with the date the crack was found on the concrete.

- Look for transverse flexural cracks on the underside of the beam between supports and on top of the deck over the piers on continuously supported bridges. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.

- Check for deteriorated concrete in the flexural zones that may be causing debonding of the reinforcing steel. This is especially critical near the ends of reinforcing steel bars, since a certain length of the bar must be embedded within sound concrete to fully develop its strength.

- Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be hanging from the reinforcing stirrups.

- Check interior concrete diaphragms over pier bearings. Cracks here often extend full-depth through the web walls and floor.

- Look for vertical cracks on the girder sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting girder movement.

- Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.

- Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. Investigate the bearing areas for spalled concrete due to friction from thermal movement or crushed concrete due to bearing pressure overloads.

- Check members under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

- Verify that any drain holes are open.

- Look for delaminations, spalls, and exposed reinforcing steel.
• Check previously repaired areas for soundness by hammer tapping.

• Document any box girder top flange transverse flexural cracks and any leaching and rust staining that may accompany them. This will usually be performed during an in-depth inspection, as the underside of a box girder’s top flange can only be seen from inside the cells.

• Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose the reinforcing.

![Figure 4:4-51: Diagonal Crack in Box Girder](image)

The inspection of post-tensioned box girders should include all of the above items, as well as the following:

• Check for transverse flexural cracks on the girder underside in the positive moment regions. Post-tensioned members are in axial compression, so any transverse flexural crack indicates a structural overload or loss of post-tensioning force. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on the girder.

• Sight down the length of the girders to check for sagging. Sagging is a sign that the beam is losing its post-tensioning force and may be unable to carry the loads for which it was designed.

• A detailed survey along the gutter lines and centerline should be conducted periodically as a part of a Special Inspection to compare measurements with as-built and previously measured elevations to assess sagging.

• Check for any super elevation irregularities on curved box girder bridges. This is a sign that torsional distress has occurred.
Examine the girder underside for parallel longitudinal cracks. These may indicate reinforcing corrosion.

Inspect the concrete at the anchorage zone for localized cracking. This may indicate inadequate detailing to resist the stressing forces.

Inspection of tension rods or post-tensioning cables should include the following:

- Look at the tensioning steel anchorages for lack of bearing or slip of the cable through the wedge. Sudden losses of force may allow the rod/cable to snap and shoot out of the anchorage.
- Pull/shake rod ends to check for looseness. Looseness indicates a complete loss of prestressing force.
- Lightly tap the tensioned length of the rod/cable (if accessible) with a rubber mallet. Similar to the strings of a guitar, tensioned members should ring, while detensioned members will produce a dull thud. As an alternative, the rods/cables may be shaken. Tensioned members should be taught. While performing these procedures, stand out of the way of the rod/cable in case it suddenly fails.
- Check any grouted anchors for soundness of the grout.
- Look for corrosion and document its extent.
- Look for broken rods/cables.
- Check section loss on the threads at the ends of a rod.
- Inspect the anchorage nuts for cracks or other damage.

![Image: Post-Tensioning Rods Protruding from the Anchorage, Indicating a Loss of Tensioning Force]

Figure 4:4-52: Post-Tensioning Rods Protruding from the Anchorage, Indicating a Loss of Tensioning Force
Figure 4:4-53: Protruding Post-Tensioning Rod
SECTION 4.4  TIMBER SUPERSTRUCTURES

Timber was probably the earliest material ever used to construct a bridge. Modern timber can be configured into many superstructure types, including slab bridges, multi-beam bridges, arch bridges, and trusses.

Subsection 4.4.1  Timber Slab Bridges

Timber slab bridges are constructed using either glued laminated or nail-laminated sawn lumber placed longitudinally between supports. The slab acts as a single wide beam spanning from substructure unit to substructure unit. There are no individual beams with this type of bridge, so the slab acts as the deck and the superstructure. Slabs are used for simple spans of about 35 feet or less and for continuous spans of slightly greater lengths. Common glued laminated slab depths range from 6-3/4 inches to 14-1/4 inches thick, using individual strips of dimensional lumber 3/4 to two inches thick to form 42-inch to 54-inch wide panels. Nail-laminated slab depths range from eight inches to 16 inches deep, using two-inch to four-inch dimensional lumber. Timber slabs may have transverse distributor beams attached to their undersides as a method to distribute live loads across the bridge width. Steel transverse post-tensioning rods may also be used for this purpose, as well as to keep the planks in alignment on glued laminated slabs.

Inspection of timber slab superstructures should include the following:

- Examine the slab’s top surface for signs of wear and abrasion, splitting, crushing, and decay.
- Examine all timber for accumulated moisture, staining, and vegetation.
- Examine all timber for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fungi or plant life and depressed areas of the wood surface. Probe suspect areas. Drill or bore suspect planks to estimate the extent of decay.
- Examine all timber for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects, and a hollow sound when the beam is tapped with a hammer.
- Check the underside of the slab at the bearing areas. Crushing of the wood is usually the result of decay, but overloads may cause crushing of sound wood.
- Check the underside of the slab in tension areas for excessive deflections, fractures, and transverse cracks. These indicate excessive flexural stresses and overloads.
- Hammer tap random and suspect areas to evaluate the wood’s soundness. A dull sound indicates deterioration.
- Probe test areas suspected to be experiencing decay. Lift a small sliver of wood from the surface using an awl, ice pick, or pocketknife. Wood that lifts up and splinters is sound, while wood that breaks up upon lifting the tool is decaying.
• Drill or bore suspect planks to estimate the extent of decay. Holes should be plugged with treated dowels after the inspection to prevent water and parasites from entering the timber’s interior.

• Look for collision damage, including scrapes, cracks, or crushed areas.

• Look for fire damage, especially near the piers or abutments where fires can be built close to the beams. Fire damaged members that exhibit large strain deformations should be reported immediately to the District Engineer or the Inspection Consultant.

• Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check suspect fasteners for looseness by striking with a hammer. The location of any missing fasteners should be noted.

• Sight along the length of the beam under traffic loads to look for excessive vertical or lateral deflections. Excessive deflections may indicate that the member cannot carry its original design load, or that other bridge members are damaged and additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.

• Listen for unusual sounds with the passage of live loads.

• Examine any overlay for signs of wear, abrasion, cracks, potholes, and impending potholes.

Subsection 4.4.2 Timber Multi-Beam Bridges

Timber, solid, sawn multi-beam bridges are constructed using three or more beams as the primary members. Span lengths are limited by the longest available length of solid lumber, so they are usually used for bridge spans from 15 to 30 feet. Typical beam dimensions are four to eight inches wide and 12 to 18 inches deep. Solid wood blocking or bridging is normally placed between the beams to keep the beam in proper alignment. Due to the limited availability of large timbers of this size and the ready availability of high-quality glued laminated beams, solid, sawn multi-beam bridges are rarely built today.

Figure 4:4-54: Two-Span Timber Bridge
Timber glued laminated multi-beam bridges are similar to sawn multi-beam bridges, except that the beams are pre-manufactured members. The beams are made by bonding several strips of wood together with a waterproof structural adhesive to form a built-up beam. By using 3/4-inch to two-inch thick strips of wood for the laminations, natural wood defects may be placed in a non-critical location or may be eliminated completely from the final product. The result is a fairly uniform beam with strength properties greater than solid wood of similar dimensions. Standard three-inch to 14-1/4-inch wide beams are common, and depths are limited only by transportation and pressure treating considerations. Clear spans up to 150 feet have been attained, though spans less than 80 feet are more common.

Inspection of timber beam bridges should include the following:

- Notify the District Engineer or the Inspection Consultant of any transverse crack or notable deflection on any timber beam.

- Check for member crushing at the abutments and piers. These are the most suspect areas because they tend to collect and retain the most moisture and debris, creating ideal environments for plant and fungal growth and insect attack. Overloads can cause crushing of sound wood. Notify the District Engineer or the Inspection Consultant of excessive crushing.

- Look for shear-related damage at and near the supports. Overloads result in high-shear stresses that cause horizontal splits to form along the length of the beam, approximately mid-height.

- Examine the high-flexural regions of the beam for signs of overload damage such as crushing of surfaces in compression and transverse cracking of surfaces in tension.

- Examine all timber for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fungi or plant life and depressed areas of the wood surface. Probe suspect areas. Drill or bore suspect members to estimate the extent of decay.
Look for any delaminations of individual wood strips in glued laminated beams. Because debonding that extends through the beam width changes the original deep, stiff member into two smaller flexible members, this type of deterioration can be especially serious.

Examine all members for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the beam is tapped with a hammer.

Look for fire damage, especially near the abutments where fires can be built close to the beams. Document any section loss.

Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check suspect fasteners for looseness by striking with a hammer. The location of any missing fasteners should be noted.

Sight along the length of the beam under traffic loads to look for excessive vertical or lateral deflections. Excessive deflections may indicate that a member cannot carry its original design load or that additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.

Listen for unusual sounds with the passage of live loads.

Examine any overlay for signs of wear, abrasion, cracks, potholes, and impending potholes.

Look for collision damage, including scrapes, cracks, or crushed areas.

Subsection 4.4.3 Timber Trusses, Covered Bridges, and Arches

Timber truss bridges are structures with two parallel trusses as the main load-carrying members. Covered bridges are truss bridges with a wood covering to prevent decay of the superstructure. Spans up to 250 feet are attainable. The deck is typically placed between the trusses. These are called through trusses when there is overhead lateral bracing, or pony trusses when there is no overhead lateral bracing. The deck may also be placed on top of the trusses. These are called deck trusses. Modern connections are made with steel bolts and gusset plates. Older trusses generally used bolts or wooden peg connections. To keep the two trusses in line longitudinally, secondary lateral bracing members diagonally connect the bottom chords. For deck and through trusses, the top chords are braced diagonally as well. Lateral bracing may be made of wood, wrought iron, or steel. Sway bracing keeps the two trusses in line laterally. On deck and through trusses, sway bracing transversely frames between the truss verticals. On pony trusses, sway bracing is usually placed as a transverse diagonal on the outsides of the trusses. It connects the top chord to transverse “outrigger” floor beam extensions and functions to prevent buckling of the top chord. Sway bracing is normally made out of wood. Truss members are theoretically loaded in either pure tension or pure compression. Truss diagonals and verticals may be timber or a combination of timber for compression members, and steel or wrought iron rods for tension members.
Loads are delivered to the trusses by way of floor beams spanning transversely between these main load-carrying members. Figure 4:4-57 provides several elevation views of typical timber covered bridges.

Modern timber arch bridges are constructed of curved glued laminated main members. Wood arches use two hinges for spans up to approximately 80 feet and three hinges for spans up to approximately 300 feet. Wood arches are most commonly used as pedestrian bridges, although they have been built for highway use. Most older timber arches were constructed with a series of individual truss-like arched segments.

Arch bridges can be deck arch, though arch, or tied arch structures and are loaded in combined compression and bending. Loads are delivered to the arches by way of floor beams spanning transversely between these main load-carrying members. Many old timber covered bridges in Indiana are composed of both a truss and an arch that work together in carrying dead load and live load.

![Figure 4:4-56: Timber Covered Bridge](image)
Figure 4:4-57: Common Timber Covered Bridge Elevations
Most covered bridges contain numerous members oversized for the original design load. Ease of fabrication and construction was a primary concern for these bridges and efficiency in member sizing was often not a consideration. These bridges were often designed for the controlling diagonal member and, thus, all subsequent diagonal members were made the same size. This practice was followed for all the members. This means only one or two of each member type are controlled by design loads, and the remaining members are progressively oversized. This provided uniform connection types and dimensions throughout the structure. A schematic illustrating the typical locations for the maximum forces in a Burr arch truss are provided in Figure 4:4-58.

Figure 4:4-58: Typical Burr Arch Truss

The Town lattice truss provides a unique design feature. Due to the redundancy in the members, each main truss member can globally be considered as one large timber beam. The top and bottom chords can be considered flanges of a simple beam, and the diagonals can be considered the web. Figure 4:4-59 demonstrates this concept. The extensive redundancy in this design permits the truss to function well after several members show signs of deterioration or damage.

Figure 4:4-59: Town Lattice Truss
Historically, the majority of timber truss failures were due to failure of a connection, not the member. Failure of a connection may prove detrimental to the entire bridge if adequate redundancy is not present. Movement over time, deterioration, large loadings, and poor details all are factors that lead to connection problems. The notching of vertical members to accommodate the connection to the diagonal is a common example of a poor detail that can contribute to a failure. This notching minimizes the section of the vertical member in an area where large compression and tension forces place this detail in a high shear zone. Figure 4:4-60 and Figure 4:4-61 illustrate this type of failure.

![Figure 4:4-60: High-Shear Timber Connection](image)

Another typical area for connection weakness is the bottom portion of the vertical member at the floor beam or lower chord. This area is subject to high shear forces and may be exposed to high water and debris damage, as well as the elements. Often the members are notched to allow for the connection, further weakening the member. Weakening of this connection may lead to the failure of the floor beam or lower chord at the connection. Figure 4:4-62 illustrates a heavily damaged vertical member/floor beam connection.

![Figure 4:4-61: Shear Failure at Connection](image)
Most covered bridges require splices of the lower chord, upper chord, and arch. These areas are subject to high stresses and often have a smaller cross-sectional area due to the notching required to form the splice. Splices can either occur in a member, or within the connection and should be reported accordingly. The splices will often indicate signs of overstressing or signs of deterioration from any movement or separation of the members. Timber splitting adjacent to the splice may be present and should be monitored for deterioration.

Bearing areas often show signs of deterioration. Numerous timber trusses utilized bearing beams. The original designers often used these beams as a sacrificial detail that would be exposed to dirt and debris, while keeping the main structural members free from deterioration. The designer anticipated these members would be replaced when they deteriorated. In practice, many of these members were left in place. This deterioration could prove detrimental to the main structural members. Figure 4:4-64 illustrates typical sacrificial bearing members.
Secondary members such as cross bracing, sway bracing, and the roof members also play a role in the overall integrity of the bridge and should not be overlooked in an inspection. These members provide lateral stiffness in the bridge and help prevent movement of members and joints. Secondary members help resist loads such as snow and wind loads that are negligible in most bridges, but can serve as potentially fatal loading conditions in covered bridges. The large surface area exposed to wind promotes large horizontal loads that can contribute to the failure of a covered bridge.

The roof may collect heavy snow that can lead to large additional gravity loads on the bridge. The additional snow load, in conjunction with a large live load, can overstress the connections or members of a covered bridge.

Inspection of timber trusses, covered bridges, and arches should include the following:

- Thoroughly inspect all connections and document any deficiencies or movement in each member.
- Check the truss bottom chord members for crushing at the abutments. These are the most suspect areas because they tend to collect and retain the most moisture and debris, creating ideal environments for plant or fungal growth and insect attack. Overloads can cause crushing of sound wood. Notify the District Engineer or the Inspection Consultant of excessive crushing.
- Look for any delaminations of individual wood strips in glued laminated members. Debonding occurring in the vicinity of connectors can be serious if the member is carrying tensile loads.
- Examine the entire member for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects, and a hollow sound when the member is tapped with a hammer.
- Look for fire damage, especially near the abutments and arch bearings where fires can be built close to the primary load-carrying members. Document any section loss.
• Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check for loose fasteners by striking with a hammer. The location of any missing fasteners should be noted.

• Sight along the length of a truss or arch under traffic loads to look for excessive vertical or lateral deflections and out-of-plumb members. Excessive deflections indicate that the member may not be able to carry its original design load, or that other bridge members are damaged and additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.

• Examine each member for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for brooming and depressed areas of the wood surface. Probe areas suspected to be experiencing decay. Drill or bore suspect planks to estimate the extent of decay.

• Look for collision damage including scrapes, cracks, or crushed areas.

• Check the arch/spandrel column interface for bearing failures. Bearing failures on timber members loaded parallel to the grain will “broom out.”

• Check the mid-height of the spandrel columns for flexural cracks, which is a sign of structural overloads or differential arch deflection.

• Look for any splitting of sawn timber members. Excessively long or wide splits may be a sign of a structural overload.

• Sight all columns to check for bowing. Excessive deflections indicate that the member has been overstressed or that the bridge is experiencing differential settlements. The measured or estimated amount of deflection should be recorded.

• Note any protective systems such as preservatives or retardants.
Figure 4:4-65: Lateral Displacement of Members

Figure 4:4-66: Movement at Connection
Subsection 4.4.4  Rods and Cables Used in Timber Superstructures

Rods and cables are used as truss members, to post-tension timber structures, or to support timber members. These members may be considered to be fracture critical if a failure would result in a collapse or partial collapse of the bridge. The inspection of any rods and cables should include the following:

- Check for corrosion and document its extent. Severe corrosion will produce section loss and an increase in tensile stresses.
- Look for broken rods/cables.
- Pull/shake rod ends to check for looseness. Looseness indicates a complete loss of post-tensioning force.
- Lightly tap the tensioned length of the rod/cable (if accessible) with a rubber mallet. Similar to the strings of a guitar, tensioned rods and cables should ring, while detensioned members will produce a dull thud. As an alternative, the rods/cables may be shaken. Tensioned members should be taught. While performing these procedures, stand out of the way of the rod/cable in case it suddenly fails.
- Inspect the anchorage nuts for cracks or other damage.
- Inspect anchorage and bearing areas for signs of crushed wood.
Figure 4:4-68: Anchor Bolts for Steel Vertical Tie Rod

Figure 4:4-69: Steel Vertical Tie Rods on Timber Covered Bridge

Figure 4:4-70: Upper Connection for Steel Vertical Tie Rods on Timber Covered Bridge
Subsection 4.4.5  Special Inspections for Timber Covered Bridges

Indiana requires a Special Inspection for each timber covered bridge. These bridges are not load-path redundant. They generally have low load-carrying capacities, and a more detailed inspection supports the preservation efforts of these historical bridges. The Special Inspection report will help identify problems and assist the owner in maintaining and preserving the bridge.

All main load-carrying members and connections/panel points are inspected and documented as a part of the Special Inspection. Floor beam connections are also inspected and documented as a part of this inspection. There are many connection details and connection types and it is up to the Inspection Team Leader to determine and distinguish between the member and the connection. Typically, the connection is defined as being 12 inches outside of the connection bolt, connection plate, or change in cross-sectional area for the connection, and the remaining portions are defined as the actual member. Figure 4:4-72 provides guidance on several common typical connection details.

Secondary members such as lateral bracing, roof members, stringers, and floor beams should be thoroughly inspected during the Routine Inspection and are not considered part of a Special Inspection. It is recommended, but not required, that a brief discussion of secondary members and associated repairs and conditions be provided in the Special Inspection report.

Figure 4:4-71: Covered Bridge in Carroll County, Indiana
The guidelines listed in this section are the minimum reporting requirements for acceptance of a Special Inspection. Although, these minimum requirements must be met for acceptance of the report by INDOT, the inspecting agency may provide alternate report formats meeting internal guidelines as long as the criteria set forth in this chapter are met. An example inspection report has been provided in Appendix C.

A Special Inspection report must include the following as a minimum:

- An inspection Plan of Action should include the following:
  - Sketches of the superstructure with locations of main members and connections clearly identified, along with an elevation view for trusses with locations labeled by letters and numbers similar to the nomenclature indicated in Part 4, Chapter 11
  - A north arrow on the sketch
  - A list of all members and connections to be inspected
  - A brief historical fact statement
  - All inspection tools and access equipment required for the inspection
  - Traffic control requirements
  - Bridge cleaning requirements
Other items that should be reviewed and made available to the inspector, if available, prior to the inspection, including the following:

- Existing bridge plans and any repair/rehabilitation plans
- Prior load ratings
- Historical data and maintenance history of the bridge
- Prior inspection reports

- A general statement discussing inspection procedures
- Date, temperature, and weather conditions of the inspection
- Time duration of the inspection
- Inspection Team Leaders and Inspection Team Members present at the inspection
- A summary of inspection results for all members and connections that show deterioration, deficiencies, or required monitoring
- Documentation of inspection results for each individual member, panel point, connection, and/or component, including the following:
  - Individual member rating
  - Noted deficiencies
  - A brief statement discussing the presence or lack of distress
- Testing performed and locations of the tests
- Recommendations for repairs and maintenance, highlighting urgent repairs and listing programmed repairs and maintenance
- Photographs of the bridge, including an approach and elevation photograph, and any posting signs
- Photographs of members or components assigned a condition rating of 4 (Poor) or less
- Photographs of problem areas warranting repair and/or monitoring
- Recommended inspection interval
The only masonry bridge superstructure form is the arch. Masonry arches have been used for building and bridge construction since ancient times. Current use of some of these structures is a testament to their durability. See Figure 4:4-73 for a picture of a masonry arch, and Figure 4:4-74 for masonry arch components.

Stone masonry arches receive both compressive and bending moments. Since an arch carries a high degree of compressive load, there should be little, if any, net tension along its cross section. Because of this, there should be no cracking at any of the masonry mortar joints due to bending moments.

Masonry arches are closed spandrel structures that have a single, solid barrel forming the primary load-carrying member. Fill material is placed on top of the arch to support the roadway, and spandrel walls are used to retain this fill. Spandrel wall failure would cause the fill to spill out, resulting in roadway settlement.
Inspection of masonry arches should include the following:

- Examine the bearing/spring line areas for signs of crushed masonry, since the highest compressive forces experienced by an arch are found at the spring line. Missing or crushed masonry units result in a loss of arch cross-sectional area, increasing the axial stresses.

- Look for crushed or missing masonry units and mortar. This would suggest a possible overload. Missing or crushed mortar results in a loss of arch cross-sectional area, increasing the axial stresses, and allows masonry units to move relative to one another.

- Check the arch and spandrel wall surfaces for bulges. This defect suggests unstable soil, and the roadway above will also likely show signs of settlement. A bulge or flatness in the arch indicates that it is not functioning properly. Significant areas of bulging should be reported immediately to the District Engineer or Inspection Consultant.

- Look for cracked, broken, or deteriorated masonry units and mortar. This would suggest weathering due to freeze/thaw effects.

- Check the entire arch for transverse mortar cracks. These are the result of excessive bending moments or arch support settlements.

- Check for longitudinal cracks in the abutments. These indicate differential settlement. Contact the District Engineer or Inspection Consultant if cracks over 1/8 inch wide are found.

- Look for flattening of the arch.
• Check for cracks in the spandrel walls near the quarter points. These indicate flexibility of the arch barrel over the center half of the span.

• Look for leaching along the entire arch and the spandrel walls. This indicates water is flowing through the mortar joints and leaching minerals. Long-term leaching will weaken the mortar.

• Check areas exposed to drainage and roadway runoff. The runoff may cause scaling.

• Check to make sure weep holes in the arch are functioning.

• Check to make sure surface drains are functioning properly and are not allowing water to penetrate the fill.

• Check for loss of fill material. Potholes in the roadway indicate loss of fill.

• Look for collision damage, including scrapes, cracks, or crushed areas.

• Examine previous repair areas for soundness.

Figure 4:4-75: Closed-Spandrel Masonry Arch
SECTION 4.6   NBI SUPERSTRUCTURE RATING

The NBI numeric condition rating describes the existing superstructure components as compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition, and 0 describing failed components that cannot, or should not, be repaired.

Because only a single number is used to rate the superstructure, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, such as isolated heavy corrosion, or a bent flange due to a traffic impact. However, widespread heavy corrosion or widespread cracked welds would certainly influence the rating. A proper rating will consider deterioration severity, plus the extent to which it is distributed throughout the superstructure.

NBI ratings are used to evaluate the state of deterioration of the superstructure material. Postings or original design capacities less than current legal loads will not influence the rating. Similarly, temporary superstructure support does not change or improve the condition of the superstructure material and will not influence the superstructure rating.

Decks that are built integral with the superstructure, such as steel or concrete box girders and decks of reinforced concrete girder bridges, are rated as separate components from the superstructure, but the superstructure rating may be affected by the deck condition. The resultant superstructure condition rating may be lower than the deck condition rating where the girders have deteriorated or been damaged.

On slab bridges, the deck is the same structural component as the superstructure, and the NBI condition ratings for the deck and superstructure must be the same.

Indiana has developed supplemental rating guidelines to assist the inspector in properly assigning condition ratings to specific components constructed of the most commonly used materials. The general condition ratings, along with the Indiana supplemental rating guidelines for superstructures, are as follows:

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE:</td>
</tr>
<tr>
<td></td>
<td>Supplemental Rating Guidelines: Used for underfill structures only.</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION:</td>
</tr>
<tr>
<td></td>
<td>Supplemental Rating Guidelines: Superstructures are properly constructed and in new condition.</td>
</tr>
</tbody>
</table>
8 VERY GOOD CONDITION: No problems noted.

Supplemental Rating Guidelines:

Concrete Superstructure – There are no noteworthy deficiencies which affect the structural capacity of the members.

Prestressed Concrete Superstructure – There are no cracks, stains, or spalls.

Steel Superstructure – There are no noticeable or noteworthy deficiencies which affect the condition of the superstructure.

Timber Superstructure – There are no noteworthy deficiencies which affect the structural capacity of the members.

7 GOOD CONDITION: Some minor problems exist.

Supplemental Rating Guidelines:

Concrete Superstructure – Some minor problems are present. Nonstructural hairline cracks without disintegration may be evident. The load-carrying capacity of structural members is unaffected.

Prestressed Concrete Superstructure – Nonstructural hairline cracks less than 0.015-inch may be present. No rust stains are present.

Steel Superstructure – Some rust may be evident without any section loss.

Timber Superstructure – Minor decay, cracking, or splitting of beams or stringers at noncritical locations may be present.

6 SATISFACTORY CONDITION: Structural elements show some minor deterioration.

Supplemental Rating Guidelines:

Concrete Superstructure – Structural members show some minor deterioration or collision damage. Hairline structural cracks or spalls may be present with evidence of efflorescence. Minor water saturation marks may be present. Generally, the reinforcing steel is unaffected.

Prestressed Concrete Superstructure – Minor concrete damage or deterioration is less than five percent. Few shrinkage cracks are present, and those that exist are tight and narrow. No shear cracks are present. Nonstructural cracks are over 0.015-inch. Isolated and minor exposure of mild steel reinforcement may be present. No prestressing strands are exposed.
Steel Superstructure – Rusting is evident, but with minor section loss of less than two percent of thickness in critical areas.

Timber Superstructure – Some decay may be present, along with cracking or splitting of beams or stringers. Fire damage is limited to surface scorching with no measurable section loss.

5 FAIR CONDITION: All primary structural elements are sound, but may have minor section loss, cracking, spalling, or scour.

Supplemental Rating Guidelines:

Concrete Superstructure – Structural members are generally sound, but may have evidence of deterioration or disintegration. Numerous hairline structural cracks or spalls may be present, with minor section loss of reinforcing steel possible.

Prestressed Concrete Superstructure – Up to five percent of prestressing strands are exposed. Less than 15 percent of any area is spalled or delaminated. Multiple shrinkage cracks are present. No shear cracks or transverse cracks are present. Hairline longitudinal cracks may be present across the bottom flange. There is leakage at the joints with light efflorescence, but no staining.

Steel Superstructure – There is section loss, but less than five percent of the thickness in critical areas of primary members. Fatigue or out-of-plane distortion cracks may be present in noncritical areas. Hinges may be showing minor corrosion problems.

Timber Superstructure – Moderate decay, cracking, splitting, or minor crushing of beams or stringers may be present. Fire damage is limited to surface charring with section loss of less than five percent of the member section.

4 POOR CONDITION: Advanced section loss, deterioration, spalling, or scour may be present.

Supplemental Rating Guidelines:

Concrete Superstructure – There is extensive deterioration. There are measurable structural cracks or large spall areas. Corroded reinforcing steel is evident with measurable section loss. Structural capacity of some members is diminished.
Prestressed Concrete Superstructure – Five to 15 percent of prestressing strands are exposed. Fifteen to 25 percent of the area is spalled or delaminated. Multiple shrinkage cracks are present, including enlarging with possible minor spalls. Tight shear cracks may be present. Hairline transverse flexural cracks across the bottom flange may also be present. Longitudinal cracks with minor efflorescence or minor rust stains may be present along the bottom flange. Transverse tendons may be loose or heavily rusted. There may be leakage at the joints with heavy efflorescence or minor rust stains. Vertical or diagonal web cracks are less than three-inches long near the open joints in the barrier.

Steel Superstructure – There is significant section loss between five percent and 25 percent, of the member section in critical areas of primary members. Fatigue or out-of-plane distortion cracks may be present in critical areas. Hinges may be frozen from corrosion. Load-carrying capacity of structural members may be affected. There may be local buckling in compression members or connections. Tension flanges or members may show elongation.

Timber Superstructure – Extensive decay, cracking, splitting, crushing of beams or stringers, or significant fire damage may be present. A diminished load-carrying capacity of members is evident. Member section loss is between five percent and 25 percent.

3 SERIOUS CONDITION: Loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in the steel or shear cracks in the concrete may be present.

Supplemental Rating Guidelines:

All Superstructures – Bearing movement or deterioration threatens the stability of the superstructure.

Concrete Superstructure – There is severe deterioration and/or disintegration of primary concrete members. Large structural cracks may be evident. Reinforcing steel is exposed with advanced corrosion and significant section loss. Local failures or loss of bond are possible.
Prestressed Concrete Superstructure – Any sagging or loss of camber may be present. Severed, heavily corroded, or deformed prestressing strands, with over 15 percent of prestressing strands exposed, may be present. Over 25 percent of the area may be spalled or delaminated. Multiple shrinkage cracks are present and are wide with spalls. Some moderate-width shear cracks are present. Open transverse flexural cracks in the bottom flange may be present. Longitudinal cracks with minor efflorescence or minor rust stains may be present across the bottom flange. Vertical or diagonal web cracks greater than three-inches long may be present.

Steel Superstructure – Severe member section loss of over 25 percent, or cracking in critical areas of primary members, may be present. Minor failures may have occurred. Significant weakening of the primary members is evident. There may be global buckling of a primary member or connection. A primary member has a crack of two inches or longer. There are cracks in a gusset plate or welds that have, or may have, propagated into primary members. There are cracks in a hanger assembly member. The connection between railroad flat cars has failed.

Timber Superstructure – Severe decay, cracking, splitting, crushing of beams or stringers, or major fire damage may be present. Member section loss is over 25 percent. Load-carrying capacity is substantially reduced. Local failure may be evident.

2 CRITICAL CONDITION: Advanced deterioration of primary structural elements may be present. Fatigue cracks in steel or shear cracks in concrete may be present, or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

Supplemental Rating Guidelines:

Concrete Superstructure – Advanced deterioration of primary concrete members may be present. There is concrete disintegration around reinforcing steel with loss of bond. Some reinforcing steel may be ineffective due to corrosion or loss of bond. Numerous large structural cracks may be present. Localized failures of bearing areas may exist.
Prestressed Concrete Superstructure – Critical damage to the concrete or the reinforcing structures may be present. Multiple shrinkage cracks, spalls with exposed reinforcing, and/or rust may be present. Wide shear cracks and/or rust may also be present. Open cracks across the bottom flange and possibly into the web may exist. An abrupt lateral offset as measured along the bottom flange or lateral distortion of exposed prestressing strands. Excessive vertical misalignment may be present. Longitudinal cracks at the interface of the web and top flange that are not substantially closed below the surface damage (this indicates permanent deformation of the stirrups) may be present.

Non-Composite Prestressed Concrete Adjacent Box Beams – Any condition worse than described for Condition 3, above, is present.

Steel Superstructure – Severe section loss of over 50 percent of thickness is present at numerous locations with through thickness section loss at some critical locations of primary members. Extensive fatigue cracking may also be present.

Timber Superstructure – Severe decay, cracking, splitting, crushing of beams or stringers, or major fire damage has resulted in significant local failures. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

1 “IMMINENT” FAILURE CONDITION: Major deterioration or section loss is present in the critical structural components or obvious vertical or horizontal movement affecting structural stability is present. The bridge is closed to traffic, but corrective action may put it back into light service.

Supplemental Rating Guidelines:

Concrete Superstructure – The bridge is closed to traffic. There is major deterioration or section loss present on primary structural elements. Obvious vertical or horizontal movement is affecting the structure’s stability.

Prestressed Concrete Superstructure – Critical damage requiring the replacement of a member is present. The bridge is closed to traffic. Temporary falsework to safeguard the public and the bridge should be installed.

Steel Superstructure – The bridge is closed.

Timber Superstructure – The bridge is closed.

0 FAILED CONDITION: The bridge is out-of-service and beyond corrective action.
One method of establishing a superstructure rating is to identify phrases within the guideline language that describes a superstructure condition more severely than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

Another method to help narrow down the superstructure rating number is to group the numbers in general categories. Ratings of 9 to 7 apply to superstructures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition and the bridge being closed to traffic. There is a significant change from a superstructure in condition rating 5 (minor section loss, but structural elements sound) to condition rating 4 (advanced section loss and advanced deterioration).
SECTION 4.7  ADDITIONAL SUPERSTRUCTURE RATINGS

For state-owned bridges, each of the following items shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 59, the NBI superstructure condition rating.

Each item shall be rated as follows unless noted:

N  Not Applicable
9  Excellent Condition
8  Very Good Condition
7  Good Condition
6  Satisfactory Condition
5  Fair Condition
4  Poor Condition
3  Serious Condition
2  Critical Condition
1  Imminent Failure Condition
0  Failed Condition

ITEM 59A.01 – BEARING RATING

Bearings carry the dead loads and live loads from the superstructure members to the substructure and accommodate bridge rotation, expansion, and contraction. Bridge movement can result from temperature changes, substructure movement, live and dead load deflections, wind loads, or quick braking of a vehicle. Movable (expansion) bearings accommodate superstructure longitudinal and rotational movements. Fixed bearings accommodate superstructure rotational movements only. Many bearing types are used in Indiana, including elastomeric bearings, rocker bearings, roller bearings, pot bearings, and various sliding plate type bearings.

Inspection of bearings should include the following items:

- Check for overall deterioration of the bearing.
- Check for bearing misalignments. Improper alignments suggest a failing bearing, excessive superstructure movement, substructure settlement, or improper construction. Signs of improper alignment include:
- A superstructure that is tight against the backwall of the abutment.
- Excessive overhang of the top sliding plate over the bottom sliding plate. The sole plate of a sliding plate bearing should normally line up with the masonry plate between temperatures of 60 to 70 degrees Fahrenheit.
- Unstable or improperly tipped rockers. The top of the rocker should be tipped away from the fixed bearing on hot days and towards the fixed bearing on cold days. Rockers are normally set vertical between temperatures of 60 to 70 degrees Fahrenheit.

![Figure 4:4-76: Unstable Rocker Bearing](image)

- Improperly positioned rollers. Rollers should be rolled away from the fixed bearing on hot days and towards the fixed bearing on cold days. Rollers are normally positioned on the centerline of the masonry plate between temperatures of 45 to 65 degrees Fahrenheit.

- Measure the distance from the girder/beam/truss to the backwall of the abutment.
- Measure the longitudinal movement on bearings that are improperly aligned. Examples of measurements to be taken are shown in Figure 4:4-78. Record the ambient temperature at which the expansion/contraction measurement was taken. Notify the District Engineer or the Inspection Consultant of any severely misaligned bearing or rocker bearing in danger of tipping over during extreme temperatures.

![Figure 4:4-77: Reinforced Concrete Box Girder Tight Against the Abutment Backwall With No Room for Further Expansion](image)
Figure 4:4-78: Longitudinal Movement Measurements

(A) Rocker Plate Bearing
(B) Roller Bearing
(C) Rocker Bearing
(D) Elastomeric Bearing
(E) Pot Bearing
• Measure the height at the front and back of an elastomeric bearing or pot bearing if the rotation is noticeable. Record the height measurements and the length of the bearing. An angle of rotation can then be calculated. The rotation calculation and examples of the measurements to be taken are shown in Figure 4:4-79.

\[ \alpha = \text{bearing rotation in degrees} = \tan^{-1}\left(\frac{b-a}{l}\right) \]

Figure 4:4-79: Bearing Rotation Measurement

• Record the ambient temperature at which measurements were taken.
• Check for detachment of the masonry plate or fixed shoe from the substructure.
• Look for bent anchor rods or anchor rods which have risen up above the masonry plate.
• Check for out-of-place bearing pads. Often elastomeric pads with waxed lubricant will walk out from under the beam/girder and should be replaced.
• Note debris that may be hindering movement.
• Check for any broken keeper bars, pintels, or retainer angles.
• Check for missing or loose anchor rod nuts.
• Check the bearing assembly for pack rust between components, or corrosion of the bearing device or anchor bolts.

• Look for full and even contact of all bearing components.

• Look and listen for signs of bearing looseness, such as movement or rattling under live loads, uplift, and loose or missing fasteners/welds.

• Look for signs of proper movement/wear on sliding plates.

• Check for excessive bulging on the sides of the elastomeric pads. Bulging in excess of about 15 percent of the pad's thickness is a cause for concern.

• Check for any uplift.

• Look for splits or tears in elastomeric pads. These may be oriented vertically or horizontally. Horizontal splits in a laminated pad indicate a serious condition and should be reported.

• Check for variable thickness of the elastomeric pads in the lateral direction, suggesting lateral rocking of the girder. This would be an unusual occurrence and when this happens, look for signs of distress in other parts of the bridge.

• Check for neoprene pad extrusion above the pot rim on pot bearings. This indicates serious distress.

Figure 4:4-80: Bearing Failure
Figure 4:4-81: Elastomeric Bearing With Uplift at the Corner

Figure 4:4-82: Steel Rocker Bearing
Look for wear or binding on guide bars. Guide bars are sometimes used on expansion pot bearings to restrict lateral movements in the transverse direction.

Check for proper pot bearing alignment. Signs include:

- A superstructure that is tight against the backwall of the abutment.
- Exposure of the piston top or top surface of the top aluminum alloy casting.
- Excessive overhang of the top sliding plate over the piston or top aluminum alloy casting. The top plate and pot should normally line up between temperatures of 60 to 70 degrees Fahrenheit, although this could vary for any individual bridge.

Look for cracked welds.

Look for loss of bearing area or deterioration of bearing area.
Note the loss of bearing under the masonry plate in Figure 4:4-85.
Figure 4:4-86: Hold-Down/Restraining Bearing

Figure 4:4-87: Steel Roller Bearing (Type D)

Note the critical misalignment and distance from the beam to backwall in Figure 4:4-87.
ITEM 59A.01A – BEARING TYPES AT ABUTMENTS

Enter the appropriate code for the bearing type at the abutments. The letter code for different bearing types is shown below. Enter the minimum distance between the abutment/backwall and the end of the beam or girder. Enter the approximate air temperature and the longitudinal movement, as shown in Figure 4:4-78. Enter the angle and direction of movement if applicable.

ITEM 59A.01B – BEARING TYPES AT INTERMEDIATE SUPPORTS

Enter the appropriate code for the bearing type at intermediate supports. The letter code for different bearing types is shown below. Enter the approximate air temperature and the longitudinal movement, as shown in Figure 4:4-78. Enter the angle and direction of movement if applicable.

<table>
<thead>
<tr>
<th>Code</th>
<th>Bearing Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>Steel Plates</td>
</tr>
<tr>
<td>C</td>
<td>Steel Curved Plates</td>
</tr>
<tr>
<td>D</td>
<td>Steel Rollers</td>
</tr>
<tr>
<td>E</td>
<td>Steel Rockers</td>
</tr>
<tr>
<td>F</td>
<td>Steel/Bronze Curved Plates</td>
</tr>
<tr>
<td>G</td>
<td>Steel/Teflon</td>
</tr>
<tr>
<td>H</td>
<td>Elastomeric – Plain</td>
</tr>
<tr>
<td>I</td>
<td>Elastomeric – Steel Plate Reinforcement</td>
</tr>
<tr>
<td>J</td>
<td>Elastomeric – Polytetrafluroethylene (PTFE) Plane</td>
</tr>
<tr>
<td>K</td>
<td>Spherical</td>
</tr>
<tr>
<td>L</td>
<td>Stainless Steel Plate</td>
</tr>
<tr>
<td>M</td>
<td>Resilient, Fiber-Free Pad with Teflon</td>
</tr>
<tr>
<td>N</td>
<td>Pot</td>
</tr>
<tr>
<td>O</td>
<td>Disc</td>
</tr>
<tr>
<td>P</td>
<td>Cylindrical</td>
</tr>
<tr>
<td>T</td>
<td>Integral</td>
</tr>
<tr>
<td>Z</td>
<td>Other</td>
</tr>
</tbody>
</table>
ITEM 59A.01C – SEISMIC RESTRAINTS

There are many types of seismic restraints used in Indiana due to changing codes and thoughts on how to restrain bridges. Check if seismic restraints have been installed.

![Figure 4:4-88: Typical Seismic Restraint](image)

ITEM 59A.02 – STEEL GIRDERS

Steel girders have built-up webs and flanges and are generally much deeper than steel beams. These can be built-up either by welding, bolting, or riveting individual members together to make the structural member. They can be used as primary longitudinal or transverse members. When used as floor beams, they are rated under Item 59A.16. Girders often have many welded attachments, including web stiffeners, which can create local areas of stress. Inspection should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the girders and their ability to function as designed.

![Figure 4:4-89: Steel Girder in Good Condition](image)
ITEM 59A.03 – STEEL BEAMS

Steel beams are considered to be “rolled” members. These can be rolled “I” shapes, channel shapes, or “H” shapes. Beams rated under 59A.03 are used as the primary longitudinal members. When used for stringers or floor beams, they are rated under items 59A.15 and 59A.16. Inspection should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the steel beams and their ability to function as designed.
ITEM 59A.04 – STEEL DIAPHRAGMS

Diaphragms are generally perpendicular to the roadway and provide bracing between the longitudinal girders or beams. Diaphragms are secondary members. Diaphragms include solid diaphragms such as channel sections and I-beams.

The inspection of diaphragms should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the diaphragm and its ability to function as designed. Note the type of diaphragm.
ITEM 59A.05 – STEEL CROSS BRACING

Cross bracings are diaphragms constructed using angles or structural tees. Cross bracings are secondary members. See Items No. 59A.26, 59A.27, 59A.28, and 59A.29 for lateral bracing.

The inspection of steel cross bracing should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the cross bracing and its ability to function as designed. Note the type of bracing members. Look for out-of-plane bending cracks whenever the cross-bracing is staggered. Look for vertical cracks in the web along vertical web stiffeners and longitudinal cracks in web-flange welds. Look for spider web cracking on back side of the web.

ITEM 59A.06 – CONCRETE GIRDERS

Girders are generally cast-in-place concrete members other than slabs. These are sometimes called Tee Beams in other states. In Indiana, post-tensioned concrete boxes and slabs are also referred to as girders. Inspection should follow the guidelines detailed in Part 4, Section 4.3, Concrete Superstructures. Rate the physical condition of the girders and their ability to function as designed. For reinforced concrete girder bridges in Indiana, the concrete deck is a structural part of the girder.
Figure 4:4-95: Reinforced Concrete Girder Bridge With Minor Rust Staining

Figure 4:4-96: Reinforced Concrete Box Girder With Exposed Steel and Hole
ITEM 59A.07 – CONCRETE BEAMS

Concrete Beams are precast concrete members. Inspection should follow the guidelines detailed in Part 4, Section 4.3, Concrete Superstructures. Note the type of beam: I-beam, channel beam, T-beam, bulb T-beam, modified bulb T-beam, “U,” or closed box.
Figure 4:4-99: Delaminated and Spalled Precast Beam With Exposed Steel

Figure 4:4-100: Prestressed Channel Beams With Exposed Strands, Longitudinal Cracks, Efflorescence, and Rust Staining
Figure 4:4-101: Prestressed Girder With Impact Damage

Figure 4:4-102: Prestressed I-Beams and Diaphragms in Good Condition
ITEM 59A.08 – CONCRETE DIAPHRAGMS

Reinforced concrete diaphragms are secondary members placed transversely between the main load-carrying members. Their cross sections are normally rectangular and are constructed with the bridge deck concrete pour. They are used between both cast-in-place and prestressed beams.

Diaphragms serve several purposes, depending on their location along the span. Intermediate diaphragms are located between the bridge supports. They serve to laterally support the beams and help distribute the live load among them so that they will act as a unit. Diaphragms over piers are considered intermediate diaphragms on continuous spans only.

End diaphragms, also called mudwalls, are located at abutments. Diaphragms are also located at piers under expansion joints. When there are no joints over the piers, these are called integral pier diaphragms or curtain walls. These diaphragms serve to keep the beams’ ends in alignment and to strengthen the end of the deck. They act as simple beams transversely spanning between the main members to deliver wheel loads to the bearings.

Rate the overall condition of concrete diaphragms and their ability to function as designed.

ITEM 59A.09 – CONCRETE SLABS

On concrete slab bridges, the deck is also the superstructure, so the rating of the deck and superstructure must be the same. This rating must match the rating for NBI Item 58.

ITEM 59A.10 – CONCRETE SLABS INTEGRAL WITH PIER

Check “Y” (yes) if the slab is constructed integral with the pier cap for interior piers only. Check “N” (no) if not. Integral abutments are covered under Items 60.01, 113 B.02, and 113 B.03.

ITEM 59A.11 – TIMBER SUPERSTRUCTURE

Rate the overall condition as detailed in Part 4, Section 4.4, Timber Superstructure. This rating must match the rating for NBI Item 59.
ITEM 59A.12 – ARCHES

Rate the overall condition of all the arch members, including the arch ring, spandrel walls, and columns. This rating must match the rating for NBI Item 59.

ITEM 59A.13 – ARCH RING

Rate the overall condition of the arch ring.
ITEM 59A.14 – SPANDREL WALLS

Rate the overall condition of the spandrel walls.

ITEM 59A.15 – STRINGERS

Stringers are generally longitudinal members used in conjunction with a floor system in a truss or two-girder bridge. Rate the overall condition of the stringers.
ITEM 59A.16 – FLOOR BEAMS

Floor beams are generally transverse members used in conjunction with a floor system in a truss or a two-girder bridge. Floor beams and their connections to trusses or two-girder systems may be fracture critical. If there are fracture critical members, they must be inspected at arm's-length. Rate the overall condition of the floor beams.

ITEM 59A.17 – KNEE BRACES

A knee brace is a short member, engaging at its ends two other members that form a right angle or a near right angle to stiffen the connecting joint. Rate the overall condition of the knee braces. Most knee braces in Indiana are located over and under floor beam connections.

ITEM 59A.18 – TRUSSES

Rate the overall condition of the trusses in accordance with Part 4, Section 4.2 for steel trusses and in accordance with Part 4, Section 4.4 for any timber trusses.
ITEM 59A.19 – TRUSS EYEBARS

Check the box marked yes if the truss is constructed using eyebars.

ITEM 59A.20 – TRUSS VERTICALS

Rate the overall condition of the truss verticals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.
ITEM 59A.21 – TRUSS DIAGONALS

Rate the overall condition of the truss diagonals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.22 – TRUSS UPPER CHORDS

Rate the overall condition of the truss upper chords in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.
ITEM 59A.23 – TRUSS LOWER CHORDS
Rate the overall condition of the truss lower chords in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.24 – UPPER BRACINGS
Rate the overall condition of the truss upper bracings in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.25 – PORTALS
Rate the overall condition of the truss portals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.26 – TOP LATERALS
Rate the overall condition of the top laterals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.27 – LATERAL STRUTS
Rate the overall condition of the lateral struts in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.28 – SWAY BRACING
Sway bracing keeps two trusses parallel. Rate the overall condition of the sway bracing in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.29 – LOWER BRACING
Rate the overall condition of the lower bracing in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.T1
Rate the condition of some part of the truss not identified above.

ITEM 59A.T2
Rate the condition of some part of the truss not identified above.

ITEM 59A.30 – CONNECTION PLATES
Rate the overall condition of the connection plates. Note any deformation in any connection plate.
ITEM 59A.31 – GUSSET PLATES

A gusset plate is any plate used to transfer load from one member to another. Rate the overall condition of the gusset plates. Note any cracks or deformation. See Chapter 11, Fatigue and Fracture Critical Inspections.

Figure 4:4-112: Bolted Gusset Plate

Figure 4:4-113: Riveted Gusset Plate
ITEM 59A.32 – STAY/BATTEN PLATES

Stay/batten plates are tie plates or diagonal bracing designed to prevent relative movement between components of a built-up member. Rate the overall condition of the stay or batten plates.

ITEM 59A.33 – LACINGS

Lacings, sometimes called lattice, are small flat plates, usually with one rivet at each end, used to tie individual sections of built-up members. Rate the overall condition of the lacings.

ITEM 59A.34 – RIVETS

Rate the overall condition of the rivets.

Figure 4:4-114: Rivets in Sound Condition

ITEM 59A.35 – BOLTS

Rate the overall condition of the bolts.

ITEM 59A.36 – SPLICE PLATES

Rate the overall condition of the splice plates.

ITEM 59A.37 – BRACKETS

Rate the overall condition of the brackets.

ITEM 59A.38 – TACK WELDS

Rate the overall condition of the tack welds.
ITEM 59A.39 – FULL WELDS

Rate the overall condition of the full welds.

ITEM 59A.40 – OTHERS

Rate the overall condition of other connection details or types. Note the type.

ITEM 59A.41 – HANGERS

Rate the overall condition of the hanger connection system, including pins or U-bolts.

Figure 4:4-115: Hangers on Through-Truss Arch Bridge

ITEM 59A.42 – TOTAL NUMBER OF HANGERS

Enter the total number of hangers or hanger assemblies.

ITEM 59A.43 – HINGES

Rate the overall condition of the hinges.

ITEM 59A.44 – PINS

Rate the overall condition of the pins.

ITEM 59A.45 – TOTAL NUMBER OF PINS

Enter the total number of pins.
ITEM 59A.46 – NUTS
Rate the overall condition of the nuts for the pins.

ITEM 59A.47 – HANGER BARS
Rate the overall condition of the hanger bars, straps, links, or U-bolts.

ITEM 59A.48 – WEB PLATES
Rate the overall condition of the web plates at pin-and-hinges or pin-and-hangers connections.

ITEM 59A.49 – MUDWALLS
Mudwalls, often called backwalls, are the vertical face of the abutment above the bearing seat. Rate the overall condition of the mud walls.

Figure 4:4-116: Mudwall With Efflorescence

ITEM 59A.50 – CURTAIN WALLS
Curtain walls are concrete diaphragms over piers without a joint. They extend down to the pier cap. Rate the overall condition of the curtain walls.

ITEM 59A.51 – COLLISION DAMAGE
Rate the overall condition of any member damaged by collision.
ITEM 59A.52 – ALIGNMENT OF MEMBERS

Rate the overall alignment of the members.
ITEM 59A.53 – DEFLECTIONS
Rate any deflection of the structure.

ITEM 59A.54 – VIBRATIONS
Rate any vibration of the structure.

ITEM 59A.55 – IMPACT
Rate the overall condition of the members damaged by the impact onto and off of the bridge deck by trucks traveling at highway speed.

ITEM 59A.56 – NOISE
Rate any noise made by the structure.

ITEM 59A.OTH1 – ADDITIONAL ITEMS
Describe and rate the condition of any additional items.

ITEM 59A.OTH2 – ADDITIONAL ITEMS
Describe and rate the condition of any additional items.
SECTION 4.8 PAINT AND TONNAGE OF STEEL

Paint acts as a physical barrier between the steel and environment. By preventing oxygen, moisture, deicing chemicals, and pollutants from coming in contact with the steel, the paint coating prevents the rust-producing electrochemical reaction from starting. Two to four paint layers typically make up the coating system and include the prime coat and one or more top coats. On older bridges, the prime coat usually contains lead, easily discerned by its orange/red-orange color in the first or second coat of paint. The paints in newer systems are usually lead-free and impregnated with zinc that acts as an additional level of protection. On painted steel, rust indicates a coating failure.

Weathering steel is not intended to be painted or galvanized. It is intended that it be left exposed to the atmosphere, developing a dense, protective oxide coating. If weathering steel remains wet for extended periods or is exposed to a corrosive atmosphere, the protective oxide coating will not form and the weathering steel will corrode. The signs of corrosion on weathering steel include deep pitting, laminar rust, flaking, or a course texture. If the weathering steel is corroding, rate the paint condition as if the steel was painted and note the type of steel.

ITEM 59B.01 – PAINT

Rate the overall condition of the paint.

N  Not applicable – no paint or weathering steel

9  Excellent Condition – recently painted – good seal

8  Very Good Condition – may be several years since painting; good seal; minor chalkiness

7  Good Condition – few areas of light rust; some chalkiness and peeling

6  Satisfactory Condition – light rust in many areas; extensive chalkiness and some peeling

5  Fair Condition – light rust in many areas with localized areas of medium rust buildup; crackling, peeling, and blistering over a large area

4  Poor Condition – many areas of medium rust and localized areas of heavy rust; significant peeling, cracking, and blistering

3  Very Poor Condition – many areas of heavy rust

2  Very Poor Condition – many areas of extremely heavy rust

1  Total Paint Failure – large areas of extremely heavy rust; little or no paint remains

0  Total Paint Failure – large areas of extremely heavy rust; little or no paint remains
ITEM 59B.02 – TYPE OF PAINT (PRIMER)

Enter the type of primer used.

- **Blank** – none or not known
- **Lead**
- **Zinc**
- **Other**

ITEM 59B.03 – PAINT SYSTEM

Enter the type of paint system used.

- **Blank** – none or not known
- **Three-coat system**
- **Two-coat system**
- **Other**
ITEM 59B.04 – PAINT COLOR

Enter the color of the top coat.

- Blank – none or not known
- Blue
- Green
- Silver
- Red
- Pink
- Orange

ITEM 59B.05 – ESTIMATED REMAINING LIFE OF PAINT AND PAINT YEAR

Enter the estimated remaining life of the paint. Enter the month and year when the entire superstructure was painted. This date should be painted on the superstructure. If portions were painted after this date, this should be noted in a comment.

ITEM 59B.06 – PAINT CONTRACT NUMBER

Enter the paint contract number.

ITEM 59B.07 – WEATHERING STEEL

Enter whether weathering steel was used or not.

- Blank – none or not known
- Y – weathering steel was used
- N – weathering steel was not used

ITEM 59C.01 – TONS OF STEEL

Enter the tons of steel used in the superstructure. Note the square footage of steel, if this has been calculated. Document all quantities from the last painting contract for future work.

OTHER COATINGS AND SEALANTS

Enter the type and condition of any coatings and sealants that are not paint.
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A bridge substructure includes all members that support the superstructure. Substructures deliver the superstructure reaction loads to the foundation soil or bedrock. Substructures must also control deflections and settlements that might create serviceability problems or unintended overloads of the superstructure. There are three main substructure components: abutments, piers, and wingwalls. Mechanically stabilized earth systems are sometimes constructed as part of an abutment or in place of a wingwall. The components and the materials used to construct substructures are discussed in this chapter.
SECTION 5.2 COMPONENTS

Subsection 5.2.1 Abutments

Abutments support the ends of a bridge adjacent to the approach roadway and retain the soil fill under the approach. Abutments must resist vertical loads from the superstructure dead and live loads, and lateral loads due to soil pressure under the approach. Lateral loads may also come from superstructure longitudinal forces including temperature effects, vehicle braking forces, and friction from expansion bearings. An abutment is designed to resist these longitudinal forces only at locations with fixed bearings. Unintended superstructure longitudinal forces are delivered to the abutment when abutment expansion bearings have frozen due to corrosion or debris accumulation.

To resist these loads, abutments must act as both compression and bending elements. For short abutment heights, up to approximately five feet, bending due to lateral soil pressure is not significant. For taller abutment heights, the bending becomes a significant factor in the structure's design.

Almost any material may be used to construct an abutment. The most common is reinforced concrete, although masonry, timber, plain concrete, mechanically stabilized earth, and steel abutments have been built.

The most common abutment types are sill, full-retaining, semi-retaining, pile-encased, and timber. These are described below and shown in Figure 4:5-1:

- **Sill abutments** are short abutments that use a single row of vertical piles for support. In Indiana, these are sometimes called end bents. They are placed at the top of the embankment and use a sloped berm or a mechanically stabilized earth wall in front of the abutment to contain the soil under the approach. Sill abutments can also be constructed as integral abutments with the piles and the ends of the superstructure encased in concrete.

- **Full-retaining abutments** are tall structures designed as cantilever retaining walls to hold back soil under the approach. Because of this function, the main reinforcing steel is placed vertically at the back face of the abutment. A spread footing, supported by the soil or two rows of piles, anchors the abutment stem below grade.

- **Semi-retaining abutments** are similar to full-retaining abutments. They are shorter than full-retaining abutments and utilize small sloped berms to minimize the height of the stem.

- **Pile-encased or integral abutments** use piles that are driven into the ground and left extending the full abutment height. The piles are then encased in concrete, forming part of the abutment stem. This type of abutment is called integral because the superstructure is locked to the top of the abutment, allowing the superstructure and substructure to act as a unit.
Timber abutments can be constructed using timber piles, timber cribs, or steel piles combined with timber caps and backwalls. These are discussed further in Section 5.5.

**Figure 4:5-1: Common Abutment Types**

(A) Reinforced Concrete Sill  
(B) Reinforced Concrete Full-Retaining  
(C) Reinforced Concrete Semi-Retaining  
(D) Reinforced Concrete Pile-Encased or Integral  
(E) Timber

**Figure 4:5-2: Reinforced Concrete Sill Abutment**
Subsection 5.2.2  Piers and Bents

Piers and bents are intermediate support points for a bridge, used mainly for medium to long structures. Piers and intermediate bents must resist vertical live loads, the weight of the superstructure, and sometimes superstructure longitudinal forces. A pier or bent is designed to resist these longitudinal forces only if the bearings are fixed. Unintended superstructure longitudinal forces are delivered to the pier or bent when the pier expansion bearings have frozen due to corrosion or debris accumulation. To resist the above loads, piers and bents must act as both compression and bending elements. Piers and bents must also resist lateral forces transverse to the bridge centerline. These forces come from wind pressures against the girders, centrifugal effects of traffic on curved bridges, and stream flows. Most piers and bents act as cantilever beams to resist loads longitudinal to the bridge centerline. Piers and bents may be configured to behave as frames, cantilever beams, or shear walls to resist loads transverse to the bridge centerline. Figure 4:5-4 shows some common pier and bent types.
Almost any type of material may be used to construct a pier or bent. The most common material is reinforced concrete, although masonry, timber, steel, and unreinforced concrete have been used.

A bent cap is the horizontal component of a bent where the bearing devices for the superstructure are placed. It also acts to tie the pillar tops together on multi-pillar bents to form a frame for resisting loads transverse to the bridge centerline. When used on a multi-pillar bent, bent caps behave as bending members. The highest shear stresses are located at the pillars. When used above solid pier walls, bent caps are simply an architectural feature formed by thickening the wall, although bending may come into play if the cap cantilevers over the ends of the wall.
Hammerheads are the horizontal component of a single pier where bearing devices for the superstructure are placed. Hammerheads act as bending members that cantilever over either side of the pier.

Figure 4:5-6: Hammerhead Pier
Pillars, sometimes called columns, are the vertical components of a bent. Pillars are commonly used with bent caps to form frames that resist loads transverse to the bridge centerline. In Indiana, a single vertical shaft supporting one or more lines of girders is called a pier. Pillars and piers directly support bent caps, hammerheads, and sometimes girders. They are primarily compression members, but they must also resist lateral bending moments due to wind loads, eccentric loading at their tops, superstructure transverse and longitudinal forces, seismic forces, and differential substructure settlements.

Hammerheads are the horizontal component of a single pier where bearing devices for the superstructure are placed. Hammerheads act as bending members that cantilever over either side of the pier.

A solid pier wall is a wide, solid shaft of constant thickness that behaves primarily as a compression member. It must also resist lateral forces due to wind and seismic loads, and bending moments due to eccentric loading at their tops, superstructure longitudinal forces, and differential structure settlements. They are often used in streams or rivers because they offer less resistance to water flow than multi-pillar piers, and offer fewer locations for drift to collect.

Web walls are full height concrete walls constructed between the pillars of multi-pillar piers. The thickness of the web wall is always less than the widths of the adjacent pillars. They change multi-pillar pier lateral behavior from a frame to a shear wall, but use less concrete than required for a solid pier wall. In Indiana, if the web wall extends to the top of the pillars, this substructure unit is called a pier. If the web does not extend to the top of the pillars, this substructure unit is called a bent.
Crash walls can be placed between the pillars of multi-pillar bents or between the stems of two individual piers supporting separate bridges. They are designed to protect the base of the pillars or piers from rail car, ship, or vehicle impacts. Normally, the thickness of a crash wall is the same as the width of the adjacent pillar or pier to prevent snagging during a collision. Crash walls extend from approximately three to eight feet above grade.

Figure 4:5-8: Crash Wall

Figure 4:5-9: Concrete Crash Wall
Subsection 5.2.3  Wingwalls

Wingwalls are required at abutment ends to retain the approach fill. Without them, the approach fill would spill or wash out, causing settlement of the roadway. Wingwalls resist lateral pressure from the approach fill and carry no vertical loads other than dead weight. Three geometries are commonly used to retain the fill: straight wings parallel to the abutment, U-shaped wings parallel to the roadway, and flared wings that form an acute angle between both the roadway and abutment. Wingwalls may be rigidly attached to the abutment. Wingwalls are only considered a part of the substructure if integral with abutment.

Almost any type of material may be used to construct a wingwall. The most common is reinforced concrete, although masonry, timber, and steel wingwalls have been built. Mechanically stabilized earth walls have also been constructed as wingwalls.

Cheek walls are concrete walls placed at either end of the abutment to protect the fascia bearings from the elements. They also serve as architectural features to hide the bearings. Cheek walls should be coded as wingwalls.

Subsection 5.2.4  Foundation Types

Two foundation types are commonly used to support substructure elements: piles and footings. Piles are structural members that transmit the bridge live and dead loads into the underlying soil or bedrock. They are often used when the soil immediately below the substructure unit is inadequate to resist the bearing pressures or to satisfy settlement criteria. They are driven into the ground with a pile driver and rely on soil friction and/or end bearing to deliver the bridge loads into the earth. Piles may be driven vertically or at a batter (angle) to resist lateral loads. Materials used for piles include steel, reinforced concrete, timber, and prestressed concrete. A bent cap, usually of reinforced concrete, is used to transfer loads from the bent pillars or the abutment stem (breastwall) to the piles.
Footings are located at the base of the substructure unit, and are sized to transmit the bridge live and dead loads directly to the supporting soil or bedrock. They also prevent sliding or overturning of the pier or abutment due to lateral soil pressures. Foundations are usually buried underground and should not be visible when the bridge is in service.

Pile bents are essentially multi-pillar bents with the piles extending above grade to act as pillars. After driving, the pile tops are tied together with a conventional bent cap.

Subsection 5.2.5 Navigation Protection

Piers over navigable water must be protected from traffic on the water. There are many types of protection, including dolphins and fenders. The inspection team should verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.

Figure 4:5-11: Cell Dolphin During Flood Conditions
Figure 4:5-12: Timber Pile Cluster Dolphins

Figure 4:5-13: Substructure-Supported Timber Fender
Steel is not commonly used for substructure elements in new designs, except as piles. However, it was often used in the past to form the bents or bent towers of large bridges.

Steel bent caps may work in conjunction with steel pillars to form a frame, or they may bear on top of individual concrete bent pillars. Hot-rolled beams have been used as bent caps for smaller bridges with multi-pillar bents. To carry large girder reaction loads, steel bent caps are often fabricated into box shapes. Bent cap boxes are usually large enough for an inspector to enter and examine the interior.

Steel bent caps should not be confused with steel cross girders. Bent caps are elements separate from the superstructure. Superstructure cross girders sit on bearings, which sit on the bent cap's top flange. The cross girders are part of the superstructure. The longitudinal superstructure girders are directly connected to the cross girder web by welding or bolting. Any bearing devices are located on the underside of the cross girder.

(Note: The superstructure girders bear on the bent cap's top flange by way of bearing devices.)
Steel bents will consist of two or more steel pillars connected along their tops by a bent cap built of steel or reinforced concrete. Most steel bent caps use vertical bearing stiffeners at their supports. Steel pillars may be rolled or built-up shapes, pipes, or fabricated box shapes. Steel pillars will normally bear on top of a concrete pedestal, supported by the foundation. No bearing will be visible if the pillars are above grade extensions of the foundation piles.

Lateral bracing transverse to the centerline of the bridge is normally used for steel pile bents or bent towers. Lateral bracing prevents bent racking due to lateral wind loads, seismic loads, and centrifugal forces.
Some abutment types may use exposed steel piles, most notably timber abutments. Steel piles are driven with sufficient length to extend above the ground to the abutment cap elevation. An abutment cap (usually reinforced concrete) is placed on the piles, and timber lagging is placed at the back face of the piles up to the bent cap. Backfill is placed behind the lagging. These steel abutment piles must resist vertical loads from the superstructure and bent cap, and lateral soil pressures from the fill under the approach. In this sense, the piles are acting as beam/columns to resist axial compressive loads and bending moments. Maximum bending stresses occur near the ground line, which is also where corrosion is most likely to take place.

The most common defect found in steel substructures is corrosion, and the heaviest corrosion is generally found at the ground line, at the water line, and below failed or leaking expansion joints. The inspector should look for signs of corrosion on all steel surfaces, but problem areas are usually places subject to traffic spray or water, or with accumulated debris or bird waste.

The inspector should look for cracks at details prone to fatigue damage. Detection of these cracks will most often occur during arm’s length inspections. Fatigue cracks usually show up as rust stains or rusty breaks in the paint. Nondestructive testing (NDT), such as dye penetrant or ultrasonic testing, may be required to confirm the presence of a crack. Any crack or suspected crack will be oriented perpendicular to the direction of stress.

Though welded structures are most often associated with fatigue concerns, mechanically fabricated members are also susceptible to fatigue damage. As with welded members, the connections are the most vulnerable locations.
All members should be checked for overload damage. Buckled compression members or components, yielded tension members or components, and crippled webs at a support all indicate overload damage.

Steel components must also be inspected for fire damage when a fire occurs on or under a bridge.

Collision or traffic impact damage can be caused by trucks, railroad cars, or ships. Signs of impact damage include scrapes, distorted members or components, and nicks or gouges on plate edges or member corners. A damaged steel pillar can be especially serious if there are only two or three pillars in the bent. Even if a complete pillar failure does not occur at the time of impact, one may occur later during an overload.

![Figure 4:5-19: Impact Damage to Steel Substructure](image)

Inspection of steel substructure components should include the following items:

- Sight down the member’s length for unusual dips and sweeps, as well as for any lateral bending or twisting. This type of damage may be due to overloads, traffic impact, or support settlement.
- Check all pillars and walls for plumb, either visually, or with a level or plumb bob.
- Look for rotation in the bent cap.
- Check corroded areas for section loss. Particular attention should be given to members adjacent to the splash zones of roadways, bearing areas, near the water line for water crossings, at the ground line, and any detail that would tend to trap water and debris.
Examine the flexure zones and tension flanges for corrosion and loss of cross-sectional area. Section loss of five percent or greater may raise the stress level an appreciable amount.

- Remove spot areas of accumulated debris accumulation to check for corrosion.
- Check rivet/bolt heads on built-up components, as corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.
- Look for pack rust, noted by an individual plate bending between fasteners. Pack rust may be present between the plies of riveted/bolted connections, such as field splices or built-up member connections.
- Look for damage in the form of plate waviness, compression flange buckling, or tension flange elongation or fracture in the high moment flexural regions. This could be the result of a structural overload, or differential pier or bent settlement. Check near the ground line of abutment piles where maximum bending compressive stresses occur.
- Examine suspect fasteners for looseness by striking the heads with a hammer.
- Look for welded repairs which reduce the member’s fatigue strength. These include patch plates fillet-welded over corroded areas, producing sudden geometric changes, and poor quality plug welds used to fill mis-drilled bolt holes.
Look for stress risers on tension flanges, such as tack welds, gouges, and indiscriminately placed attachment welds. Flaws such as these should be marked, recorded, and ground smooth, if possible. Until the areas are repaired, the member should be closely monitored to spot crack development.

Look for bearing stiffeners welded to a tension flange. These welds act as stress risers and could be a crack initiation point. Carefully check the welds and flange on these components for cracks.

Investigate groove welds used to join the ends of web plates or different size flange plates.

Examine intersecting welds for cracks.

Investigate back-up bars that are welded together end-to-end and are located within tension or stress reversal zones for fatigue cracks.

Investigate any web or flange longitudinal stiffeners that are welded together end-to-end and are within tension or stress reversal zones. Pay particular attention to all questionable details located along the tension flanges.

Check all welded attachments, including the transverse stiffeners and diaphragms.

Look for fire damage, especially near the piers, bents, or abutments where fires can be built close to the beams. Fire-damaged members that exhibit large strain deformations should be reported immediately to the District Engineer or the Inspection Consultant.

Inspect submerged substructure members visually and by probing to check for scour and erosion.

Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.

Subsection 5.3.1 Fracture Critical Steel Substructures

A fracture critical member is one that is in tension or with a tension element whose failure would probably cause a portion of or the entire bridge to collapse. The most common steel substructure member classified as fracture critical is a single I-girder or box girder bent cap supported by two pillars. The fracture critical element is the tension flange of the bent cap. See Part 4, Chapter 11 for information on Indiana’s Fracture Critical Inspection procedures.
Concrete is the most common material used to construct bridge substructures. Around the turn of the 20th century, massive concrete substructures were built to replicate the more commonly used masonry substructures. The ease of placement, formability, and long-term durability of concrete was quickly recognized, and this led to the near cessation of building masonry substructures.

**Subsection 5.4.1 Unreinforced Concrete Piers and Abutments**

Although unreinforced concrete substructures are no longer built, some older and generally smaller bridges are supported by unreinforced concrete piers and abutments. Inspection of these substructures is the same as for reinforced concrete substructures. Since these substructures are generally larger in mass than comparable reinforced construction, cracking may be of less consequence. These generally older structures may have more freeze/thaw deterioration and deterioration from sulfate attack and reactive aggregates than newer structures.

![Figure 4:5-21: Unreinforced Concrete Abutment](image1)

![Figure 4:5-22: Freeze/Thaw Disintegration of an Unreinforced Concrete Abutment](image2)
Subsection 5.4.2  Reinforced Concrete Piers, Bents, and Abutments

Concrete pier, bent, and abutment elements are generally constructed using cast-in-place methods. Pillars, piers, bents, and abutments provide support for the superstructure’s gravity loads, as well as bridge lateral and longitudinal loads.

Figure 4:5-23: Reinforced Concrete Abutment

Figure 4:5-24: Reinforced Concrete Multi-Pillar Bents
Traffic impact damage is caused by trucks, railroad cars, or ships. Signs of impact damage include scrapes, spalling, cracking, and misalignment. A damaged bent pillar can be especially serious if there are only two or three pillars for a bent. If a complete pillar failure does not occur at the time of impact, one may occur during an overload.

**Figure 4:5-25: Pillar Spall With No Exposed Rebar**

Inspection of reinforced concrete substructures should include the following:

- Sight down the superstructure parapet to look for unusual dips or sweeps.
- Check for tipping or rotation by using a plumb bob and laterally sighting the element from a distance.
- Look for bridge components that do not line up with one another, such as wingwalls that have shifted laterally relative to the abutment at an expansion joint.

**Figure 4:5-26: Tipped Wingwall**
Check and measure the alignment of expansion bearings relative to the masonry plate and backwall. Excessive superstructure expansion in hot weather or contraction in cold weather may actually be a sign of substructure rotation or sliding.

Investigate all cracks. Measurements and the dates taken should be recorded in the Central Database and written with a lumber crayon directly on the element.

Check the base of all pillars, shafts, or walls for transverse flexural cracks. These cracks indicate excessive bending. This bending may be from expansion bearings that have locked up, or from wind or centrifugal effects.

Check the mid-height of walls and pillars for flexural cracks. This is a sign of structural overloads or differential substructure settlement.

Examine all walls for diagonal cracks which can indicate excessive lateral shear.

Examine all walls, pillars, or shafts for vertical cracks and crushed concrete. This could be the result of a serious structural overload.

Figure 4:5-27: Transverse Flexural Cracks at the Base of a Pillar
Examine all bearing seats for cracking and spalling. The pedestals and grout pads under the bearings should also be checked for cracking, spalls, and deterioration that reduce the bearing area.

Check the bent cap/pillar interface for horizontal or diagonal flexural cracks in the pillar. These cracks will originate at the inside corner of the cap/pillar junction and are a sign of excessive lateral bending.

Look for shear cracks in the bent caps over and near the supports. Shear cracks will be diagonal, extending up from the pillar towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be hanging from the reinforcing stirrups. Maximum crack widths should be measured and noted on the bridge inspection report. The District Engineer or Inspection Consultant should be contacted immediately if shear cracks with possible loss of aggregate interlock are found.

Look for vertical flexural cracks in the bent caps, either on the underside between pillars, or top side above pillars or shafts. Wide cracks in a flexural region indicate a serious structural overload.
Figure 4:5-29: Reinforced Concrete Bent Cap

(Note the vertical cracks under the second and third girders in Figure 4:5-29.)

- Check for shear cracks near the tops of pillars.
- Check the construction joint between the abutment backwall and bearing seat for deterioration and leakage.
- Check all surfaces for delaminations, spalls, and exposed reinforcing steel. Suspect areas are in roadway splash zone or bridge drainage areas, at water lines for water crossings, and at grade.

Figure 4:5-30: Delaminated and Spalled Pillar
Look for efflorescence, and note if it is stained with rust since this suggests reinforcing steel corrosion.

Note any abrasion of the concrete surface located within a waterway.

Note if any soil, rock or debris has been piled against the walls or pillars. This may cause lateral forces on the member not originally accounted for in the original design.

Look for granular soil deposits outside the base of the wall caused by failed weep holes or excessive joint gaps.

Check previously repaired areas for soundness by hammer tapping.

Drag or scrape a probing rod along the surface of any submerged concrete to check for the presence of cracks, spalls, or abrasion.

Check for deteriorated concrete in the flexural zones that could be causing debonding of the reinforcing steel.

Look for the presence of debris or standing water on the bearing seat. Debris suggests a failed or leaking expansion joint. Standing water indicates that the bearing seat is dished. Salt-laden standing water will eventually migrate to the reinforcing steel, causing corrosion, delaminations, and spalls.
Check that any weep holes present are clear and functioning properly.

Inspect submerged substructure members visually and by probing to check for scour and erosion.

Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.
Timber bents, abutments, and wingwalls are most often constructed using sawn lumber.

Figure 4:5-33: Timber Abutment and Wingwalls

(Note the lead sheets on the piles in Figure 4:5-33.)

Timber pillars are almost exclusively round piles that extend above the ground line. Pillars for timber bents may also bear on reinforced concrete pedestals located at the ground line. Bents of either type are laterally stabilized through the use of timber bracing. The tops of the timber pillars are tied together with a timber, reinforced concrete, or rolled steel bent cap to help create a frame and to deliver the superstructure loads to the bent pillars. Since timber pillars are vertical members, the permeable end grain is directly exposed to rain. Thin lead or zinc sheets are often draped over the ends to keep them dry.

Timber cross-bracing is used to support timber bents against the forces of lateral loads. It is also sometimes used for longitudinal bridge support. The bracing forms an “X” shape, with each brace starting near one end of the bent at the cap and ending at the opposite end near grade or the water surface. The braces are most often bolted to each timber pillar they cross. Cross-bracing is needed to prevent bent racking due to lateral wind loads, seismic loads, and centrifugal forces. Sawn solid members are usually used for bracing.
Steel piles are also used with wood lagging in timber abutments. The inspection of these piles is covered in Section 5.3 of this chapter.

Timber abutments are generally designed as one of two common structure types. The first is a timber bent abutment. It is built by driving timber or steel piles into the ground. These piles extend above the grade approximately to the girder bearing elevation and receive vertical bearing loads from the superstructure through the abutment cap. Sawn timber lagging is then placed along the back face of the piles to the abutment cap, forming a wall. The embankment is then created by backfilling behind the lagging wall. The timber lagging holds back the soil by spanning between the piles. The piles act as beams/columns to resist axial compressive loads and bending moments. Maximum bending stresses occur near the ground line, which is also where decay is most likely to take place. Timber or reinforced concrete caps are used to tie the abutment piles together.

Timber crib abutments are the second common type of timber abutment. Rectangular timber elements are stacked to form a cell, similar to how a log cabin is built. This cell is then filled with soil to form the embankment. Timber crib abutments act as gravity-retaining devices, using the mass of the crib and the contained fill material to resist sliding from exterior soil lateral pressures. There are no piles used in this type of abutment.
Timber wingwalls are almost exclusively used in conjunction with timber abutments, using similar construction to the abutment. Their purpose is to retain the approach backfill at the abutments.

Inspection of timber substructure members should include the following:

- Sight all substructure members for plumb visually, or using a plumb bob.
- Sight along all pillars and walls to check for bowing. Excessive deflections indicate that the member has been overstressed or that the bridge is experiencing differential settlements. The measured or estimated amount of deflection should be recorded.
Examine all timber members for signs of decay. Signs include discolored wood with a soft, rotted texture. Look for fungi and depressed areas of the wood surface.

Figure 4:5-37: Bulging of a Timber Abutment

Figure 4:5-38: Timber Column Decay at Ground Line
• Perform probe tests in areas of suspected decay. Using an awl, ice pick, or pocketknife, lift a small sliver of wood from the surface. Wood that lifts up and splinters is sound, while wood that breaks up upon lifting the tool is decaying. Drill or bore suspect members to estimate the extent of decay.

• Examine all timber members for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the member is tapped with a hammer.

• Look for any splitting of sawn timber members. Excessively long or wide splits may be a sign of a structural overload. Splits along a bolt line may render the member ineffective to carry the load.

![Figure 4:5-39: Split Bent Cap End](image)

Note the plant growth in Figure 4:5-39.

![Figure 4:5-40: Split Timber Pillar](image)
- Check the cap/pillar interface for bearing failures. Bearing failures on timber members loaded parallel to the grain will "broom out."

- Check the mid-height of all pillars and walls for flexural cracks, which are signs of structural overloads or differential deflection.

- Check for cap crushing at girder bearings, piles, or pillars. These areas tend to collect and retain moisture and debris, creating ideal environments for fungal growth and insect attack.

- Look for shear-related damage in timber caps at and near the supports. Overloads result in high-shear stresses that cause horizontal splits to form along the length of the cap, at approximately mid-height. Splits will allow fungi and insects access to the untreated interior of a cap.

- Examine the high flexural regions of the cap for signs of overload damage, such as crushing near the compression surface, and transverse cracking at the tension surface.

- Sight along the length of the cap for excessive vertical or lateral deflections. Check for cap rotation that may be caused by eccentric beam loading. The measured or estimated amount of deflection should be recorded.

- Check the lagging or cribbing for excessive deflections. Excessive deflections may allow the soil behind the boards to spill or wash out, causing settlement to the approach above.

- Look for any rotted or broken lagging boards. This may occur at a weak spot in the wood, such as a knot.

- Look for fire damage, noting the depth, extent, and location of any charring.

- Check the fasteners (bolts, lag screws, etc.) for corrosion or slipping. Check for loose fasteners by striking with a hammer. A dull sound indicates a loose fastener. The location of any missing fasteners should be noted.

- Examine the bearing seat for dirt or debris.

- Inspect submerged substructure members visually, and by probing, to check for scour and erosion.

- Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.
Figure 4:5-41: Timber Pillars, Cap, and Cross-Bracing
Masonry has been used for bridge substructures for thousands of years. Even after steel and reinforced concrete gained favor over masonry arches in the 1800s, masonry was still used for piers, abutments, and wingwalls. Eventually, concrete substructures won favor over masonry, and new masonry bridge substructure construction is mostly limited to use as a decorative effect on small, local bridges.

Concrete form liners, having the look of old masonry, are becoming popular. Coatings and pigmented concrete can make these elements look realistic when viewed from a distance. The inspector should be careful to inspect these substructures as reinforced concrete.

**Subsection 5.6.1 Masonry Substructure Members**

Masonry piers are solid, unreinforced masonry walls, built wide and heavy enough so that tensile stresses due to bending are virtually eliminated. Masonry abutments and wingwalls are solid, unreinforced masonry walls that act as gravity retaining walls to contain the soil located under the approach. They rely on dead weight and any soil bearing on top of them to provide enough frictional resistance at their footings to prevent sliding. They are built wide and heavy enough so that tensile stresses due to bending from lateral soil pressures are virtually eliminated.

![Figure 4:5-42: Masonry Abutment](image)
Inspection of masonry substructure components should include the following:

- Look for cracked, split, spalled, loose, or missing stone masonry units. This would suggest weathering due to freeze/thaw effects. Missing or crushed masonry results in a loss of cross-sectional area, increasing the axial stresses.

- Look for deteriorated, loose, or missing mortar. This would suggest weathering due to freeze/thaw effects. Missing or deteriorated mortar results in a loss of cross-sectional area, increasing the axial stresses.

- Look for efflorescence. This indicates water is flowing through the mortar joints, leaching out cementitious minerals. Extended efflorescence will weaken the mortar.

- Check areas exposed to drainage and roadway runoff. The runoff may cause scaling of the masonry units.

- Check the abutment and wingwall surfaces for bulges. This defect suggests unstable soil. The roadway above may also show signs of settlement.

- Check to make sure surface drains are functioning properly and do not allow water to penetrate the approach fill behind the abutment.

- Check to make sure weep holes are functioning.

- Examine previous repair areas for soundness.

- Check tall substructure units for plumb visually, or using a plumb bob.
- Look for vegetation growing inside of cracks, or between the mortar and masonry unit. Plant roots can exert prying forces that further deteriorate these materials.

- Note any abrasion of the masonry for pier walls located within a waterway.

- Examine the top surface (bearing seat) of pier walls and abutments for cracking and spalling. Deterioration in these areas may be caused by frozen expansion bearings that transmit lateral forces not anticipated in the original design.

- Note if any soil, rock, or debris has been piled against any wall. This will cause lateral forces not accounted for in the original design.

- Examine the bearing seat for dirt or debris.

- Inspect submerged substructure members visually and by probing to check for scour and erosion.

- Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.
Figure 4:5-45: Masonry Arch
SECTION 5.7 MECHANICALLY STABILIZED EARTH WALLS

Mechanically stabilized earth walls use precast concrete panels in conjunction with steel straps to reinforce the fill under the approach. The steel straps act as shear reinforcing for the soil, forcing it to act as a large mass rather than as many individual particles that could easily slide. In this way, a gravity retaining wall is made of soil. The concrete panels prevent the fill from washing out.

When mechanically stabilized earth walls are used on bridges, there is no physical connection to the abutment. They are not considered wingwalls or abutments. Generally, sill abutments supported on either spread footings or piles are placed on top of the soil mass at the top of the wall. The precast panels carry no vertical loads. For inspection and coding purposes, information on the condition of mechanically stabilized earth walls should be entered in the Central Database under the associated abutment or under wingwall, as appropriate. Structural concerns should be reported immediately to the District Engineer or the Inspection Consultant.

Inspection of mechanically stabilized earth walls should include the following items:

- Note any wall lean or misalignment.
- Check that any weep holes present are clear and functioning properly.
- Note if any precast concrete panels are bulging out or tipping.
- Note any mechanically stabilized earth wall panels that are shifting out of place or allowing fill to wash out.

Figure 4:5-46: Sill Abutment and Mechanically Stabilized Earth Wall
SECTION 5.8 SLOPE PROTECTION

On many bridges, an embankment of soil is placed in front of the abutments to retain soil under the approach from spilling through the abutment, to protect and provide support for the abutment piles, and to protect the abutment from errant vehicles on the roadway below.

Sometimes vegetation is used to stabilize the embankment. If vegetation cannot grow on these slopes, the embankment is extremely vulnerable to the erosive effects of rain, runoff, and wind. Because the embankment receives little direct sunlight, most plants do not grow well. Without plant roots to anchor the soil, slope protection is required under most bridges. The slope protection shields the embankment from erosive effects caused by the environment.

Concrete slope protection is usually constructed using relief-jointed, cast-in-place panels. Concrete slope protection is typically used in urban areas when the aesthetics of a bridge is deemed important, and in areas where crushed aggregate slope protection may lead to vandalism.
Older concrete slope protection may be constructed using individual, rectangular, concrete slabs or masonry pavers that cover the slope in front of the abutment. Animals often dig underneath the slabs and water flows through these holes, eroding deep voids underneath concrete slabs. Often, the individual slabs or pavers will settle and crack. If cracks open up, runoff water can undermine the panels. This can lead to additional cracking, buckling of the panels, and the erosion of the slope.

Asphaltic slope protection is often used in rural settings. A continuous mat of asphalt covers the entire slope. Often the mat will settle and crack as the slope consolidates and settles beneath it. Once cracks open, runoff water can undermine the mat, which can lead to additional cracking, buckling, and erosion of the slope.

Riprap slope protection is often used to protect slopes, especially at stream crossings. Riprap is large, crushed rock. The size of rock used depends on the flow velocity, but riprap between six inches and two feet in diameter is normally used. Revetment riprap is used for general erosion and minor scour protection. Class-1 and Class-2 riprap are larger and are used for higher velocity flow to protect against scour, or to fill deep erosion holes. A geotextile fabric is placed underneath the riprap to prevent the underlying soil from eroding away. Riprap slope protection relies upon its mass and the interlocking properties of the stone to prevent sliding down the slope.
Inspection of slope protection should include the following:

- Look for signs of undermining or erosion of the slope.
- Look for washed-out soil at the base of the slope. If water runoff or drainage is causing damage to the slope or slope protection, note the source of the water and the condition of the drainage element, if any. Common sources include leaking expansion joints; deteriorated, leaking, or incorrectly located surface drains and down spout pipes; and poor approach pavement drainage.
- Notify the owner if slope protection erosion deposits soil on the roadway or sidewalk underneath the bridge.
- Look for missing protection on the slope and at the toe of the slope. Note whether additional material should be placed on the slope.
- Check to see if areas of stone or asphalt have slid down the slope.
- Look for cracked or deteriorated concrete.
- Check for concrete panels that have settled, buckled, or moved.
- Check for cracks, settling or buckling of asphalt.
- Confirm that any vegetation is well-established and is actively stabilizing the slope.
- Note any bare areas.

Figure 4:5-51: Bare Slope
SECTION 5.9  SOIL AND FOUNDATION FAILURES

Settlement of piers, bents, abutments, and wingwalls is caused by the same forces for all substructures, regardless of the material used to construct the substructure.

subsubsection 5.9.1 Soil Failures

Common to all foundation types, soil failures can occur due to excessive soil bearing stresses, long-term consolidation, slope failures, soil characteristic changes, and erosion.

- **Soil bearing**: Under design loads, soils under spread footing foundations will behave similar to a linearly elastic spring; deflection is proportional to the load applied. Bearing capacity failures occur when loads are so great that the soil becomes overstressed, ceasing to behave as a linear spring. Large deflections will occur with little increase in the applied load. These failures may be seen in the field as heaving of the soil surface in the footing vicinity, as well as soil cracking adjacent to the footing.

- **Consolidation**: Consolidation is the long-term compression of cohesive soils (clays and silts) under static loads. This gradual compression results in the settlement of spread footings. Since consolidation occurs primarily under dead loads, excessive settlements are usually the result of improper design.
- **Slope failure:** Abutments and wingwalls are susceptible to lateral movements due to slope failures. Slope failures occur when the weight of the embankment being retained exceeds the shear strength resistance of the soil below. Slope failures typically begin when the toe of the slope fails. The mass of soil slips downward, carrying the abutment or wingwall along with it. Slope failures cause settlement of the approach and heaving in front of the abutment or wingwall.

- **Soil characteristic changes:** Changes in soil characteristics include frost action and saturation. When water within the soil freezes, it causes the soil mass to expand. This expansion can heave up substructure elements if the frost extends below the footing, or it can push laterally on retaining elements, causing them to tilt. Excessive water within the soil mass under an approach, or behind or in front of a retaining wall, can saturate the soil. This can reduce the soil strength or increase soil weight and lead to slope failures. Excessive water can cause additional lateral pressures on abutments or wingwalls for which they may not have been designed.

- **Erosion:** Soil embankments placed in front of abutments or wingwalls may be required by design to help restrain these elements against sliding. If this embankment is washed away during floods or heavy rain, the retaining elements may slide laterally due to horizontal earth pressures behind.

### Subsection 5.9.2  Foundation Deficiencies

Foundation failures are rare, with the exception of those attributable to scour. Deterioration of a spread footing will cause it to lose bearing area. This results in increased soil bearing stresses and a possible bearing capacity failure or increased settlement. Piles not driven to sufficient depth may also allow substructure settlements. Short piles may not have enough area to reduce pile/soil frictional stresses to an acceptable level, thereby allowing the pile to slip. If the water table rises, it could cause liquefaction under a substructure.

Differential settlement is a primary cause of bridge damage. It occurs when abutments, piers, or bents vertically settle different amounts than adjacent substructure units. This can cause great strains and overstresses to superstructure and substructure members, particularly in continuous bridges. Uniform settlement may have little, if any, structural effect on the bridge. This occurs when all substructure units settle approximately the same amount, merely lowering the bridge elevation or slightly tipping the piers.

Inspection of substructures for soil and foundation deficiencies should include the following:

- Look for any sign of vertical superstructure misalignment by sighting along the bridge.

- Look for expansion joints which have opened up excessively at abutments and have either closed completely or opened up above the piers or bents. These may indicate differential settlement.

- Check and measure the clearance between the girder ends and abutment backwall.
• Check and measure the clearance between the girder ends on bridges with multiple simple spans.

• Look for embankment erosion in front of abutments and wingwalls and mechanically stabilized earth walls.

• Look for heaving in front of abutments, wingwalls, and mechanically stabilized earth walls.

• Look for settlement of approaches.

• Look for bridge components that do not line up with one another, such as wingwalls that have shifted laterally relative to the abutment at an expansion joint.

• Check for pier or bent tipping or rotation using a plumb bob and laterally sight the bridge from a distance.

• Check for standing water or wet areas in front of wingwalls or abutments.

• Check for vertical cracks.

• Check for rotation or leaning in the substructure element. Note the location and magnitude.

• Check for bearing tipping in the opposite direction of what temperature dictates; this could be an indication of substructure movement.
SECTION 5.10 NBI SUBSTRUCTURE RATING

Part of every Routine Inspection is rating the substructure according to the Federal Highway Administration (FHWA) General Condition Rating Guidelines. The numeric condition ratings of these guidelines describe existing bridge components as compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition and 0 describing failed components.

The rating must characterize its overall general condition of the superstructure. It should not be used to describe local areas of deterioration, such as isolated heavy spalling. However, widespread heavy spalling would influence the rating. A proper rating will consider the severity of deterioration, plus the extent to which it is distributed throughout the substructure. The rating given to Item 60 should be consistent with the one given to Item 113 whenever a rating of 2 or below is determined for Item 113.

National Bridge Inventory (NBI) ratings are used to evaluate the state of deterioration of the substructure material. Postings or original design capacities less than current legal loads will not influence the rating. Temporary substructure supports do not improve the condition of the substructure material and will not influence the substructure rating.

Indiana has developed supplemental rating guidelines to assist the inspector in properly assigning condition ratings to specific components constructed of the most commonly used materials. The general condition ratings, along with the Indiana supplemental rating guidelines for substructures, are as follows:

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td></td>
<td>Indiana Supplemental Rating Guidelines: Used for underfill structures, culverts, and spandrel arches where footings cannot be seen.</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION</td>
</tr>
<tr>
<td></td>
<td>Indiana Supplemental Rating Guidelines: There are no noticeable or noteworthy deficiencies that affect the condition of the substructure. There may be insignificant scrape marks caused by drift or collision.</td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – No problems noted.</td>
</tr>
<tr>
<td></td>
<td>Indiana Supplemental Rating Guidelines:</td>
</tr>
<tr>
<td></td>
<td>Concrete Substructure – There may be shrinkage cracks, light scaling, or insignificant spalling which does not expose the reinforcing steel. There may be insignificant damage caused by drift or collision with no resulting misalignment.</td>
</tr>
<tr>
<td></td>
<td>Steel Substructure – There may be insignificant damage caused by drift or collision with no resulting misalignment.</td>
</tr>
</tbody>
</table>
Timber Substructure – There may be insignificant damage caused by drift or collision with no resulting misalignment.

Masonry Substructure – There may be insignificant spalling of the masonry units. Damage caused by drift or collision may have occurred, but with no resulting misalignment.

7 GOOD CONDITION – Some minor problems may be present.

Indiana Supplemental Rating Guidelines:

Concrete Substructure – There may be minor cracking or spalls with no detrimental effect on the bearing area. Minor scouring may have occurred.

Steel Substructure – Leakage of expansion devices may have started minor rusting without measurable section loss. Minor scouring may have occurred.

Timber Substructure – Insignificant decay, cracking, or splitting may be present. Minor scouring may have occurred.

Masonry Substructure – There may be minor cracking of the mortar or spalls/cracking of the masonry units with no detrimental effect on the bearing area. Minor scouring may have occurred.

6 SATISFACTORY CONDITION – Structural elements show some minor deterioration.

Indiana Supplemental Rating Guidelines:

Concrete Substructure – Minor deterioration or disintegration, spalls, cracking, or efflorescence with little or no loss of bearing area may be present. Shallow, local scouring may have occurred near the foundation.

Steel Substructure – Corrosion, but no measurable section loss may be present. Shallow, local scouring may have occurred near the foundation.

Timber Substructure – Minor decay, cracking, or splitting may be present. Fire damage is limited to surface scorching with no measurable section loss.

Masonry Substructure – Minor deterioration or disintegration and spalls or cracking of the masonry units or mortar with little or no loss of the bearing area may be present. Shallow, local scouring may have occurred near the foundation.
5 FAIR CONDITION – All primary structural elements are sound, but may have minor section loss, cracking, spalling, or scour.

Indiana Supplemental Rating Guidelines:

Concrete Substructure – Measurable, but minor, section loss may exist, with possible exposed reinforcing steel. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

Steel Substructure – Corrosion with measurable, but minor, section loss of less than five percent may be present. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

Timber Substructure – Moderate decay, cracking, or splitting may be present. A few secondary members may need replacement. Fire damage is limited to surface charring with minor, measurable section loss. There may be some exposure of piles as a result of erosion, reducing penetration.

Masonry Substructure – Minor deterioration or disintegration and spalls or cracking of the masonry units and mortar with little or no loss of the bearing area may be present. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

4 POOR CONDITION – Advanced section loss, deterioration, spalling, or scour may be present.

Indiana Supplemental Rating Guidelines:

Concrete Substructure – Structural cracks or settlement with advanced deterioration may be present. Additional backfilling is required. Extensive scouring or undermining of the footing is affecting the stability of the unit and requires corrective action. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present, along with wingwall rotation, causing roadway settlement. Severe impact damage may be present.

Steel Substructure – Corrosion with extensive section loss, between five percent and 10 percent, may be present. Extensive scouring or undermining of the footing is affecting the stability of the unit and requires corrective action. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present wingwall rotation, causing roadway settlement. Severe impact damage may be present.
Timber Substructure – Substantial decay, cracking, splitting, or crushing of primary members may be present, requiring replacement. Section loss of greater than five percent may be present. Extensive exposure of piles as a result of erosion, thus reducing penetration and affecting the stability of the unit, may also be present. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present, along with wingwall rotation, causing roadway settlement. Severe impact damage may be present.

Masonry Substructure – Structural cracks or settlement with advanced deterioration of the masonry units and mortar may be present. Additional backfilling is required. Extensive scouring or undermining of the footing is affecting the stability of the unit and requires corrective action. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present, along with wingwall rotation, causing roadway settlement. Severe impact damage may be present.

3 SERIOUS CONDITION – Loss of section, deterioration, spalling, or scour have seriously affected primary structural components, making local failures possible. Fatigue cracks in steel or shear cracks in concrete may be present.

Indiana Supplemental Rating Guidelines:

Concrete Substructure – Severe disintegration may be present. The reinforcing steel is exposed with advanced stages of corrosion. There is severe section loss in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.

Steel Substructure – There is severe section loss of greater than 10 percent in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.

Timber Substructure – There is severe section loss in critical stress areas and section loss of greater than 10 percent of the cross-sectional area. Bearing areas are seriously deteriorated with considerable loss of bearing. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.
Masonry Substructure – Severe disintegration of the masonry units and mortar may be present. There is severe section loss in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.

![Figure 4:5-53: Railroad Bridge With Settled Pier](image)

2 **CRITICAL CONDITION** – Advanced deterioration of primary structural elements exists. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

**Indiana Supplemental Rating Guidelines:**

**Concrete Substructure** – The concrete cap is soft and spalling, with reinforcing steel exposed with no bond to concrete. The top of the cap is split, or a pillar has undergone a shear failure. Scouring is sufficient and the substructure is near a state of collapse. Piers or bents have settled.

**Steel Substructure** – Members have critical section loss. Holes in the web and/or knife-edged flanges are typical. Scouring is sufficient and the substructure is near a state of collapse. Piers or bents have settled.

**Timber Substructure** – The primary members are crushed or split and ineffective. Piers or bents have settled. Section loss of greater than 20 percent of the cross-sectional area may be present.

**Masonry Substructure** – Scouring is sufficient and the substructure is near a state of collapse. Piers or bents have settled.
### “IMMINENT” FAILURE CONDITION
Major deterioration or section loss is present in critical structural components, or obvious vertical or horizontal movement affecting structural stability is present. The bridge is closed to traffic, but corrective action may put it back in light service.

### FAILED CONDITION
The bridge is out-of-service and beyond corrective action.

One suggested method for establishing a substructure rating is to identify phrases within the general condition/Indiana supplemental guideline language that describe a substructure condition more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose a reinforced concrete substructure has extensive delaminations, plus spalling with exposed reinforcing steel. The spalls occur on the tension side of the caps and on random sides of the piers or pillars, but section loss of the reinforcing steel is minimal. Condition rating 4 indicates that there is advanced deterioration and spalling. Condition rating 3 indicates that deterioration and spalling have seriously affected the primary structural components, and that the reinforcing steel is in the advanced stages of corrosion. Using the method described above, Condition rating 3 describes a situation more severe than what actually exists on the substructure. Therefore, a rating of 4 would be appropriate.

Another way to help narrow down the substructure rating number is to group the numbers in more general categories. Ratings of 9 to 7 apply to substructures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition. It is important to note that there is a significant change from a substructure in condition rating 5 (minor section loss, but structural elements sound) to condition rating 4 (advanced section loss and advanced deterioration). A reduction in load-carrying capacity can be calculated when a substructure enters condition rating 4.
## SECTION 5.11 ADDITIONAL SUBSTRUCTURE ITEMS

Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 60, the NBI substructure condition rating. Each item shall be rated as follows unless noted:

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<tr>
<th>Rating</th>
<th>Condition</th>
</tr>
</thead>
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<tr>
<td>N</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition</td>
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<td>8</td>
<td>Very Good Condition</td>
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<td>5</td>
<td>Fair Condition</td>
</tr>
<tr>
<td>4</td>
<td>Poor Condition</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition</td>
</tr>
<tr>
<td>1</td>
<td>Imminent Failure Condition</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition</td>
</tr>
</tbody>
</table>

### ITEM 60.01 – ABUTMENT BRIDGE SEAT

The bridge seat, sometimes called a bearing seat, is the top surface of the breastwall (stem) upon which the bearing devices for the superstructure are placed. Pedestals are sometimes constructed on the bridge seat, generally built when the bearing device was changed in a rehab. Pedestals should be noted when rating this item.

![Figure 4:5-54: Backwall, Bridge Seal, and Breastwall (Stem)](image-url)
Figure 4:5-55: Bridge Seat and Pedestal With No Noteworthy Deficiencies

Figure 4:5-56: Bridge Seat With Deterioration, Spalls, and Cracking
ITEM 60.02 – ABUTMENT BACKWALL

Backwalls are the section of an abutment or end bent that retains the soil under the approach from spilling onto the bearing seat. The back side, the side away from the bridge, may also provide support for concrete approaches and provide anchorage for expansion joint devices. This is sometimes incorrectly referred to as a mudwall. However, mudwalls are end diaphragms between beams/girders that bear directly on a bridge seat, when no bearing devices are used. Mudwalls serve the same function of retaining soil from the approach.

![Abutment Backwall With Vertical Crack](Image)

Figure 4:5-57: Abutment Backwall With Vertical Crack

ITEM 60.03 – ABUTMENT BREASTWALL

The breastwall, or stem, is the main body of the abutment. It functions to deliver the superstructure reaction loads to the foundation and to retain much of the soil behind the abutment.
ITEM 60.04 – ABUTMENT BENT CAP

On pile abutments, a bent cap ties the piles together and also functions as a bridge seat. There are many types of bent caps. On newer integral concrete abutments, where the cap is only partly visible, it can be difficult to determine where the pile cap ends and the superstructure begins.
ITEM 60.05 – WINGWALLS

Rate the condition of any bridge wingwalls. Note the type of wingwall. Wingwalls for culverts and underfill structures are coded under Item 62.11, described in Part 4, Chapter 9 of this manual. For integral abutments, use this to rate the condition of the cheek wall. If piles are used, and visible, describe them here and rate them under Item 60.07. Note any visible piles here.

Figure 4:5-60: Masonry Wingwall in Good Condition

Figure 4:5-61: Wingwall With Mortar Deterioration
Figure 4:5-62: Reinforced Concrete Wingwall in Good Condition

Figure 4:5-63: Concrete Wingwall With Advanced Deterioration
Figure 4:5-64: Reinforced Concrete Wingwall

Figure 4:5-65: Timber Wingwall in Good Condition
ITEM 60.06 – FOOTINGS

Rate the condition of any visible footings. Note the type and size of any footings.

ITEM 60.07 – PILES

Describe and rate the condition of any exposed piles, including piles used as pillars in a bent and piles used on the wingwalls. Note if the piles are on the wingwalls.
Figure 4:5-68: Concrete Pile With Severe Section Loss

Figure 4:5-69: Wood Piles
ITEM 60.08 – SCOUR/UNDERMINING FOR ABUTMENTS

Rate the condition of the scour or undermining for abutments in the water. This will be coded “N” if the structure is not over water. This is a rating of the conditions noted in the field and is not the scour assessment rated under Item 113.

8  Pile-supported footing with channel bottom above the footing
5  Pile-supported footing; channel bottom within the footing; no undermining; spread footing with channel bottom above the footing; unknown footing with channel bottom above the footing
3  Spread footing with channel bottom within the footing; no undermining
1  Footing is undermined

ITEM 60.09 – EROSION/UNDERMINING FOR ABUTMENTS

Rate the condition of the erosion or undermining for abutments and wingwalls not in the water.
ITEM 60.10 – CONCRETE SLOPE WALLS

Rate the condition of the concrete slope walls, paver stones on slope walls, and blocks on slope walls.

Figure 4:5-71: Concrete Slope Wall With Cracks

Figure 4:5-72: Concrete Slope Wall With Displacement
ITEM 60.11 – SETTLEMENT OF THE ABUTMENTS

Rate any noticeable settlement of the abutments. Notes and measurements are required for any rating of 5 or less.

- **7 Good Condition** – no noticeable settlement
- **6 Satisfactory Condition** – barely noticeable settlement
- **5 Fair Condition** – minor settlement
- **4 Poor Condition** – settlement affects structure
- **3 Serious Settlement**
- **2 Critical Settlement**
- **1 Imminent Failure Condition**
- **0 Failed Condition**

ITEM 60.12 – INTERMEDIATE PIER: PIER CAP

A pier or bent cap is the horizontal component of a pier where the bearing devices for the superstructure are placed. Rate the condition of the pier caps for any intermediate piers and note the material used: steel, timber, reinforced concrete, prestressed concrete, or post-tensioned concrete.

*Figure 4:5-73: Concrete Bent Cap With Widespread Spalling*
Figure 4:5-74: Bent Cap With Delaminations

Figure 4:5-75: Bent Cap With Corrosion
ITEM 60.13 – INTERMEDIATE PIER: COLUMN (SOLID STEM)

Rate the condition of the intermediate piers and pier walls. Rate the pillars in a multi-pillar bent under Item 60.14.
ITEM 60.14 – INTERMEDIATE PIER: CONCRETE PILLARS

Rate the condition of the concrete pillars in intermediate bents.
ITEM 60.15 – INTERMEDIATE PIER: CONCRETE PILES

Describe and rate the condition of any exposed concrete piles, including piles used as pillars in a bent.
ITEM 60.16 – INTERMEDIATE PIER: TIMBER PILES

Describe and rate the condition of any exposed timber piles, including piles used as pillars in a bent.

Figure 4:5-82: Timber Pile With Serious Decay at Ground Line

Figure 4:5-83: Split Timber Pile With Rot

Note the penetration of the screw driver in Figure 4:5-83.
ITEM 60.17 – INTERMEDIATE PIER: STEEL PILES

Describe and rate the condition of any exposed steel piles, including piles used as pillars in a bent.

Figure 4:5-84: Steel Pile

ITEM 60.18 – INTERMEDIATE PIER: FOOTING

Rate the condition of any visible footings for intermediate piers.

ITEM 60.19 – INTERMEDIATE PIER: CRASH WALLS

Rate the condition of the crash walls for any intermediate bents.

Figure 4:5-85: Bent With Crash Wall
ITEM 60.20 – INTERMEDIATE PIER: BRACINGS

Rate the condition of the bracings used for any intermediate bents.

Figure 4:5-86: Concrete Bent With Crash Wall

Figure 4:5-87: Intermediate Timber Bracings
ITEM 60.21 – INTERMEDIATE PIER: EROSION/UNDERMINING

Rate the erosion or undermining for any intermediate piers or bents. Erosion and undermining occur when water from the roadway washes away supporting material. This is a 0 to 9 condition rating and is not the scour assessment rated under Item 113.

ITEM 60.22 – INTERMEDIATE PIER: SCOUR/UNDERMINING

Rate the condition of the scour or undermining for any intermediate piers or bents units in the water. This will be coded “N” if the structure is not over water. This is a rating of the conditions noted in the field and is not the scour assessment rated under Item 113.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Pile supported footing with channel bottom above the footing</td>
</tr>
<tr>
<td>5</td>
<td>Pile supported footing; channel bottom within the footing; no undermining; spread footing with channel bottom above the footing; unknown footing with channel bottom above the footing</td>
</tr>
<tr>
<td>3</td>
<td>Spread footing with channel bottom within the footing; no undermining</td>
</tr>
<tr>
<td>1</td>
<td>Footing is undermined</td>
</tr>
</tbody>
</table>

ITEM 60.23 – INTERMEDIATE PIER: SETTLEMENT

Use the following scale to rate any noticeable settlement for intermediate piers and bents. Notes and measurements are required for any rating of 5 or less.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td><strong>Good Condition</strong> – no noticeable settlement</td>
</tr>
<tr>
<td>6</td>
<td><strong>Satisfactory Condition</strong> – barely noticeable settlement</td>
</tr>
<tr>
<td>5</td>
<td><strong>Fair Condition</strong> – minor settlement</td>
</tr>
<tr>
<td>4</td>
<td><strong>Poor Condition</strong> – significant settlement</td>
</tr>
<tr>
<td>3</td>
<td><strong>Serious Settlement</strong></td>
</tr>
<tr>
<td>2</td>
<td><strong>Critical Settlement</strong></td>
</tr>
<tr>
<td>1</td>
<td><strong>Imminent Failure Condition</strong></td>
</tr>
<tr>
<td>0</td>
<td><strong>Failed Condition</strong></td>
</tr>
</tbody>
</table>

ITEM 60.24 – GENERAL DETERIORATION: CONCRETE

Rate the general condition of the substructure concrete.
ITEM 60.25 – GENERAL DETERIORATION: STEEL

Rate the general condition of the substructure steel.
ITEM 60.26 – GENERAL DETERIORATION: TIMBER

Rate the general condition of the substructure timber.

ITEM 60.27 – GENERAL DETERIORATION: EPOXY COATING

Rate the general condition of the epoxy coating of any coated steel in the substructure.
ITEM 60.28 – GENERAL DETERIORATION: DEBRIS ON BRIDGE SEATS

Rate the amount of debris on the bridge seats, using the following guidelines:

9  No debris
7  Minor debris, but not affecting action of the bearings
5  Significant debris, but not affecting action of the bearings
3  Debris is affecting action of the bearings or is trapping moisture
1  Debris has caused failure of the bearing

Figure 4:5-92: Debris on Bridge Seat, Trapping Moisture

ITEM 60.29 – GENERAL DETERIORATION: COLLISION DAMAGE

Rate the damage to the substructure from collisions. Note all scrapes. When one member has been hit, check all members beyond the point of impact for damage. The full extent of damage may not be noticeable immediately after impact.
ITEM 60.30 – PLUMB: ABUTMENTS
Enter “Yes,” “No,” or “N/A.” Note direction and description of any problem in the notes.

ITEM 60.31 – PLUMB: PIERS
Enter “Yes,” “No,” or “N/A.” Note direction and description of any problem in the notes.

ITEM 113B.01 – TOTAL NUMBER OF ALL PIERS
Enter the total number of bridge piers or bents.

ITEM 113B.02 – ABUTMENT #1 TYPE
Enter the type of abutment #1 from the code list below. This will be the abutment at the south or west end of the bridge unless the bridge ends at another substructure of another bridge.

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Concrete spread footing; no piles</td>
</tr>
<tr>
<td>B</td>
<td>Timber spread footing; no piles</td>
</tr>
<tr>
<td>C</td>
<td>Stone spread footing; no piles</td>
</tr>
<tr>
<td>D</td>
<td>Concrete spread footing on piles</td>
</tr>
<tr>
<td>E</td>
<td>Concrete bent cap on soil on piles</td>
</tr>
</tbody>
</table>
ITEM 113B.03 – ABUTMENT #2 TYPE

Enter the type of abutment #2. This will be the abutment at the north or east end of the bridge unless the bridge ends at another substructure of another bridge. The code is as shown above in Item 113B.02.

ITEM 113B.05 – NUMBER OF INTERMEDIATE PIERS

Enter the number of intermediate bridge piers/units.

ITEM 113B.06A – TYPE OF INTERMEDIATE PIERS

Enter the type of intermediate pier or bent used on the bridge that is most critical for scour.

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Concrete spread footing; no piles</td>
</tr>
<tr>
<td>B</td>
<td>Timber spread footing; no piles</td>
</tr>
<tr>
<td>C</td>
<td>Stone spread footing; no piles</td>
</tr>
</tbody>
</table>
## BRIDGE INSPECTION MANUAL

## PART 4: BRIDGE INSPECTION

### Additional Substructure Ratings

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Concrete spread footing on piles</td>
</tr>
<tr>
<td>E</td>
<td>Concrete bent cap on soil on piles</td>
</tr>
<tr>
<td>F</td>
<td>Steel H-columns extending out of the ground</td>
</tr>
<tr>
<td>G</td>
<td>Steel shells extending out of the ground</td>
</tr>
<tr>
<td>H</td>
<td>Steel caissons extending out of the ground</td>
</tr>
<tr>
<td>I</td>
<td>Timber bent extending out of the ground</td>
</tr>
<tr>
<td>J</td>
<td>Concrete piles, plus steel shell or H-column encased</td>
</tr>
<tr>
<td>K</td>
<td>Concrete piles, plus steel reinforcing encased</td>
</tr>
<tr>
<td>L</td>
<td>None (for some multi-plate arches, etc.)</td>
</tr>
<tr>
<td>M</td>
<td>Other (describe)</td>
</tr>
<tr>
<td>N</td>
<td>Not applicable</td>
</tr>
<tr>
<td>O</td>
<td>Unknown foundation type</td>
</tr>
<tr>
<td>P</td>
<td>Timber bent cap; cap on soil; piles buried</td>
</tr>
<tr>
<td>Q</td>
<td>Combination A and I (pier widening)</td>
</tr>
<tr>
<td>R</td>
<td>Combination A and D (pier widening)</td>
</tr>
<tr>
<td>S</td>
<td>Other combinations (pier widening)</td>
</tr>
<tr>
<td>T</td>
<td>Combination A and C (pier widening)</td>
</tr>
<tr>
<td>U</td>
<td>Integral bent on piles on soil</td>
</tr>
</tbody>
</table>

### ITEM 113B.06B – TYPE OF INTERMEDIATE PIERS

Enter the second most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

### ITEM 113B.06C – TYPE OF INTERMEDIATE PIERS

Enter the third most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

### ITEM 113B.06D – TYPE OF INTERMEDIATE PIERS

Enter the fourth most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.
ITEM 113B.06E – TYPE OF INTERMEDIATE PIERS

Enter the fifth most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

ITEM 113B.06F – TYPE OF INTERMEDIATE PIERS

Enter the sixth most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

ITEM 113.08 – NUMBER OF PIERS IN WATER

Enter the number of piers or bents that are currently in water. If this is different than the number normally in the water, explain in the notes. This number is used in state underwater contracts as a limit on the number of units that an Underwater Consultant can inspect without permission of the State Program Manager.

ITEM 113.09 – NUMBER OF PIERS WITH SCOUR

Enter the number of piers or bents with scour. Identify which piers or bents have scour in the notes.

ESTIMATED REMAINING LIFE

Enter the estimated remaining life, in years, of the substructure in the Central Database. Assume no repair work will be completed.
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Approaches are the slabs or roadways located on either end of the bridge. Approaches need to be monitored because they can affect the safety and serviceability of a bridge. A poor approach can increase impact loads to the bridge deck and the end expansion joints. It can also reduce the safety of the bridge, leading to vehicle impacts to the structure.

Figure 4:6-1: Concrete Approach
SECTION 6.2  APPROACH INSPECTION

The primary function of the approach is to provide a smooth transition between the roadway pavement and the bridge deck. This smooth transition decreases the impact forces on the bridge superstructure, increasing bridge safety and driver comfort.

The pavement structure varies with the type of approach roadway. Bituminous approaches utilize a bituminous wearing surface over a concrete or bituminous subbase. Concrete approaches are constructed with a concrete slab over an aggregate subbase and a relief joint. The subgrade material for these approaches is the prepared and compacted soil or gravel immediately beneath the approach. Gravel approaches are installed over compacted fill.

Vertical settlement of the approach is caused by the consolidation or loss of the subgrade materials. Settlement is especially a problem near the abutment. Heave or uplift can also occur due to rotation of the abutment or the expansion of frozen subgrade material.

The riding surface of any approach should be smooth, free of potholes, and properly sloped for drainage. Embankment slopes along the roadway shoulder should have adequate vegetation or riprap to provide erosion control. Roadway inlets located in the approach area should be in good condition and fully operational. Joints between the approach and the abutment backwall should be examined. Joints designed for thermal movement must be checked for movement and leaking.

Subsection 6.2.1  Concrete Approaches

A concrete approach is a reinforced concrete slab that bears on the abutment at one end. The opposite end bears on a sleeper slab or compacted fill. A sleeper slab is a strip footing running the width of the approach. The approach slab functions as a reinforced concrete bridge designed to span between the abutment and the sleeper slab. If there is no sleeper slab, the concrete approach slab bears on the compacted fill. If these approach slabs are not reinforced, they are subject to flexural cracking as the fill settles.

Modern design calls for a concrete approach slab to be connected to the abutment with a minimal amount of reinforcing to allow for movement of the slab. The slab is poured with the deck and saw cut over the reinforcing.

Concrete approaches on concrete roadways typically have a pavement relief joint between the approach and the roadway pavement. A relief joint is a strip of asphalt that compresses as the roadway pavement expands or migrates towards the bridge. Compression of this relief joint reduces the roadway pavement lateral load on the approach and abutment backwall.
Inspection of concrete approaches should include the following:

- Look for settlement or heaving of the approach roadway. If settlement has occurred, check for evidence of a crack close to the center of the approach. Settlement may be caused by lost fill material under or around the abutment.

- Look for common concrete defects in the approach, such as potholes, cracking, and dips. Cracking, unevenness, or movement under traffic in a concrete approach may indicate a void under the approach from fill settlement, erosion, or pumping.

- Examine the joint between the approach and the abutment backwall. Some of these joints are designed for thermal movement. Determine if there is adequate clearance to provide for this movement. If the joint was designed for a water seal, determine if the seal is leaking.

- Examine the embankments and slopes for evidence of erosion or undermining.

- Check the drainage system for evidence that it is operating properly.

- Notify the bridge owner of any approach settlement that forces motorists to slow down.

![Figure 4:6-2: Concrete Approach With Wide Cracks](image)
Subsection 6.2.2  Bituminous Approaches

A bituminous approach consists of asphalt paving placed over a concrete or bituminous subbase and compacted fill material. Inspection of bituminous approaches should include the following:

- Check for approach settlement. Pronounced settling will be evident if the top corner of the abutment backwall or paving notch is exposed, or a significant dip in the approach pavement is evident. Settlement may be caused by lost fill material under or around the abutment.

- Look for ruts in the wheel paths of the traffic lane(s).

- Look for approach cracking.

- Look for potholes or localized dips in the approach. Dips may be caused when fill has washed out underneath the approach pavement.

- Check for approach raveling. Raveling is the progressive separation of aggregate from the asphalt binder. The pavement surface will have a gravel-like appearance.

- Check for approach shoving, which will have the appearance of transverse ripples. Shoving is caused by a lack of pavement structure stability.

- Examine the embankments and slopes for evidence of erosion or undermining.

- Check that the drainage system is operating properly.

- Notify the bridge owner of any approach settlement that forces motorists to slow down.

Figure 4:6-3: Bituminous Approach Roadway in Very Good Condition
Figure 4:6-4: Bituminous Approach Roadway With Cracks

Figure 4:6-5: Bituminous Approach With Wedge
Figure 4.6-6: Bituminous Approach Roadway With Transverse Cracks

Subsection 6.2.3 Gravel Approaches

Gravel approaches are used on unpaved roads in rural areas with very low traffic volumes. Inspection of gravel approaches should include the following:

- Check for potholes or depressions. Potholes or depressions can be a safety hazard to motorists and can increase traffic impact on the bridge.
- Look for ruts in the wheel paths of the traffic lane.
- Check for approach gravel that has pushed onto the bridge deck.
- Look for approach gravel material that has washed off of the roadway.
- Examine the embankments and slopes for evidence of erosion or undermining.
- Check that the drainage system is operating properly.
SECTION 6.3 NBI APPROACH ALIGNMENT RATING

The National Bridge Inventory (NBI) rating for the approach alignment (Item 72) is based on the adequacy of the approach roadway alignment. It identifies bridges which do not function properly or adequately due to the alignment of the approaches. The roadway alignment is compared to the existing highway alignment, not current standards.

For example, if the highway alignment requires a substantial reduction in speed, and the approach only requires a minor additional reduction in speed, the rating would be 6.

Speed reductions necessary because of the width of the bridge and not the alignment are not considered in evaluating this item.

Rate the reduction in speed over one bridge length or 200 feet, whichever is greater, in accordance with the following criteria:

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – no speed reduction required</td>
</tr>
<tr>
<td>6</td>
<td>SATISFACTORY CONDITION – a very minor speed reduction of less than five mph is required</td>
</tr>
<tr>
<td>4</td>
<td>POOR CONDITION – a speed reduction between five and 10 mph is required</td>
</tr>
<tr>
<td>3</td>
<td>SERIOUS CONDITION – horizontal or vertical alignment requires a substantial reduction of more than 10 mph in the vehicle operating speed from that on the highway section</td>
</tr>
<tr>
<td>1</td>
<td>FAILURE CONDITION – vehicles must slow to 10 mph or less before driving onto the bridge</td>
</tr>
</tbody>
</table>

The rating for NBI Item 72 must be entered in the Central Database.
The following items pertaining to the approaches are required to be rated and entered into the Central Database for state bridges. Each item shall be rated as a stand-alone item, assessing its condition independently. Each item shall be rated as follows unless otherwise noted:

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted; functioning as designed
7  Good Condition – some minor problems, but functioning as designed
6  Satisfactory Condition – minor problems, but functioning as designed
5  Fair Condition – minor deterioration, but functioning as designed
4  Poor Condition – advanced deterioration or not able to function as designed
3  Serious Condition – deterioration or inadequate to function as designed
2  Critical Condition – deterioration and inadequate to function as designed
1  Imminent Failure Condition – unsafe
0  Failed Condition – beyond corrective action

ITEM 72.01 – ALIGNMENT FOR THE ROADWAY CARRIED ON THE BRIDGE

This condition rating is the rating described in Section 6.3 for NBI Item 72. The rating reflects any speed reduction required from the speed on the highway. Rate the reduction in speed over one bridge length or 200 feet, whichever is greater, in accordance with the following:

8  VERY GOOD CONDITION – no speed reduction required
6  SATISFACTORY CONDITION – a very minor speed reduction of less than five mph is required
4  POOR CONDITION – a speed reduction between five and 10 mph is required
3  SERIOUS CONDITION – horizontal or vertical alignment requires a substantial reduction of more than 10 mph in the vehicle operating speed from that on the highway section
1  FAILURE CONDITION – vehicles must slow to 10 mph or less before driving onto the bridge
ITEM 72.02 – APPROACH SLAB FOR THE ROADWAY CARRIED ON THE BRIDGE

The condition rating reflects the overall condition of the bridge approach slabs, including settlement, potholes, cracking, dipping, rutting, shoving, pushing, and the condition of the drainage system.

ITEM 72.03 – RELIEF JOINTS FOR THE ROADWAY CARRIED ON THE BRIDGE

A relief joint is a strip of asphalt that compresses as the roadway pavement expands or migrates towards the bridge. Compression of this relief joint minimizes the roadway pavement from pushing on the approach and abutment backwall. Rate the overall condition of the joints.

ITEM 72.04 – APPROACH GUARDRAIL FOR THE ROADWAY CARRIED ON THE BRIDGE

Rate the condition of the guardrail and the adequacy of the guardrail to redirect vehicles safely compared to new guardrail meeting existing guardrail standards.

ITEM 72.05 – PAVEMENT ON THE ROADWAY CARRIED ON THE BRIDGE

Rate the overall condition of the approach pavement for the roadway carried on the bridge, including potholes, cracking, dipping, rutting, shoving, pushing, and the condition of the drainage system. Rate the pavement over one bridge length, or 200 feet, whichever is greater.

ITEM 72.06 – SHOULDERS ON THE ROADWAY CARRIED ON THE BRIDGE

Rate the overall condition of the shoulders, including slope stability and safety.

ITEM 72.07 – MEDIAN ON THE ROADWAY CARRIED ON THE BRIDGE

Rate the median for its ability to safely separate traffic.

ITEM 72.08 – ALIGNMENT FOR THE ROADWAY UNDER THE BRIDGE

Rate the reduction in speed of the roadway passing under the bridge over one bridge length, or 200 feet, whichever is greater, in accordance with the following:

8  VERY GOOD CONDITION – no speed reduction required
6  SATISFACTORY CONDITION – a very minor speed reduction of less than five mph is required
4  POOR CONDITION – a speed reduction between five and 10 mph is required
ITEM 72.09 – GUARD RAIL FOR THE ROADWAY UNDER THE BRIDGE

Rate the condition of the guard rail along the roadway under the bridge and the adequacy of the guard rail to redirect vehicles safely, as compared to new guardrail meeting existing guardrail standards.

ITEM 72.10 – IMPACT ATTENUATORS FOR THE ROADWAY UNDER THE BRIDGE

Rate the ability of the impact attenuators to provide a safe cushion in a crash.

ITEM 72.11 – PAVEMENT FOR THE ROADWAY UNDER THE BRIDGE

Rate the overall condition of the roadway under the bridge, including potholes, cracking, dipping, rutting, shoving, pushing, and the condition of the drainage system.

ITEM 72.12 – SPEED REDUCTION FOR THE ROADWAY CARRIED ON THE BRIDGE

This rating reflects any speed reduction required for the roadway carried on the bridge from the speed on the highway:

1. Substantial; over five mph
2. Minor; less than five mph
3. None

ITEM 72.13 – SPEED REDUCTION FOR THE ROADWAY UNDER THE BRIDGE

This rating reflects any speed reduction required for the roadway carried on the bridge from the speed on the highway.

1. Substantial; over five mph
2. Minor; less than five mph
3. None

ITEM 72.14 – POSTED SPEED LIMIT FOR THE ROADWAY CARRIED ON THE BRIDGE

Enter the posted speed limit for the roadway carried on the bridge.
ITEM 72.15 – POSTED SPEED LIMIT FOR THE ROADWAY UNDER THE BRIDGE

Enter the posted speed limit for the roadway under the bridge. If there is more than one roadway under the bridge, input the highest speed limit and list the other speed limits in the notes.

ITEM 72.16 – EMBANKMENT

Enter the overall condition of the embankment along the roadway, not along the channel.

ITEM 72X – OVERALL CONDITION RATING

Enter the overall condition rating for the approach, including pavement condition, alignment, and drainage. This can be different than Item 72.

ITEM 72X – RATING BASIS

Describe what item(s) governed the Item 72X rating.

ITEM 63XF – ESTIMATED REMAINING LIFE OF APPROACH FEATURES

Estimate the life in years of the approach features, assuming no work will be done. Enter this data in the Central Database.
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PART 4: BRIDGE INSPECTION

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For any structure crossing a waterway, scour, flooding, and drift or debris buildup can affect the stability of a bridge. Scour at substructure foundations can cause instability and bridge failures. Flooding can cause failures due to scour of the substructure, erosion of the embankment, or lateral water flow pressures on the bridge. Drift and debris aggradations can impart loads on substructure units for which they were not designed, as well as create conditions causing scour and flooding.

This chapter discusses the interaction between scour, the channel condition, waterway adequacy, and the bridge foundation. It also describes how to inspect the channel and channel protection, assess the waterway adequacy, inspect a bridge for scour, and prepare a scour Plan of Action.

Figure 4:7-1: Erosion Behind a Wingwall
SECTION 7.2 CHANNEL AND CHANNEL PROTECTION

Subsection 7.2.1 Introduction

Channel and Channel Protection Inspections are required to identify conditions which could damage the bridge. Bridge damage related to the condition of the channel is usually from the undermining of the substructure units and/or exposure and deterioration of the substructure units. It is imperative to record and monitor the channel and channel protection conditions for any changes caused by natural or man-made circumstances. This can help establish the scour potential of a particular bridge site and allow inspectors to monitor the bridge and channel for change.

Subsection 7.2.2 Channel Protection

Scour is the removal of material from the streambed or embankment as a result of the erosive action of stream flow. Scour and inspecting for scour are discussed further in Section 7.4 of this chapter.

To guard against the effects of scour, the channel banks must be protected and the stream must be controlled. Channel protection and hydraulic control structures include both natural and man-made features. Natural channel protection includes banks with well-established vegetation and streambeds consisting of bedrock or boulders. Man-made control structures and channel protection include the following:

- **Riprap** – large stones or boulders placed along the bank or substructure units that rely on their mass for stability against the flow of water. Riprap may be natural or man-made. It is usually placed on a geotextile fabric to prevent erosion of the soil underneath. Designed scour countermeasures must be in accordance with the Indiana Department of Transportation (INDOT) Design Manual. See Figure 4:7-2 for an example of riprap protection.

- **Channel lining** – a layer of concrete across all or part of the channel. It provides a hard, nonerodible surface, and also increases the flow rate of the stream to drain the upstream region more quickly. See Figure 4:7-3 for an example of protection with concrete channel lining.

- **Erosion control mats** – interconnected concrete bags or blocks placed in the channel bottom or embankments as an armor layer. Geotextile fabric can be placed under the mats.

- **Gabions** – wire mesh baskets filled with stone. The baskets are normally tied to each other and anchored to the bank. They are used in a similar manner to riprap, but may be placed on steeper slopes.

- **Slope stabilization** – treatment of the existing bank with plantings, geotextile, or wire mesh to prevent erosion. See Figure 4:7-4 for an example of slope protection utilizing well-established vegetation.
- **Guide banks/wing dams** – devices that direct/control natural stream flows to protect against abutment scour.

- **Spur dikes** – devices constructed to redirect flows smoothly through the bridge waterway opening. They are used to protect the highway embankments by forcing scour to occur at the ends of the dikes.

![Figure 4:7-2: Riprap Channel Protection in Good Condition](image)

![Figure 4:7-3: Concrete Channel Lining Protection](image)
Subsection 7.2.3 Inspection

The channel condition rating covers the areas immediately upstream, downstream, and directly under the bridge. The type of waterway has a significant influence on the condition of a channel. Fast-flowing water can cause channel changes and increase the likelihood of scour and erosion problems. Slow-flowing water can create channel obstructions and location changes due to debris and ice buildup. Lake channels are subject to aggradations and location changes. Levees are earthen flood control structures along a river and their inspection is not a part of this manual.

Channel inspection should include the following:

- Look for stable banks upstream and downstream of the bridge. Stable banks will be gradually sloped and well-vegetated.
- Probe around the substructure unit bases with a rod to check for areas of local scour.
- Check for evidence of structure settlement due to scour, such as substructure rotation, differential settlement, and lateral movement or misalignment of the superstructure or railing. A plumb bob or sighting along the bridge railing can often help in making this determination.
- Check the condition of channel protection devices. Riprap should be firmly in place on the banks and not scattered throughout the channel. Erosion control mats and channel linings should not be undermined. Guide banks and spur dikes should be stable.
- Look for evidence of bank instability, such as sloughing due to scour and lateral steam movements.
- Look for debris or sediment buildup that could redirect the stream flow.
Look for debris caught on the upstream end of piers or between pier columns. This can create localized increased water velocities and lead to scour.

Look for signs of streambed degradation, such as exposed bridge substructure elements or exposed utility crossings that were previously buried.

Note any signs of lateral stream movement. The waterway should normally be centered under the structure and flow should be parallel to the substructure units. Sketches or photographs should be taken during each inspection to monitor the alignment.

Check for obstructions to stream flow such as cattle guards and fences. These can trap debris, possibly causing sediment buildup and redirection of the stream flow.

Check for evidence of stream flow within the floodplain, such as bent plant material or waterborne debris.

Note obstructions within the floodplain, such as trees or buildings. These affect the main channel stream flow during floods.

Check if stream flow is impinging behind protective devices. For example, stream flow should not be pooling on the upstream side of a wing wall.

Look for evidence of overtopping by floodwaters. This may include damaged girder bottom flanges or truss bottom chords, drift or debris lodged between girders, cross-frames, bearing areas, scrape or water marks on surrounding trees, or bearings exhibiting transverse displacements.

Figure 4:7-5: Stable Upstream Channel
Subsection 7.2.4  NBI Rating for Channel and Channel Protection

The channel and channel protection condition rating, National Bridge Inventory (NBI) Item 61, is concerned with water flow, channel protection, channel damage due to flow, and waterway stability. Damage to any part of the bridge should be reflected in the corresponding NBI condition rating for the component that is damaged.

Rating the channel and channel protection is done according to the Federal Highway Administration (FHWA) General Condition Rating Guidelines. The numeric condition ratings describe existing channel and channel protection devices compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in new or excellent condition, and 0 describing failed devices.

A proper rating will consider the severity of the deterioration and the extent to which the deterioration affects the channel condition and performance. Because only a single number is used to rate the channel and its protection, the rating must characterize its overall condition. The rating should not be used to describe local areas of deterioration. Local areas of deterioration should be described in notes provided with the inspection. However, widespread riprap washouts or large quantities of trash/debris located within the channel, for example, would influence the rating.

The channel and channel protection general condition ratings are as follows:

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE – use only when bridge is not over a waterway</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION – no noticeable or noteworthy deficiencies which affect the condition of the channel</td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – banks are protected or well-vegetated; river control devices, such as spur dikes and embankment protection, are not required or are in a stable state</td>
</tr>
<tr>
<td>7</td>
<td>GOOD CONDITION – bank protection is in need of minor repair; river control devices and embankment protection show minor damage; banks and/or channel have minor amounts of drift</td>
</tr>
<tr>
<td>6</td>
<td>SATISFACTORY CONDITION – bank is beginning to slump; river control devices and embankment protection have widespread minor damage; minor streambed movement evident; debris is restricting the channel slightly</td>
</tr>
<tr>
<td>5</td>
<td>FAIR CONDITION – bank protection is being eroded; river control devices and/or embankment have major damage; trees and brush restrict the channel; signs of lateral movement may be present</td>
</tr>
</tbody>
</table>
4  POOR CONDITION – bank and embankment protection is severely undermined; river control devices have severe damage; large deposits of debris are in the channel; significant channel migration may be present

3  SERIOUS CONDITION – bank protection has failed; river control devices have been destroyed; streambed aggradation, degradation, or lateral movement has changed the channel to now threaten the bridge and/or approach roadway; debris/drift piles block more than half the channel and/or flood plain

2  CRITICAL CONDITION – channel has changed to the extent the bridge is near a state of collapse; debris/drift piles completely block the channel and/or flood plain

1  IMMINENT FAILURE CONDITION – bridge closed because of channel failure; corrective action may put it back in light service

0  FAILED CONDITION – bridge closed because of channel failure; replacement necessary

One suggested method for establishing the channel and channel protection rating is to identify phrases within the general condition guideline language that describes a condition more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose the channel has extensive sloughing upstream, plus small amounts of debris within the channel. The sloughing has caused the stream to begin pooling behind one of the wing walls, but there is no evidence of scour/undermining. Condition rating 5 indicates that bank protection is being eroded, and that the embankment has major damage. Trees and brush also restrict the channel. Condition rating 4 indicates that bank and bank protection is severely undermined. River control devices have severe damage, and large deposits of debris are in the channel. Using the method described above, Condition rating 4 describes a situation more severe that what actually exists within the channel. Therefore, a rating of 5 would be appropriate.
Figure 4:7-6: Slumping Channel

Figure 4:7-7: Undermined Abutment
Subsection 7.2.5 Additional Channel and Channel Protection Items

State-owned bridges must be rated for the following channel and channel protection items in addition to the items required by the National Bridge Inspection Standards (NBIS). Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 61, the NBI channel and channel protection condition rating. Each item shall be rated as follows unless noted:

- **N** Not Applicable
- **9** Excellent Condition
- **8** Very Good Condition
- **7** Good Condition
- **6** Satisfactory Condition
- **5** Fair Condition
- **4** Poor Condition
- **3** Serious Condition
- **2** Critical Condition
- **1** Imminent Failure Condition
- **0** Failed Condition
ITEM 61.01 – SCOUR/EROSION UPSTREAM

Enter the overall condition rating for the scour and erosion upstream of the bridge. Note the location, possible causes, and observations. Show the scoured and eroded areas on any drawings made for NBI Item 113.

ITEM 61.02 – SCOUR/EROSION DOWNSTREAM

Enter the overall condition rating for the scour and erosion downstream of the bridge. Note the location, any observations, and possible causes. Show the scoured and eroded areas on any drawings made for NBI Item 113.

ITEM 61.03 – DRIFT

Enter the overall rating for drift. Drift is the accumulation of branches and logs. Identify where drift is located and any plans to remove it. Note if this is a frequent problem and if drift has been removed in the past. Keep track of when drift has been removed and any work order or contract numbers, if available. Show the location of the drift on any drawings made for NBI Item 113.

![Figure 4:7-9: Dangerous Drift Buildup](image)

ITEM 61.04 – VEGETATION

Enter the overall condition rating for the vegetation. Recommend clearing, if necessary. Recommend that trees be cut back from truss bridges to keep leaves out of the lower chords. Trees should be cleared from around and under the bridge to prevent them from applying forces to the bridge. Trimmed vegetation under and around bridges will keep the channel, superstructure, and substructure functioning as designed. Trees must be trimmed, as needed, to allow access for the underbridge inspection machines.
ITEM 61.05 – CHANNEL CHANGE

Rate any changes in the depth of the channel, the angle of attack of the flow, or movement of the entire channel as follows:

N  NOT APPLICABLE – use only when bridge is not over a waterway

8  VERY GOOD CONDITION – no change in the depth of the channel, the angle of attack of the flow, or the location of the channel

6  GOOD CONDITION – less than 20 percent change in the depth of the channel; angle of attack is less than 10 degrees; minor change in the location of the channel

4  POOR CONDITION – less than 50 percent change in the depth of the channel; angle of attack is less than 20 degrees; significant change in the location of the channel

2  SERIOUS CONDITION – more than 50 percent change in the depth of the channel; angle of attack has increased to more than 20 degrees; location of the channel has moved to a point threatening a substructure unit

1  IMMINENT FAILURE CONDITION – bridge is closed because of changes in the channel; corrective action may put it back in light service

0  FAILED CONDITION – bridge is closed; replacement necessary

ITEM 61.06 – ADEQUACY OF OPENING

Rate the general condition of the waterway opening. This should match the rating given for NBI Item 71.
ITEM 61.07 – MISCELLANEOUS HYDRAULIC FEATURES

Identify the type and location of any miscellaneous hydraulic features, such as dams, weirs, or spur dikes. Enter the overall condition rating for any miscellaneous hydraulic features and how they influence the condition of the channel and channel protection.

![Figure 4:7-11: Cattle Guard Trapping Debris](image1)

ITEM 61.08 – CHANNEL PROTECTION

Enter the overall condition rating for the channel protection. Note any observed deficiencies in the channel protection.

![Figure 4:7-12: Natural Vegetated Channel Protection with Slumping Banks](image2)
ITEM 61.09 – TYPE

Enter the type of channel protection in place. Note and photograph any type of channel protection not listed below.

A Riprap
B Metal sheet piling
C Metal retaining walls with metal piles
D Timber retaining walls with timber piles
E Concrete retaining walls with concrete piles
F Sand bags
G Earth levee*
H Other
I Concrete slope wall
J Vegetation
N N/A; None

*A levee is an earthen flood control structure along a river. It does not provide channel protection, but is included here to allow the inspection team to note its presence.
Figure 4.7-14: Metal Sheet Piling Used to Deflect Debris

Figure 4.7-15: Sand Bags
Figure 4:7-16: Earth Levee

Figure 4:7-17: Other – Dam
Figure 4:7-18: Concrete Slope Wall

Figure 4:7-19: Vegetation
Rate the channel alignment for movement and/or location as follows. Note the angle of attack.

<table>
<thead>
<tr>
<th>Code</th>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not Applicable</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition</td>
<td>channel has not moved and is appropriately located</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition</td>
<td>minor streambed movement evident</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition</td>
<td>lateral movement has changed the channel to threaten the bridge and/or the approach roadway</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition</td>
<td>channel has moved to the extent that the bridge is near a state of collapse</td>
</tr>
<tr>
<td>1</td>
<td>Imminent Failure Condition</td>
<td>bridge is closed because of channel alignment; corrective action may put it back in light service</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition</td>
<td>bridge is closed because of channel alignment; replacement necessary</td>
</tr>
</tbody>
</table>

Figure 4:7-20: Channel Has Migrated
Figure 4:7-21: Bridge Closed Due to Channel Change
SECTION 7.3 WATERWAY ADEQUACY

Subsection 7.3.1 NBI Rating of Waterway Adequacy

Waterway adequacy is an appraisal of the existing bridge hydraulic opening. The hydraulic opening is the opening available for water to pass under the bridge. It is essentially an area bounded by the streambed, abutment faces, and the underside of the bridge superstructure.

The waterway adequacy appraisal considers overtopping frequency, as well as the significance of traffic delays caused by overtopping. Overtopping frequency can be obtained from a review of the historic records of the bridge, or an assessment of the adequacy of the bridge opening relative to the area drained. Figure 4:7-23 explains the coding for the rating of NBI Item 71, waterway adequacy. These ratings are a function of the roadway classification.

Inspectors should note sediment/debris accumulation or vegetation growth that may block or partially block the hydraulic opening. Inspectors should also note newly paved areas or developments that could increase the amount of runoff into the stream and increase high-water elevations.

Figure 4:7-22: Bridge With Flooded Approaches
### Functional Classification

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Bridge not over a waterway</td>
</tr>
<tr>
<td>9</td>
<td>Bridge deck and roadway approaches above flood water elevations (high water); chance of overtopping is remote</td>
</tr>
<tr>
<td>8</td>
<td>Bridge deck above roadway approaches; slight chance of overtopping roadway approaches</td>
</tr>
<tr>
<td>6</td>
<td>Slight chance of overtopping bridge deck and roadway approaches</td>
</tr>
<tr>
<td>4</td>
<td>Bridge deck above roadway approaches; occasional overtopping of roadway approaches with insignificant traffic delays</td>
</tr>
<tr>
<td>3</td>
<td>Bridge deck above roadway approaches; occasional overtopping of roadway approaches with significant traffic delays</td>
</tr>
<tr>
<td>2</td>
<td>Occasional overtopping of the bridge deck and roadway approaches with significant traffic delays</td>
</tr>
<tr>
<td>2</td>
<td>Frequent overtopping of the bridge deck and roadway approaches with significant traffic delays</td>
</tr>
<tr>
<td>2</td>
<td>Occasional or frequent overtopping of the bridge deck and roadway approaches with severe traffic delays</td>
</tr>
<tr>
<td>0</td>
<td>Bridge is closed</td>
</tr>
</tbody>
</table>

#### Figure 4.7-23: Item 71, Waterway Adequacy Appraisal Ratings

In rating waterway adequacy, the following are used to describe the likelihood of overtopping:

- Remote – greater than 100 years
- Slight – 11 to 100 years
- Occasional – three to 10 years
- Frequent – less than three years

In rating waterway adequacy, the following are used to describe the traffic delay:

- Insignificant – minor inconvenience; highway passable in a matter of hours
- Significant – traffic delays of up to several days
- Severe – long-term delays to traffic with resulting hardship
Subsection 7.3.2  Additional Waterway Adequacy Items

State-owned bridges must be rated for the following items, in addition to Item 71. Each item shall be rated as described.

ITEM 71.1X – OVERTOPPING POSSIBILITIES

Enter the possibility of overtopping in accordance with the definitions below. Provide comments specific to this item.

1  Remote – greater than 100 years
2  Slight – 11 to 100 years
3  Occasional – three to 10 years
4  Frequent – less than three years

ITEM 71.2X – OVERTOPPING TRAFFIC DELAYS

Enter the overall significance of traffic delays caused by overtopping in accordance with the definitions below. Provide comments specific to this item.

1  Insignificant – minor inconvenience; highway passable in a matter of hours
2  Significant – traffic delays of up to several days
3  Severe – long-term delays to traffic with resulting hardship
SECTION 7.4  SCOUR

Subsection 7.4.1  Introduction

Scour is the general or localized erosion of the streambed or bank material due to flowing water. Scour often occurs around obstructions in waterways, such as piers and abutments, or near debris. A scour critical bridge is a bridge with a foundation element that has been determined to be unstable due to observed scour at the bridge site, or due to the scour potential determined from a scour evaluation. Designed scour countermeasures are actions taken to correct an existing or potential scour problem. They have been evaluated by a hydraulic engineer for a specific bridge and location. Designed scour countermeasures may include the placement of riprap, installation of armoring along an embankment, or other means to reduce the likelihood of scour.

Subsection 7.4.2  Scour Evaluation Study

If a bridge is over water or has elements that could be submerged during a flood, the bridge needs to be evaluated for susceptibility to scour and to determine if countermeasures are required to ensure the stability of the structure. A Scour Evaluation Study is performed by the Division of Production for state-owned bridges, and by the Inspection Consultant for county or local bridges. A Scour Evaluation Study is performed for all new bridges, for bridges rehabilitated using Federal Aid funding, or if a bridge is being evaluated for scour countermeasures. The input from the inspection team is instrumental to the Scour Evaluation Study team in recommending a rating for NBI Item 113. Based on the recommendations in the Scour Evaluation Study and the input from the inspection team, the State Program Manager determines the rating for Item 113 for state bridges, and the Inspection Consultant determines the rating for toll road, county, or local bridges.

A Scour Evaluation Study considers the hydraulic, geotechnical, and structural characteristics of the bridge and the site where it is located. Details for conducting a Scour Evaluation Study are included in the FHWA Technical Advisory – T5140.23, Evaluating Scour at Bridges. The anticipated depth of scour is computed as a part of this study. The following data is considered in this evaluation:

- Existing and historic site conditions regarding the streambed, scour, and channel stability
- Soil borings or other data indicating the soil composition at and below the elevation of the streambed
- Stream discharge, slope, flow velocities, and the location and depth of backwaters
- The location, type, and skew of substructure units
- The angle of attack
- The flood history
Subsection 7.4.3 Scour Inspection

Scour can fail otherwise sound structures, so it is critical that bridges are inspected for scour during Initial Inspections, Routine Inspections, and as called for in the Plan of Action for any scour critical bridge. Underwater Inspections are required if it is not possible perform this inspection as a part of the Inventory and Routine Inspections. If probing indicates a changed condition, an In-Depth Channel Bottom Survey should be performed. If the inspection team concludes that the calculated scour depth identified in the Scour Evaluation Study is not consistent with the site conditions, they should recommend that the bridge be re-evaluated.

Probing the bridge substructure elements in water will provide information on local scouring or exposure of the foundation. Signs of scour include an exposed top or side of the footing. Unless the footing is embedded in the exposed bedrock, it is rare that the original design would call for the footing to be exposed. Also, excessively loose or unconsolidated sediment in the streambed can suggest an area of scour. When scour is found, the inspector should attempt to angle the probe to allow probing under the foundation. The conditions noted should be recorded and a recommended cycle for re-inspection established, based on the observed conditions, the likelihood of scour occurrence, and the criticality of the bridge for continued service.

Inspectors need to recognize and understand the relationships between the bridge, the stream, and the floodplain. Before beginning the inspection of a bridge for scour, the inspection team should review the existing plans and previous inspection reports. Items to review include:

- Previous scour evaluations to determine if the bridge is scour critical.
- Any scour Plan of Action previously developed for the bridge.
- Previous streambed cross sections.
- Aerial photographs or sketches that indicate the past position of the streambed.
- Bridge foundations shown on the plans (if any), including pile tip elevations.
- Sub-surface soil condition reports.
- Any special items to be checked during the inspection.
- All equipment needed to obtain streambed cross sections.
- Scour Committee reports for state-owned bridges.
The Scour Inspection should include the following:

- Probe around each substructure unit in water for scour and undermining.
- Record the location, length, width, and depth of any scour holes.
- Check for changes in the streambed elevation.
- Note the type of bed material.
- Check for changes in the streambed cross section or alignment. Note if the streambed has shifted to a different location. This is especially important for multi-span bridges.
- Check for the rotational movement or settlement of the substructure units.
- Check for any damage to any scour countermeasures such as the subsidence of armoring or loss of protection.
- Note if the bridge is narrower than the width of the stream or reservoir.
- Note any erosion of the embankment.
- Note drift or debris on the upstream side of the piers or abutments.
- Note if the embankments cross the floodplain or restrict water flow during periods of high water.
- Note aggressive stream characteristics such as high velocity, steep slope, or deep flow.
- Note the angle of attack.
- Note the condition of any substructure unit protection or countermeasures.

Figure 4:7-25: Flooded Bridge

04/02/2009 08:23
Subsection 7.4.4  NBI Rating of Scour

The NBI coding for Item 113 is shown in Figure 4:7-26. A bridge is considered scour critical if the foundations are determined to be unstable due to observed scour at the bridge site, or if the bridge has calculated or assessed scour potential. Item 113 is rated 4 if scour has been observed in the field and the foundation is stable, but action is required to protect exposed foundations. Item 113 is rated 3 if the bridge has assessed or calculated scour potential. Item 113 is rated 2 if the field review shows extensive scour has occurred and the foundation is not stable. Item 113 is rated 1 if the field review shows extensive scour has occurred and failure of piers/abutments is imminent. Item 113 is rated 0 if the bridge has failed.

When the scour rating is 2 or less, the foundation rating, Item 60, should be 2 or less.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>The bridge is not over a waterway.</td>
</tr>
<tr>
<td>U</td>
<td>This is a bridge with an unknown foundation that has not been evaluated for scour. Until the risk can be determined, a Plan of Action should be developed and implemented to reduce the risk to users from a bridge failure during and immediately after flood events. See Section 7.7.</td>
</tr>
<tr>
<td>9</td>
<td>The bridge foundations (including piles) on dry land are well above flood water elevations.</td>
</tr>
<tr>
<td>8</td>
<td>The bridge foundations are determined to be stable for the assessed or calculated scour condition. Scour is determined to be above the top of footing (see example A in Figure 4:7-27) by assessment (i.e., bridge foundations are on rock formations that have been determined to resist scour within the service life of the bridge), by calculation, or by installation of properly designed countermeasures.</td>
</tr>
<tr>
<td>7</td>
<td>Designed countermeasures have been installed to mitigate an existing problem with scour and to reduce the risk of bridge failure during a flood event. Instructions contained in a Plan of Action and have been implemented to reduce risk to users from a bridge failure during or immediately after a flood event.</td>
</tr>
<tr>
<td>6</td>
<td>Scour calculation/evaluation has not been made. (Use this only where a bridge has not received an initial inspection.)</td>
</tr>
<tr>
<td>5</td>
<td>The bridge foundations are determined to be stable for assessed or calculated scour condition. Scour is determined to be within the limits of footing or piles (see Example B in Figure 4:7-27) by assessment (i.e., bridge foundations are on rock formations that have been determined to resist scour within the service life of the bridge), by calculation, or by installation of properly designed countermeasures.</td>
</tr>
<tr>
<td>4</td>
<td>The bridge foundations are determined to be stable for assessed or calculated scour conditions. The field review indicates action is required to protect exposed foundations.</td>
</tr>
</tbody>
</table>
| 3    | The bridge is scour critical and the bridge foundations are determined to be unstable for assessed or calculated scour conditions:  
  * Scour within limits of footing or piles (see Example B in Figure 4:7-27)  
  * Scour below spread-footing base or pile tips (see Example C in Figure 4:7-27) |
| 2    | The bridge is scour critical. The field review indicates that extensive scour has occurred at the bridge foundations. The foundations are determined to be unstable by:  
  * A comparison of calculated scour and observed scour during the bridge inspection, or  
  * An engineering evaluation of the observed scour condition reported by the bridge inspector in Item 60. |
| 1    | The bridge is scour critical. The field review indicates that failure of the piers/abutments is imminent. The bridge is closed to traffic. Failure is imminent based on:  
  * A comparison of calculated scour and observed scour during the bridge inspection, or  
  * An engineering evaluation of the observed scour condition reported by the bridge inspector in Item 60. |
| 0    | The bridge is scour critical. The bridge has failed and is closed to traffic. |

Figure 4:7-26: NBI Scour Ratings
Examples of calculated scour depth and the actions needed for different cases are shown in Figure 4:7-27.

<table>
<thead>
<tr>
<th>EXAMPLES:</th>
<th>CALCULATED SCOUR DEPTH</th>
<th>ACTION NEEDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Above top of footing</td>
<td><img src="image1" alt="Diagram" /></td>
<td>None - indicate rating of 8 for this item</td>
</tr>
<tr>
<td>B. Within limits of footing or piles</td>
<td><img src="image2" alt="Diagram" /></td>
<td>Conduct foundation structural analysis</td>
</tr>
<tr>
<td>C. Below pile tips or spread-footing base</td>
<td><img src="image3" alt="Diagram" /></td>
<td>Provide for monitoring and scour countermeasures as necessary</td>
</tr>
</tbody>
</table>

**SPREAD FOOTING (NOT FOUNDED IN ROCK)**

![Diagram](image4)

**PILE FOOTING**

![Diagram](image5)

Figure 4:7-27: Actions Needed After Calculating Scour Depth
Subsection 7.4.5 Scour Plan of Action

For every bridge identified as scour critical (a rating of 3 or less for Item 113), a Plan of Action must be developed. It must include:

1. General Information about the bridge, including the following:
   a. County name
   b. County number
   c. INDOT district number
   d. Bridge number
   e. NBI number
   f. Facility carried
   g. Feature intersected
   h. Year constructed
   i. Whether the bridge serves a designated emergency route
   j. Average daily traffic
   k. Year of average daily traffic
   l. Daily truck percent
   m. Date of the most recent cross section
   n. A copy of the most recent channel cross section with comments as needed
   o. Soil information

2. Information about the Plan of Action, including the following:
   a. Date the Plan of Action was approved
   b. Date the Plan of Action was updated
   c. Recommended update frequency for the Plan of Action
   d. Author of the Plan of Action
   e. Person responsible for maintaining the Plan of Action
   f. Any concurrences on the Plan of Action
3. A summary of the scour status of the bridge, including the following:
   
a. Official scour rating for the bridge (Item 113A) with notes as needed
b. Proposed scour rating for the bridge (Item 113B) with notes as needed
c. Substructure rating for the bridge (Item 60) with notes as needed
d. Substructure rating for each individual substructure unit in the water
e. Channel condition rating (Item 61) with notes as needed on the channel condition and material
f. Condition of the culvert, if applicable (Item 62), with notes as needed
g. Waterway adequacy rating (item 71) with notes as needed
h. Comments on the scour history of the bridge
i. Comments on the flood history

4. Information on the monitoring plan, including the following:
   
a. Reason for any monitoring program
b. What needs to be monitored
c. Triggers that initiate monitoring such as flood stage, inches of rain in a designated time period, etc.
d. Person or agency who will monitor the bridge
e. Any monitoring preparations such as Q100 flow lines marked on a pier
f. Specific signs that would indicate a problem, such as sagging superstructure
g. Monitoring termination criteria
h. Comments on the monitoring method
i. Any monitoring history
j. Bridge owner contact information

5. Information on any countermeasures, including the following:
   
a. Existence of any countermeasures
b. Rating of any countermeasures
c. Observations about the countermeasures
d. Recommendation on what countermeasures are needed
6. Emergency traffic information, including the following:
   a. Closure plan
   b. Detour route
   c. A note that only an approved Inspection Team Leader can reopen the bridge

7. Recommendations, including the following:
   a. Recommendations for Routine Inspections
   b. Recommendations for Underwater Inspections
   c. Countermeasure recommendations

Attachments to the Plan of Action may include boring logs, bridge elevation drawings, a plan showing the locations of scour holes, drift, or debris. It may also include supporting documentation, calculations, and photos.

Major river bridges or other unique bridges may require more extensive Plan of Action documentation. The Plan of Action must be maintained in the Central Database. A copy must also be available for use during field inspections.

Subsection 7.4.6 Scour Plan of Action for Bridges with Unknown Foundations

If a bridge with an unknown foundation has been coded as scour critical in accordance with the field observations or the assessment process described in Section 7.5, a Plan of Action needs to be developed as described in Subsection 7.4.5 above.

If a bridge with an unknown foundation remains coded U for Item 113, a Plan of Action must be developed based on a risk assessment that considers safety to the traveling public and the consequences of the loss of service of the structure. This Plan of Action may be less detailed than a Plan of Action for a scour critical bridge, but it must protect the users during and after a flood event and provide a proactive plan for addressing the bridge scour concerns in the future.

For a bridge considered at low risk, as discussed in Section 7.5, the Plan of Action will generally require monitoring bridges for scour during routine inspections and after triggering events. If scour or a rainfall event has been observed in excess of predetermined events or limits, the bridge may need to be considered for an in-depth foundation investigation.

For a bridge considered at moderate risk, as discussed in Section 7.5, the Plan of Action will be developed in accordance with an engineering evaluation of the risk and the level of certainty of the information available for that bridge. If scour or a rainfall event has been observed in excess of predetermined events or limits, the bridge should be considered for an in-depth foundation investigation.
For a bridge considered at high risk, as discussed in Section 7.5, a Plan of Action similar to that developed for a scour critical bridge must be developed. This Plan of Action will require more frequent monitoring than bridges considered low or moderate risk. If any significant changes in the streambed occur, the inspection team should recommend an in-depth foundation investigation, installation of designed countermeasures, or the timely design and installation of a new bridge.

Figure 4:7-28: Flood Event
SECTION 7.5 unknown foundations

Subsection 7.5.1 Confirm Coding

Identifying scour critical bridges allows for the efficient allocation of monitoring time and money to install countermeasures or replace bridges. The scour evaluation team needs to check all available information for any bridge coded U or 6 to ensure that the foundation is actually unknown. A code designation of 6 is only used after a new bridge has been identified and before the initial inspection is performed.

If the foundation has been completely and confidently identified, a Scour Evaluation Study should be made in accordance with Hydraulic Engineering Center (HEC) 18. The completion of this evaluation can be made in order of the priority, determined by the importance of the road, as follows:

1. Principal Arterial – Interstate
2. Principal Arterial – Other Freeways or Expressways
3. Other Principal Arterial
4. Minor Arterial
5. Major Collector
6. Local Road

Subsection 7.5.2 Classifying Scour Risk for Bridges with Unknown Foundations

If the type, location, and depth of the foundation cannot be completely and confidently identified, the scour evaluation team should classify the bridge based on risk of failure and impact to users as high-, moderate-, or low-risk.

Factors that should be considered in this classification include the following:

- Functional classification of the inventory route (Item 26)
- Designated level of service (Item 5C)
- Detour length (Item 19)
- Year built (Item 27)
- Average daily traffic (Item 29)
- Average daily truck traffic (Item 109)
- Navigational clearances (Item 39 and 40)
- Condition ratings (Items 58, 59, 60, 61, and 62)
- Waterway adequacy (Item 71)
BRIDGE INSPECTION MANUAL Chapter 7: Scour, Channels, and Waterways
PART 4: BRIDGE INSPECTION Unknown Foundations

- Strategic Highway Network (STRAHNET) highway designation (Item 100)
- Designated national network (Item 110)
- Aggravating stream characteristics such as high velocity, steep slope, or deep flow
- Evidence of an actively degrading channel
- Evidence of embankment movement or settlement
- Type of bed material
- The angle of attack/alignment of channel
- Significant overbank or floodplain flow (floodplain greater than 150 feet wide)
- Possibility of bridge overtopping
- Evidence of scour and/or degradation
- Evidence of structural damage due to scour, such as substructure movement or settlement
- Condition of any abutment and/or pier protection
- Condition and functioning of any existing countermeasures
- Any history of excessive drift or debris
- The size of the drainage area

In Indiana, a bridge with an unknown foundation can be considered low-risk without further study only if it meets all of the following criteria:

- The average daily traffic (ADT) is less than 4000.
- The bridge is not on a marked state highway.
- The inventory route is not a STRAHNET route.
- The bridge has no history of scour-related problems following a 100-year flood event.
- The bridge has no history of significant debris buildup.
- The substructure, Item 60, is rated 5 or higher.
- The channel and channel protection, Item 61, is rated 7 or higher.
- The waterway adequacy, Item 71, is rated 6 or higher.
- The angle of attack is less than 20 degrees.
In Indiana, a bridge with an unknown foundation is considered high-risk if so designated by the District Bridge Engineer or the Inspection Consultant in consultation with the Inspection Team Leader, or if it meets any one of the following criteria:

- The ADT is greater than 25,000.
- The substructure, Item 60, is rated 3 or less.
- The channel and channel protection rating for Item 61 is 4 or less.
- The waterway adequacy rating for Item 71 is 4 or less.
- The inventory route is a STRAHNET route.
- The angle of attack is greater than 40 degrees.
- Scour greater than 4-feet deep has been documented at the bridge site.

Bridges with unknown foundations not meeting the criteria for low-risk, and not classified as high-risk, will be classified as moderate-risk.

**Subsection 7.5.3  Unknown Foundations Classified As High-Risk**

If a bridge with an unknown foundation is considered high-risk, the scour evaluation team should positively identify the type, location, and depth of the foundation with appropriate methods of discovery such as nondestructive testing (NDT) or invasive techniques such as test pits. The scour evaluation study should then be completed and Item 113 re-coded. A Plan of Action for the bridge must be prepared and implemented until the scour evaluation study is completed.

**Subsection 7.5.4  Unknown Foundations Classified As Moderate-Risk**

If the available information, including inspection reports, scour evaluation reports, and plans, do not allow the scour evaluation team to confidently identify the foundation characteristics, the scour evaluation team should assume foundation characteristics using inference methods. Inferences and assumptions must be justified within an acceptable degree of engineering confidence. To support these assumptions, the study should include the following:

- Research common practices for the time period and type of bridge, including:
  - Review any historical technical inventory of project plans.
  - Review any standard sheets.
  - Review any construction specifications.
  - Review any design guidance.
Review information available for nearby bridges of similar type and age with known foundations.

Review any geologic data available from the site or from nearby bridge sites.

If the scour evaluation team is confident that the information gathered is reasonable, considering the risk characteristics of the bridge, the team should conduct the scour evaluation using the inferred information and re-code Item 113. An Inspection Team Leader, licensed in the state of Indiana, must certify the re-coding of any bridge previously identified as U to any coding other than scour critical. If the information gathered is not sufficient, positive discovery methods should be used to identify the bridge foundation, or a Plan of Action should be developed and implemented for the U-coded bridge.

**Subsection 7.5.5 Unknown Foundations Categorized As Low-Risk**

If the available information, including inspection reports, scour evaluation reports, and plans, do not allow the scour evaluation team to confidently identify the foundation, they should assume foundation characteristics using inference methods as described above. If the information inferred is adequate to assess scour vulnerability, a scour evaluation should be completed and Item 113 re-coded. An Inspection Team Leader, licensed in the state of Indiana, must certify the re-coding of any bridge previously identified as U to any coding other than scour critical. If the information gathered is not adequate, a Plan of Action should be developed and implemented for the U-coded bridge.
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CHAPTER 8 BATS AND SWALLOWS

SECTION 8.1 INTRODUCTION

Some species of bats are listed as endangered under federal or state law, and cliff swallows are protected under the Migratory Bird Treaty Act. Inspectors must perform a preliminary screening for bats and cliff swallows as a part of each inspection for state-owned bridges.

Figure 4:8-1: Cliff Swallow Nests

Figure 4:8-2: Cliff Swallow Colony
Cliff and barn swallows often nest under highway bridges on concrete walls or beams, typically near large waterways or reservoirs. Cliff swallow nests have a distinctive rounded top, as shown above in Figures 4:8-1 and 4:8-2. Cliff swallows are a colony nesting bird and there may be several to hundreds under one bridge.

Barn swallows do not nest in colonies. Their nests are generally found alone and the shape is indistinct, as shown in Figure 4:8-3. Barn swallows are not tracked by the Indiana State Department of Natural Resources, but are discussed here to highlight the differences between cliff swallows and barn swallows.

Bats are more likely to be found on concrete or wood bridges than on steel bridges, and are generally located near a large river or wide floodplain. The preliminary screening for bats should include the following:

- Take care not to touch any bats or expose yourself to danger. If bitten, call the Department of Health at 317-233-1325 and record the incident immediately. Few bats have rabies; however, it is a deadly virus. If bitten by a bat, you will need rabies post-exposure shots.
- Look for bats flying or roosting (hanging) and note the approximate number of bats.
- Note any dead or injured bats.
- Listen for high-pitched squeaking or chirping and identify the location of such sounds, preferably with a sketch, for later examination by bat biologists.
- Note bat droppings and their location. Bat droppings are small and mouse-like, but less regular, and are usually brown or black in color. Older droppings may be gray. Check under likely roosting spots such as cracks, cave-like areas, and expansion joints. See Figures 4:8-5 and 4:8-6.
- Note any pungent urine smell.
- Look for four- to six-inch wide horizontal, dark stains located on supports beams and walls below the bridge deck. The stains often appear wet.
- Closely check cracks, which are often used as a foothold in roosting.
- Closely check expansion joints and areas providing cave-like conditions.
Figure 4:8-3: Single Barn Swallow Nest

Figure 4:8-4: Bat Droppings
Figure 4:8-5: Bats Roosting Along Crack and Associated Staining

Figure 4:8-6: Bat Guano on Riprap
Figure 4:8-7: Bat
SECTION 8.3 CODING

The presence of cliff swallow nests and the approximate number of nests found on a bridge must be noted in the Central Database. Add photos to the bridge file.

Inspectors must note the presence of bats or possible nesting sites in the Central Database. Estimate of the number of bats if possible. Add photos to the bridge file.
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CHAPTER 9 UNDERFILL STRUCTURES

SECTION 9.1 INTRODUCTION

In Indiana, an underfill structure is defined as a structure where vehicles do not drive directly on a structural deck set on superstructure elements. Closed-spandrel arch bridges are considered underfill structures only if the level of soil or fill is higher than the level of the copings or headwall/spandrel walls. Many states call these structures culverts or tunnels. When underfill structures span more than 20 feet, they are classified as bridges and documented as culverts. Underfill structures spanning 20 or less feet are considered small structures.

Underfill structures do not have a roadway deck or bridge joints at the end of the bridge. They are usually covered by roadway fill material, typically called overburden, or embankment. The roadway rests on the fill material. Often this fill extends laterally a significant distance from the edge of the pavement. This area can support vegetation.

Underfill structures are designed to carry the soil dead load above the structure, as well as the live loads due to traffic above. Above certain fill heights, live loads will arch over the structure and only the soil dead loads will be carried by the structure. An underfill structure’s strength is achieved through its own material properties and confining lateral pressures from the surrounding soil.

Figure 4:9-2 shows some examples of typical underfill structures. If you are unsure if a structure should be designated as an underfill structure, contact the State Program Manager for clarification.
Figure 4:9-2: Typical Underfill Structures
SECTION 9.2 TYPES OF UNDERFILL STRUCTURES

Underfill structures are constructed from a wide variety of materials, including concrete, steel, and aluminum. They may be constructed of stone, masonry, timber, or plastic. This section discusses the typical shapes of these structures, the structural categories, and the end treatments that the inspector may encounter.

Subsection 9.2.1 Underfill Structure Shapes

The underfill structure shape chosen for a location may or may not be dependent upon hydraulic performance requirements. Other factors that may affect the shape chosen are structural requirements, potential for clogging by debris, vertical clearance, and the need for a natural stream bottom. Typical underfill structure shapes include the following:

- **Circular**: This is the most common underfill structure shape. Although hydraulically and structurally efficient, it can reduce the width of a stream and is more prone to clogging than other shapes. Soil pressures around circular-shaped underfill structures are directed towards the middle of the shape and are fairly uniform all around.

- **Pipe Arch**: This shape is used when the distance from the stream bottom to roadway is limited. It is arched on top and flattened on the bottom. The flattened bottom allows a wider stream to flow through. As with circular underfill structures, pipe arch structures are prone to clogging. Since they closely approximate a true arch, soil pressures on the underside are fairly low, with high reaction pressures occurring at the bottom corners. They are not as structurally efficient as a circular shape.

- **Elliptical**: Elliptical shapes have the same advantages and disadvantages as pipe arch underfill structures. They may be oriented horizontally or vertically.

- **Arch**: Arches are open shapes used when limited obstruction to stream flow is required, and where the natural stream bottom is generally resistant to scour. They offer less obstruction to stream flow than pipe arches. The spring lines of arches bear on footing foundations, and riprap is commonly used to protect them from erosion if the stream bottom is not resistant to scour. Soil pressures on the sides of an arch structure try to push the sides towards the center of the stream, resulting in the top of the arch being pushed up. Soil dead loads above the top of the arch help restrain this “peaking” tendency.

- **Tied Arch**: These are similar to arch underfill structures, but they have a floor covering the natural streambed and a tie device embedded in the floor to keep the walls together.
- **Box:** These are square or rectangular-shaped structures. They are commonly chosen because they are adaptable for many site conditions and they can be used when the distance from the stream bottom to roadway is limited. Box underfill structures always have a floor (natural streambed is covered). They are not as structurally efficient as other shapes.

- **Frame:** These are similar to box underfill structures, but frames do not have a floor, so the natural streambed is exposed. The walls of these frames bear on footing foundations.

- **Multiple Barrel:** Multiple barrel or cell underfill structures are simply a series of pipes, arches, or boxes placed side by side. Their use is common when the distance from the stream bottom to the roadway is limited. Their major disadvantage is that waterway debris is easily snagged by the cell walls or soil between the openings. Refer to Figures 4:9-3 through 4:9-5 for views of multiple barrel underfill structures.

- **Tunnels:** A tunnel is a type of underfill structure that carries vehicle, pedestrian, or rail traffic. See Figure 4:9-6.

![Figure 4:9-3: Two-Cell Reinforced Concrete Underfill Structure](image-url)
Figure 4:9-4: Two-Barrel Corrugated Steel Underfill Structure

Figure 4:9-5: Five-Barrel Corrugated Steel Underfill Structure
Subsection 9.2.2 Structural Categories

Underfill structures can be structurally flexible or rigid. It is important for an inspector to understand the structural behavior of an underfill structure so that a proper assessment can be made as to the cause of any damage found. Structural behavior is dependent upon the material from which an underfill structure is built.

(a) FLEXIBLE UNDERFILL STRUCTURES

Underfill structures constructed of corrugated metal are flexible, and can be easily deformed under load if not properly installed. Because the thinness of the corrugated metal plates leaves these structures with little bending strength of their own, they must rely on the surrounding soil/backfill material for support and shape retention.

A metal pipe with no lateral soil support will "squash" or flatten under vertical loads. The top of the pipe will deflect downward, and the sides of the pipe will bulge outward. Properly compacted soil surrounding the pipe will restrain the sides from bulging. This keeps the pipe ring in compression, and allows the structure to support vertical loads with acceptable deflections by way of arching action.
(b) **RIGID UNDERFILL STRUCTURES**

Cast-in-place concrete, precast concrete, and masonry underfill structures are considered to be rigid. The construction material is stiff enough to resist bending and to support vertical loads independent of the surrounding soil. As such, tension and compression stresses due to bending are created in the structure. When viewed from the inside, a rigid underfill structure will experience tensile stresses on the top and bottom surfaces, while compressive stresses will be generated on the sides. These stresses will be opposite on the soil side. Rigid underfill structures do not appreciably deflect before they crack or fracture.

**Subsection 9.2.3 End Treatments**

Structures at the ends of underfill structure openings are called end treatments. End treatments are used to control erosion, support backfill, improve hydraulic efficiency, and provide additional stability to the underfill structure ends. The most common types of end treatments include the following:

- **Projection:** A simple barrel extension beyond the embankment. No additional support is used.

- **Pipe End Section:** Similar to a projection, a pipe end section is simply a length of underfill structure pipe added to the end of the underfill structure barrel. End sections often have a small, monolithic apron.

- **Mitered End:** The end of the underfill structure is cut to match the slope of the embankment. The cut starts at the top of the underfill structure and slopes down towards the bottom.

- **Skewed End:** On underfill structures skewed to the roadway, their ends may be cut parallel to the roadway.

- **Headwalls/Wingwalls:** Headwalls are vertical walls surrounding the end of the underfill structure. They are used in conjunction with wingwalls to retain fill, prevent erosion, and improve the hydraulic capacity of the underfill structure.

- **Aprons:** These devices are used in the streambed to reduce or prevent scour and erosion at the inlets and outlets of underfill structures. These usually have a buried end which extends down into the channel bottom approximately 18 inches to prevent undercutting. They are typically constructed with concrete or riprap.
Figure 4:9-7: Mitered End Treatment

Figure 4:9-8: Headwall and Wingwalls
SECTION 9.3 UNDERFILL STRUCTURE INSPECTIONS

Prior to inspecting an underfill structure, the inspector should review all available information about the structure. Inspectors should check to see if a soil analysis was conducted prior to building an underfill structure. Structures built over compactable soils can settle under the roadway, leaving a sag along the barrel length of the structure. An initial review will help establish equipment needs, inspection procedures, and flag areas of existing distress. Most inspections will require rubber boots or hip waders and a flashlight. A range pole/probing rod should be used to check for scour or deterioration below the water level.

Many underfill structures are large enough that the entire length can be inspected from the inside. Smaller underfill structures that cannot safely or practically be entered should be examined by looking through the opening from both ends. Locations along sectional underfill structures may be conveniently referred to by using structure joints as station numbers from one end of the pipe. Defect positions along the circumference of the barrel should be referenced like hours on a clock.

The structural inspection of any underfill structure will include an inspection of the structure itself, the roadway over the structure, plus the wingwalls, curbs, sidewalks, and railings, if these elements exist. A National Bridge Inventory (NBI) condition rating must be assigned to the underfill structure, as well as the channel, channel protection, and waterway adequacy. A rating must be assigned for the embankment, roadway approach, and approach roadway alignment. An NBI appraisal rating must also be assigned for the railing, approach guardrail, guardrail transitions, and guardrail end treatments if these items exist.

Inspectors should evaluate underfill structures for possible re-lining work if significant defects are found. This repair work is not an appropriate solution for all defects, but could add many years of service to some structures.

Subsection 9.3.1 Underfill Structure Inspection Hazards

There are a number of hazards that must be considered both in preparations for, and during, an underfill structure inspection.

Long underfill structures, or those with blocked ends, may have inadequate oxygen levels, or high concentrations of toxic or explosive gasses. Three people must perform the inspection in these situations in accordance with the confined space policy defined in Part 1, Chapter 4. Gas monitors must be worn and continuous ventilation may be required throughout the inspection to provide a safe working environment. Lifeline ropes clipped to the inspectors must be used so that the monitor can pull a disabled person out of the pipe.

Soft muck and scour holes may be present within the streambed inside of an underfill structure. High water flow rates and slippery bottoms or floors can knock an inspector off of his/her feet. Probing rods, life vests, and hard hats should always be used while wading through these hazardous conditions.
Wading should not be attempted unless the water level allows sufficient head room. If wading is not possible, Underwater Inspection methods are required to properly perform the inspection. Refer to Part 1, Chapter 3 for Underwater Inspection equipment and personnel requirements.

Quicksand is produced when water flows upward through sand. When the flow is strong enough, sand particles are lifted up out of the streambed and kept suspended by the turbulent nature of the upward rising water. A similar situation may be found at the outlet of an underfill structure conveying large quantities of water. The falling water creates a scour hole and constant turbulence to keep the streambed sand particles suspended. An inspector who steps into the scour hole will actually float higher in the sand/water mixture than in pure water and can generally swim away from the scour hole.

Hazardous chemicals may be present in the stream water itself. A fire or explosion may result from careless behavior, such as smoking, in these conditions.

Debris accumulation and low water flow rates within underfill structures may provide ideal shelter for animals. The inspector should be aware that snakes, rodents, or dead animals may be present.

Tunnels should be inspected when traffic is at a minimum. It may be necessary to close lanes or close the tunnel. Coordination with the tunnel and roadway owners is critical.

Subsection 9.3.2 Types of Underfill Structure Distress

There are four general types of distress that any underfill structure can experience. Figures 4:9-9 through 4:9-11 show some typical types of material distress. High earth loads, water velocities, soil corrosiveness, and age can produce the following types of distress:

- **Shear or Bending Failures**: High embankments impose high loads on all sides and can cause shear or bending failures. These failures may result in excessive global flattening, sheared-off bolts, or localized dents/bulges in steel underfill structures. Concrete underfill structures will exhibit longitudinal cracking, concrete crushing, or excessive deflections.

- **Settlement**: Foundation settlement may be seen as a sag or rise in steel underfill structures. Differential vertical or lateral displacements at construction joints and pipe segment joints, or pipe segment joints that have opened up, suggest settlement of concrete underfill structures. Lateral movement of concrete box sections may also be observed.
Scour, Undermining, and Piping: High-water velocities within long, slender openings can result in scouring and undermining of the underfill structure ends. Scouring or undermining may also occur along the footings when the underfill structure has no bottom. Undermining can lead to a loss of bearing and subsequent structure settlement. Piping is the unintended flow of water around the outside of an underfill structure. It can begin where undermining of the end treatment or barrel allows water to flow. It may also occur at interior joints that have opened up due to soil settlements. Water inside of the underfill structure may flow out through the open joints. When this occurs, water flow can erode the surrounding soil, creating an artificial pipe. Piping can become a serious problem when an underfill structure loses its lateral soil support.

General Deterioration: Factors such as weathering, soil corrosiveness, abrasion, and chemical exposure cause deterioration of any construction material over time.
Figure 4:9-10: Masonry Headwall Separating From the Barrel

Figure 4:9-11: Through Thickness Section Loss at Water Line of Wall Separating Two Cells
Figure 4:9-12: Precast Concrete Underfill Structure
SECTION 9.4 STEEL UNDERFILL STRUCTURES

Steel underfill structures are usually constructed of corrugated, galvanized steel. Some Indiana counties use old steel railroad tank cars for underfill structures. Several types of steel structures are used, including corrugated metal pipes, structural steel plate pipes, corrugated steel boxes, and long-span corrugated steel structures.

Corrugated metal pipe underfill structures are either circular or pipe arch in shape and are factory-made into a complete, closed section. Pipe seams are either riveted, spot-welded, bolted, lock-seamed, or continuously welded. Corrugation patterns may be circumferential or spiral, and diameters up to 12 feet are readily available. These pipes are often protected with a galvanizing or bituminous coating.

Structural plate, steel pipe underfill structures are field assembled and constructed with multiple pre-curved corrugated plates. The field-assembled plate sections are fastened together with bolts to form a continuous pipe. Fastened plate edges oriented along the barrel length are called seams, while plate edges transverse to the barrel are called joints. Circular, pipe arch, elliptical, and arch underpass shapes are commonly found with spans up to 26 feet. They are galvanized for corrosion protection.

Corrugated steel box underfill structures approximate a rectangular shape, though their corners are rounded, sides tilted slightly, and tops slightly curved. They are reinforced in areas of maximum bending, and are available in spans up to about 20 feet.

Long-span corrugated steel structures are similar to structural plate steel pipes, but long-span underfill structures require longitudinal and circumferential stiffening members due to their great lengths.

The primary concern in inspecting steel underfill structures is the maintenance of the structure shape. Barrel misalignment, joint and seam condition, localized damage, and corrosion must also be checked.

Because steel underfill structures depend upon well-compacted soil to help retain their shape, excessive flattening or widening suggests a soil failure. As a minimum, the height and widest opening should be measured at both ends. If size and water flow permit, measurements in the middle of the barrel and at the quarter points should also be recorded. Bolted joints are excellent places to take measurements because they can be easily found for comparison measurements on subsequent inspections. Measurements should always be taken at the inside crest of the corrugations. Critical measurements to be taken during an inspection for the most common barrel shapes are shown below in Figures 4:9-14 through 4:9-16. For shapes not provided, refer to the Bridge Inspector’s Reference Manual (BIRM).
Structural inspection of steel underfill structures should include the following items:

- Measure the height and width of the barrel at the ends, middle, and quarter points. These measurements should be compared to the original dimensions shown on the design drawings and previous inspections, if available. Excessive flattening suggests a soil failure. See Figures 4:9-14, 4:9-15, and 4:9-16 below for the required measurements for round steel pipe structures, structural plate pipe arches, and structural plate arches.

- Measure the corrugation and thickness of the cross section.

- Indicate on the report the extent of any flattening found. Include the affected length along the barrel and the location of the distress.

- Examine the roadway above for any dips, cracking, settlement, or patching that would suggest a failing structure below.

- Check for horizontal misalignments by sighting down the barrel length.

- Check for vertical misalignments sighting down the barrel length. Note the presence of localized deep water or sediment accumulation at low spots within the barrel.

- Look for localized damage in the form of dented, flattened, or bulged areas. Bulged areas on the bottom of a round barrel suggest settlement over a local hard spot. Bulged areas on the bottom of an arch pipe suggest the corners have settled. Small areas of localized damage are usually not critical. Localized damage may jeopardize the barrel's ability to carry its ring compression loads.

- Look for corrugation misalignments and “cusped” seams along the fastener lines. Cusped seams are separations in the plate lap caused by loose fasteners. This results in a discontinuity of the barrel curvature that can allow moisture and backfill inside.

- Examine all seams and joints for plate separation. Measure any separations found. A small rod or flat rule should be used to probe through any separation to check for voids in the backfill.

- Check for cracking at the bolt holes. These are usually caused by excessive barrel strains due to deflections.

- Check for loose bolts by tapping lightly with a hammer.

- Check the entire barrel for the extent and severity of corrosion. The heaviest corrosion will normally appear near the water surface. Sharp blows with a hammer are the accepted method for the inspector to evaluate the general integrity of the steel.

- Look for signs of abrasion along the barrel. Abrasion can accelerate the corrosion process by scraping away the metal's protective coating.
• Examine the inlet and outlet of the barrel for signs of scour or undermining underneath a closed pipe. This could lead to piping.

• Examine for scour or footing undermining along the length of arch underfill structures. Undermining may allow the concrete footing to rotate, failing the arch.

• Examine end treatments and wingwalls for damage, deterioration, debris accumulation, streambed scour, undermining, settlement, tipping, and embankment erosion. These deficiencies can cause hydraulic inefficiencies and roadway settlements.

• Check for excessive joint openings between headwalls, wingwalls, and aprons.

Figure 4:9-13: Tearing at Connection
1. **MINIMUM MEASUREMENTS REQUIRED:**
   HORIZONTAL DIAMETER = AC

2. **IF FLATTENING OBSERVED MEASURE:**
   CHORD AND MID ORDINATE OF FLATTENED AREA

3. **IF HORIZONTAL DIAMETER EXCEEDS DESIGN BY MORE THAN 10% MEASURE:**
   VERTICAL DIAMETER = BD

---

Figure 4:9-14: Critical Measurements for Round Steel Pipe Underfill Structures
1. MINIMUM REQUIRED MEASUREMENTS - AC, BD  
SPAN = AC  
RISE = BD  

2. IF AC EXCEEDS DESIGN BY 3% OR MORE, MEASURE
BF, ED, AND HORIZONTAL SPAN OF TOP ARC

Figure 4:9-15: Critical Measurements for Steel Pipe Arch Underfill Structures
Figure 4:9-16: Critical Measurements for Steel Plate Arch Underfill Structures

1. MINIMUM REQUIRED MEASUREMENTS:
   SPAN = AD + DC
   RISE = BD

2. MINIMUM REQUIRED ELEVATIONS - B

3. IF BD GREATER THAN DESIGN BY 5% OR MORE, CHECK SIDE CURVATURE

4. IF AD AND DC ARE NOT EQUAL, CHECK SIDE CURVATURE

5. IF BD LESS THAN DESIGN BY 5% OR MORE, CHECK TOP CURVATURE
Concrete underfill structures may be cast-in-place or precast. Cast-in-place concrete structures are typically box-shaped, arch-shaped, or three-sided concrete frames with separated footings. Cast-in-place underfill structures can be designed to fit the specific needs of a site.

Precast underfill structures are available in several standard shapes, including circular, box, elliptical, pipe arch, and arch. Sizes up to 12-feet wide are commonly available for closed shapes. Most modern concrete bridge sized precast structures are frames often called three-sided structures. Most frames and some arches are set on concrete footings, some with driven piles and others set in bedrock.

Proper bedding compaction and preparation during construction is critical if precast closed sections are to perform well in service. Properly prepared bedding material (usually crushed stone) under the sections will evenly support them. Voids within the bedding will force the rigid pipe sections to span over these soft spots, often resulting in transverse cracks. Voids under the mid-length of a section will lead to cracks on the bottom half of the pipe at mid-length. Voids under the ends of a section will lead to cracks on the top half of the pipe.

Improper compaction of fill material on the sides may lead to longitudinal cracks. Without proper soil side support, the structure will want to flatten under vertical loads. Because concrete is a rigid material, it will not flex, and longitudinal cracks along the top, bottom, and sides will result.

Barrel misalignment, joint condition, and localized wall damage are areas of concern during any concrete underfill structure inspection. Rigid underfill structures develop longitudinal or transverse cracks as a result of overloading or differential settlement. Rigid underfill structures do not significantly deform unless loaded to failure. Cracks can also result from improper shipment or placement during construction. The initial inspection should check for these defects.

Structural inspections of concrete underfill structures should include the following items:

- Examine the roadway above for any dips, cracking, settlement, or patching that would suggest a failing structure below.

- Check for horizontal misalignments by sighting down the barrel length.

- Check for vertical misalignments by sighting down the barrel length and noting the presence of localized deep water or sediment accumulation at low spots within the underfill structure.

- Look for open joints. Open joints may allow water infiltration into the underfill structure, possibly allowing the backfill material to enter as well. This can lead to roadway settlement above and debris accumulation within the barrel. Open joints that allow water to flow out of the barrel (exfiltration) may cause soil erosion. This can also lead to structure and roadway settlements.
• Look for cracks, delaminations, or spalls at expansion joints or precast section joints. This type of deterioration suggests improperly functioning joints, possibly due to settlement.

• Look for longitudinal cracks along the barrel or cell length. These may be caused by excessive overloads, improper fill compaction of barrel sections, or lateral differential settlements of box sections. Medium to wide crack widths should be measured and recorded.

• Examine box tops when these elements double as the riding surface of traffic above. Longitudinal cracks in the box top may be caused by traffic overloads.

• Look for transverse cracks. These may be caused by differential settlements along the barrel length, often the result of improper bedding material preparation.

• Check the entire barrel or cell for delaminations, spalls, exposed reinforcing steel, cracking, and leaching. Note the location of such defects.

• Examine the inlet and outlet of the barrel for signs of scour or undermining underneath a closed pipe. This could lead to piping.

• Check for scour or footing undermining along the length of underfill structures with footings. Undermining may allow the concrete footing to rotate, causing structural failure.

• Look for signs of abrasion along the length of the barrel.

• Examine any anchor bolt conditions at the spring line of precast underfill structures.

• Examine end treatments and wingwalls for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies and roadway settlements.

• Check for excessive joint openings between headwalls, wingwalls, and aprons.

• For tunnels, ensure that the drainage system is operating properly. Poor drainage can lead to ponding or flooding in the tunnel.

• For tunnels, the inspector should evaluate the condition of any lighting inside the tunnel and note any damaged or nonfunctioning lights. All conduit and junction boxes should be inspected for damage, corrosion, loose mounting brackets, and missing covers.

• Tunnel ventilation systems should be assessed. Check for intact vent cover grates, working blowers, working filtration systems, if applicable, adequate air exchange, and the presence of fumes or smoke.
Figure 4:9-17: Probing Concrete Underfill Structure
Masonry underfill structures are rarely constructed today, but they can still be found in-service. They are built of stone or brick formed into arch or box shapes. Joints between the masonry units may be mortared, set in concrete, or set in place with no mortar. Masonry is still used sometimes to construct headwalls for underfill structures of other material types for aesthetic reasons. Material deterioration is the primary concern of any masonry underfill structure. Figure 4:9-18 depicts typical deterioration for masonry structures. In addition, signs of soil distress or overloading may show up as wall or arch bulging. For masonry tunnels, follow the inspection guidelines in Part 4, Chapter 4.

Figure 4:9-18: Masonry Underfill Structure With Severe Deterioration of Mortar Joints
Subsection 9.6.2  Aluminum Underfill Structures

Aluminum underfill structures are flexible and distress will appear primarily as shape distortions caused by soil failures or overloads. The shape and construction of aluminum underfill structures are similar to steel and they should be inspected in a manner similar to steel underfill structures, as described in Section 9.4.

Subsection 9.6.3  Plastic Underfill Structures

Plastic underfill structures are circular in shape and are only used for underfill diameters of five feet or less. They are normally made of high-density polyethylene and are considered flexible underfill structures. Distress will appear primarily as shape distortions caused by soil failures or overloads. Plastic structures can be placed side-by-side to achieve a span greater than 20 feet.

Subsection 9.6.4  Timber Underfill Structures

Timber underfill structures are usually in the shape of a box and are constructed of individual heavy timbers. They are not common because the dark and damp conditions within the box provide an ideal environment for fungi and parasites to thrive. Material deterioration is the primary concern of any timber underfill structure. In addition, signs of soil distress or overloading may show up as wall or ceiling bulging.

Subsection 9.6.5  Inspection of Other Underfill Structures

Structural inspections of other underfill structures should include the following items:

- Examine the roadway above for any dips, cracking, settlement, or patching that would suggest a failing structure below.
- Check for horizontal misalignments by sighting down the barrel length.
- Check for vertical misalignments by sighting down the barrel length. Note the presence of localized deep water or sediment accumulation at low spots within the barrel.
- Look for any wall, arch, or ceiling bulges. The location and size of such distress should be recorded.
- Examine the inlet and outlet for signs of scour or undermining underneath masonry underfill structures with a floor, and plastic underfill structures.
- Examine for scour or footing undermining along the length of underfill structures without floors. Undermining may allow the footing to rotate, failing the structure.
- Look for signs of abrasion along the length of the barrel.
- Examine end treatments for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies and roadway settlements.
• Check for excessive joint openings between headwalls, wingwalls, and aprons.

• Look for cracked, crushed, or missing masonry units or mortar.

• Look for signs of excessive masonry weathering.

• Measure the height and width of plastic underfill structures at the ends, middle, and at 25-foot intervals in between. These measurements should be compared to the original dimensions shown on the design drawings, if available. Excessive flattening suggests a soil failure.

• Indicate the extent of any flattening found. Include the affected length along the barrel, and location of the distress.

• Look for localized damage in the form of dented, flattened, or bulged areas. Bulged areas on the bottom of a round barrel suggest settlement over a local hard spot.

• Check the joints for separation and backfill infiltration.

• Look for cracked or split timbers. These may be the result of a structural overload.

• Look for signs of timber decay due to fungi or parasites.

• Check for broken or missing timbers. These may allow backfill material to enter, causing roadway settlement above.

• Examine exposed fasteners for deterioration.
The culvert/underfill structure condition rating assesses the current condition of the structure as compared to its original, as-built condition. Postings or original design capacities less than current legal loads will not influence the rating. Because only a single number is used to rate the structure, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, but widespread deterioration would influence the rating. Temporary supports do not improve the condition of the construction material or influence the rating.

The general Federal Highway Administration (FHWA) condition ratings are listed below, followed by supplemental rating guidelines to assist the inspector in properly assigning condition ratings for the most commonly used materials. Reference the BIRM for supplemental rating guidelines for less common structures and materials.

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong> Use if structure is not an underfill structure.</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong> No deficiencies; new condition.</td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – No problems noted.</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong> No noticeable or noteworthy deficiencies. Insignificant scrape marks caused by drift.</td>
</tr>
<tr>
<td></td>
<td><strong>Steel and Aluminum Structures</strong> – Superficial corrosion with no pitting may be present. Minor construction defects may be present and the protective coating for steel structures is intact. Smooth curvature in the barrel is evident and horizontal shape measurements are within 10 percent of design for round pipes and three percent for pipe arches. The rise in structural plate arches is within three percent of the design. Seams and joints are tight with no openings and no erosion is present at the footings.</td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Structures</strong> – No settlement or misalignment is present. Joints are tight with no defects apparent. No cracking, spalling, or scaling is present and the surface is in good condition.</td>
</tr>
<tr>
<td></td>
<td><strong>Stone and Masonry Structures</strong> – No settlement or misalignment is present. The mortar is tight with no defects apparent. No cracking, missing, or dislocated masonry is present and the surface is in good condition. The invert shows no signs of scour.</td>
</tr>
</tbody>
</table>
GOOD CONDITION – Some minor problems.

**Supplemental Rating Guidelines:** Insignificant damage caused by drift with no misalignment may be present. Local minor scouring near the cut-off wall, wingwalls, or pipes may also be present.

**Steel and Aluminum Structures** – Smooth symmetrical curvature with superficial corrosion and no pitting or slight pitting may be present. Local section loss of less than 10 percent may be present. The protective coating is ineffective for steel structures. The top half of the pipe is smooth. Minor flattening of the bottom may exist for round pipe, and the bottom half is flattened, but still curved for pipe arches. Horizontal shape measurements are within 10 percent of the design for round pipes, and within three percent to five percent greater than design for pipe arches. Structural plate arches have a smooth and symmetrical shape with slight flattening of the top or sides in one section, and the rise is within three percent to four percent of the design. The footings have minor erosion, causing minor differential settlement and minor cracking in the footing.

**Concrete Structures** – Shrinkage cracks, light scaling, and insignificant spalling which does not expose reinforcing steel may be present with no settlement. Misalignment is less than one inch at joints and joints have up to 1/2-inch openings with possible infiltration/exfiltration. Joint material is deteriorated at up to five percent of the joints. Hairline cracking may be present at isolated locations, and slight spalling or scaling is present on the invert.

**Stone and Masonry Structures** – No settlement with misalignment of less than one inch at the joints is present. Shallow mortar deterioration at up to five percent of the underfill structure is present. Surface deterioration of masonry at isolated locations may be present with minor scour at the invert.

SATISFACTORY CONDITION – Structural elements show some minor deterioration.

**Supplemental Rating Guidelines:** There is local minor scouring at the cut-off wall, wingwalls, or pipes.
Steel and Aluminum Structures – A smooth curvature, but nonsymmetrical shape, is present with local section loss up to 25 percent. The top half of the pipe has a smooth curvature, but the bottom half has flattened significantly for round pipes, or has flattened for pipe arches. Horizontal shape measurements are within 10 percent of the design for round pipes, and five percent greater than the design for pipe arches. Structural plate arches have a smooth, but nonsymmetrical shape with slight flattening of the top and sides throughout, and the rise is within four percent to five percent of the design. Hairline cracking at the bolt holes in one or more seams, one inch or less openings, and evidence of minor backfill infiltration at the joints and seams may be present. Footings have moderate cracking and differential settlement due to moderate erosion.

Concrete Structures – Deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spalls on concrete walls and slabs maybe present up to one inch of misalignment and settlement at isolated locations. Joint material is generally deteriorated with minor cracking or spalling at joints. Joints have one inch of maximum separations with possible infiltration or exfiltration. Cracks are less than 1/8-inch wide, some with minor delaminations or spalling. The invert and the bottom of top slab have scaling less than 1/4-inch deep, or small spalls are present. Minor scour near footings may be present.

Stone and Masonry Structures – Deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spalls on masonry walls may be present. There is up to one-inch of misalignment and settlement. Shallow mortar deterioration over no more than 20 percent of the structure, missing mortar at isolated locations, possible infiltration or exfiltration, and minor cracking may be present. Minor cracking of masonry units and minor scour near the footings may also be present.

5 FAIR CONDITION – All primary structural elements are sound, but may have minor section loss, cracking, or spalling.

Supplemental Rating Guidelines – Minor settlement or misalignment may be present with noticeable scouring or erosion at cut-off walls, wingwalls, or pipes.
Steel and Aluminum Structures – Metal underfill structures have significant distortion and deflection in one section with significant corrosion or deep pitting. Moderate thinning with global section loss of less than 10 percent and/or local section loss of less than 50 percent may be present. Significant distortion at isolated locations in the top half and extreme flattening of the invert for round pipe, or slight reverse curvature in one location for pipe arches, may also be present. Horizontal shape measurements are between 10 percent and 15 percent greater than the design for round pipe, or within five percent to seven percent for pipe arches. For structural plate arches, there is significant distortion and deflection in one section, the sides are beginning to flatten, the shape is nonsymmetrical, and the rise is within five percent to seven percent of the design. Moderate cracking at the bolt holes in one seam near the bottom of pipe and slight deflection of the pipe caused by backfill infiltration through joints and seams may be present.

Concrete Structures – Moderate to major deterioration or disintegration, extensive cracking and moderate leaching, or spalls on concrete walls and slabs may be present. Up to two inches of misalignment and settlement throughout the pipe with possible piping may also be present. Joints are open and allowing backfill to infiltrate. Significant cracking or joint spalling is evident, and crack widths greater than 1/8 inch with moderate delamination and moderate spalling, exposing reinforcing steel at up to five percent of the structure, may be present. Large areas of the invert may have surface scaling or spalls greater than 1/4-inch deep. Moderate scour along the footing may exist and protective measures may be required to prevent undermining.

Stone and Masonry Structures – Moderate to major deterioration or disintegration, extensive cracking and leaching, or spalls on masonry walls with up to two inches of misalignment or settlement may be present. The mortar is deteriorated at up to 50 percent of the structure with loose or missing mortar at up to five percent of the structure. Infiltration staining is apparent. Minor cracking and slight dislocation of masonry units, large areas of surface scaling, and moderate scour along the footing may exist. Protective measures may be required to prevent undermining.

4 POOR CONDITION – Advanced section loss, deterioration, or spalling may be present.

Supplemental Rating Guidelines: Considerable settlement or misalignment and considerable scouring or erosion at cut-off walls, wingwalls, or pipes may be present.
Steel and Aluminum Structures – Significant distortion and deflection throughout and extensive corrosion or deep pitting with pronounced thinning may be present. Some deflection or penetration exists when struck with a pick hammer. Global section loss of up to 20 percent and local section loss of up to 75 percent may exist. Round pipes have significant distortion throughout the length of the pipe, and the lower third may be kinked. Pipe arches have significant distortion along the top of the arch, and the bottom has reverse curvature. Horizontal shape measurements are between 10 percent to 15 percent greater than the design for round pipe, and more than seven percent greater for pipe arches. For structural plate arches, there is significant distortion and deflection throughout, the sides are flattened with a radius of no more than 100 percent greater than the design, and the rise is within seven percent to eight percent of the design. Cracking at the bolt holes on one seam near the top of pipe, with up to two-inch crack propagation on each side of the bolt holes may exist. Deflection caused by backfill infiltration through open joints and seams may be present with footings that are rotated due to erosion and undercutting. Settlement has caused damage to the arch. Significant undercutting and extreme differential settlement of the footing, causing major cracking in the footing, may be present.

Concrete Structures – Large spalls with exposed reinforcement, heavy scaling, wide cracks, considerable efflorescence, or opened construction joints permitting loss of backfill may be present. Up to three inches of misalignment and settlement of the pipe, with evidence of piping, may also exist. The end sections of precast pipes are dislocated and about to drop off. Up to two inches of differential movement and separation at the joints with significant infiltration and exfiltration may be present. Extensive cracking with crack widths greater than 1/8 inch and with efflorescence and spalling at up to 10 percent of the underfill structure may be present. At up to five percent of the underfill structure, spalls with exposed and corroded reinforcing steel with no more than 10 percent section loss may exist. The invert has extensive surface scaling greater than 1/2-inch deep. Scour along footings with slight undermining may exist and protection is required to prevent further undermining.

Stone and Masonry Structures – Large spalls, heavy scaling, wide cracks, considerable efflorescence, or opened construction joints permitting loss of backfill may exist. Up to three inches of misalignment and settlement may be present. The mortar is severely deteriorated over no more than 75 percent of the underfill structure. Loss of mortar, infiltration, and exfiltration between masonry and stone units, along with the displacement of individual units, may exist. Scour along the footings with slight undermining may be present. Protection is required to prevent further undermining.
3  **SERIOUS CONDITION** – Loss of section, deterioration, or spalling has seriously affected the primary structural components. Local failures are possible.

**Supplemental Rating Guidelines:** Any condition described in Condition Rating 4 that is excessive in scope, along with severe movement or differential settlement of the segments and loss of fill may be present. Holes may exist in walls or slabs. Integral wingwalls are nearly severed from the structure. Severe scour or erosion at cut-off walls, wingwalls, or pipes may exist.

**Steel and Aluminum Structures** – Extreme distortion and deflection in one section, extensive corrosion, or deep pitting with scattered perforations may exist, with global section loss up to 30 percent and local section loss up to 100 percent. Round pipes have extreme deflection at isolated locations, flattening of crown, and a crown radius of 20 to 30 feet. Pipe arches have extreme deflection in the top arch in one section, and the bottom has reverse curvature throughout. Horizontal shape measurements are more than 115 percent of the design for circular pipes, and more than 117 percent of the design for pipe arches. For structural plate arches, there is extreme distortion and deflection in one section, the sides are virtually flat, the shape is extremely nonsymmetrical, and the rise is within eight percent to 10 percent of the design. Up to three-inch long cracks on either side of the bolt holes on one or more seams may be present. Footings are rotated, severely undercut, and have major cracking and spalling.

**Concrete Structures** – Shear cracks may be present. Up to four inches of ponding water due to sagging and misalignment of the structure may be present. The end section of precast pipes has dropped off. Up to three-inch joint openings and differential movement, along with dislocated joints in several locations, exposing fill material, may exist. Infiltration or exfiltration, causing misalignment of pipe and depressions or settlement in the roadway, may be present. Extensive cracking throughout no more than 30 percent of the structure may accompany spalling with exposed reinforcement that has 10 percent section loss throughout no more than 10 percent of the structure. Scaling has exposed reinforcing steel in the bottom of the top slab or invert. Severe footing undermining with differential settlement, causing minor cracking or spalling in footing and walls, may be present.
Stone and Masonry Structures – Up to four inches of ponding water due to sagging and misalignment of the pipe may be present. Missing mortar with infiltration or exfiltration, causing misalignment of the structure and depressions or settlement in the roadway throughout no more than 10 percent of the structure, may also exist. Individual masonry units in the lower part of the structure are missing or crushed. Severe footing undermining with differential settlement, causing minor cracking or spalling in footing and minor distress in walls, may be present.

CRITICAL CONDITION – Advanced deterioration of primary structural elements exists. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

Supplemental Rating Guidelines: The structure is not functioning due to misalignments. Integral wingwalls have collapsed and there is severe settlement of the roadway due to loss of fill. Sections of the structure may have failed and can no longer support embankment. Complete undermining at cut-off walls and pipes may exist. Corrective action is required to maintain traffic.

Steel and Aluminum Structures – Extreme distortion and deflection throughout, along with extensive perforations due to corrosion on up to five percent of the structure, may be present. Round pipes have extreme deflection and distortion throughout the pipe, flattening of the crown, and a crown radius over 30 feet. Pipe arches have extreme deflection along the top of the pipe. Horizontal shape measurements are more than 120 percent of the design for circular pipes, and more than 107 percent of the design for pipe arches. For structural plate arches, there is extreme distortion and deflection throughout, the sides are flattened, the shape is extremely nonsymmetrical, and the rise is not within 10 percent of the design. Seams are cracked from bolt to bolt with significant amounts of backfill infiltration. Severe differential settlement of the footing has caused distortion and kinking of the arch.

Concrete Structures – Severe cracks with more than two inches of differential movement, along with exposed reinforcement with more than 20 percent section loss throughout at least 20 percent of the structure may be present. The top slab or invert concrete is completely deteriorated over more than three percent of the structure. Severe footing undermining with significant differential settlement, causing severe cracks in the footing and distress in the walls, may be present.

Stone and Masonry Structures – Individual masonry units in the top of the structure are missing or crushed. Severe footing undermining with significant differential settlement, causing severe cracks in the footing and distress in walls, may be present.
1  "IMMINENT" FAILURE CONDITION – Major deterioration or section loss is present in
critical structural components, or obvious vertical or horizontal movement is affecting the
structural stability. The bridge is closed to traffic, but corrective action may put it back in
light service.

Supplemental Rating Guidelines: The road is closed to traffic.

Steel and Aluminum Structures – The invert is completely deteriorated. Round pipes
are partially collapsed with the crown in reverse curvature. Pipe and plate arches are
partially collapsed. Seams have failed.

Concrete Structures – The structure is partially collapsed. Severe footing undermining
is present.

Stone and Masonry Structures – The structure is partially collapsed. Severe footing
undermining is present.

0  FAILED CONDITION – The bridge is out-of-service due to a partial or complete collapse.
Replacement is necessary.

To establish a rating, identify phrases within the guidelines that describe a rating more severe than what
actually exists. The correct rating number will be one number higher than the one describing the more
severe condition.

For example, suppose a steel underfill structure has surface corrosion at the invert and waterline, plus
random joint bolts that have minor to moderate corrosion. The seams are tight. The structure is an
eight-foot-wide arch pipe, with a measured horizontal dimension of eight feet, four inches (4.2 percent
greater than the design value). Condition Rating 7 indicates that there is moderate rust or pitting, and the
horizontal dimension of the structure is between three percent to five percent of the design value. There
may be minor openings at the seams. Condition Rating 6 indicates that there is fairly heavy rust with
minor pitting and slight thinning. There may be evidence of backfill infiltration at the seams, and the
horizontal dimension of the structure is greater than five percent of the design value. Using the method
described above, Condition Rating 6 describes a situation more severe than what actually exists.
Therefore, a rating of 7 would be appropriate.

Ratings of 9 to 7 apply to structures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor
condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition.
SECTION 9.8 ADDITIONAL UNDERFILL/CULVERT RATINGS

Subsection 9.8.1 Condition Ratings

Additional items to be rated for the Central Database are listed below. Some items are shown below in Figure 4:9-19. Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 62, the NBI culvert condition rating. Each item shall be rated as follows unless noted:

- **N** Not Applicable
- **9** Excellent Condition – new
- **8** Very Good Condition – no problems noted
- **7** Good Condition – some minor problems
- **6** Satisfactory Condition – structural elements show some minor deterioration
- **5** Fair Condition – minor section loss, cracking, or spalling
- **4** Poor Condition – advanced section loss, deterioration, or spalling
- **3** Serious Condition – loss of section, deterioration, or spalling has seriously affected components
- **2** Critical Condition – advanced deterioration of primary elements
- **1** Imminent Failure Condition – roadway closed to traffic
- **0** Failed Condition – beyond corrective action
ITEM 62.01 – BARREL

The barrel is the main body of the structure and consists of the portion of the structure that is under the fill. Typically, the barrel is the largest portion of the structure and the barrel rating will be the same as the overall rating, unless the ends of the structure are in much worse condition. The overall rating should never be higher than the barrel rating. The barrel rating should be selected using the relevant rating guidelines in Subsection 9.7.1.
ITEM 62.02 – ALIGNMENT

The alignment rating considers both the horizontal and vertical deflection of the structure. The rating should be selected using the relevant guidelines from Subsection 9.7.1.

ITEM 62.03 – STEEL

Rate the condition of the steel in steel barrels using the relevant guidelines from Subsection 9.7.1. The rating of the steel may be different than the barrel rating since the structure is flexible and the barrel rating may be governed by the alignment.

ITEM 62.04 – BOLTS

The longitudinal seams and transverse joints of some steel structures are bolted together with high-strength bolts in two rows: one row in the crests, and one row in the valleys of the corrugations. Check the tightness of the bolts by tapping lightly to detect movement. Check for corrosion, which can cause section loss and increased stress in the bolts.

<table>
<thead>
<tr>
<th></th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition – new</td>
</tr>
<tr>
<td>8</td>
<td>Very Good Condition – no problems noted</td>
</tr>
<tr>
<td>7</td>
<td>Good Condition – some minor problems</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition – one percent of bolts are loose, missing, or corroded with section loss</td>
</tr>
<tr>
<td>5</td>
<td>Fair Condition – three percent of bolts are loose, missing, or corroded with section loss</td>
</tr>
<tr>
<td>4</td>
<td>Poor Condition – five percent of bolts are loose, missing, or corroded with section loss</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition – 10 percent of bolts are loose, missing, or corroded with section loss</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition – 15 percent of bolts are loose, missing, or corroded with section loss</td>
</tr>
<tr>
<td>1</td>
<td>Imminent Failure Condition – 20 percent of bolts are loose, missing, or corroded with section loss</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition – beyond corrective action</td>
</tr>
</tbody>
</table>
ITEM 62.05 – CONCRETE

Rate the condition of the concrete in structures with concrete barrels. The rating should be selected using the relevant guidelines in Subsection 9.7.1. The rating will usually match the rating for the barrel, unless the barrel rating is governed by the alignment.

Figure 4:9-20: Spalling Concrete on Underfill Structure

ITEM 62.06 – STONE

This item is only applicable to structures with stone barrels. The rating should be selected using the guidelines in Subsection 9.7.1 related to the deterioration of the stone barrel. The rating will usually match the rating for the barrel, unless the barrel rating is governed by the alignment.

ITEM 62.07 – HEADWALL

A headwall is a structural wall, usually made of concrete, at the inlet and outlet of an underfill structure to protect the embankment slopes, anchor the structure, and prevent undermining.

ITEM 62.08 – APRONS

Aprons are used in the streambed to reduce or prevent scour and erosion at each end of the structure. Aprons may consist of a concrete slab, grouted or ungrouted riprap, or other material, and usually include a cut-off wall to protect against undermining.
ITEM 62.09 – EROSION/SCOUR/UNDERMINING

Erosion generally refers to the loss of bank material and a lateral movement of the channel. Scour is related to a lowering of the streambed material by flowing water. Scour is classified into two types: local and general scour. Local scour is usually caused by a specific flow obstruction that causes a constriction of flow and occurs primarily at the outlet. Note any channel cleaning up or downstream which may have lowered the profile. This lowering can work its way to the culvert and cause scour underneath the structure. General scour extends farther along the stream and is not localized around a particular obstruction. General scour can involve a gradual lowering of the streambed and can result in abrupt drops in the channel that move upstream in peak flow, called head cutting. Head cutting can be a serious problem if it occurs in the downstream channel, since it may threaten the structure as it moves upstream. Undermining occurs when the load-bearing soil under the structure is removed by scour or erosion, resulting in an unsupported portion of the structure. The rating should be selected using the relevant portions of the rating guidelines in Subsection 9.7.1.

ITEM 62.10 – CONSTRUCTION JOINTS

Construction joints are the joints between concrete pours, joints between precast or fabricated sections of pipe, or seams between steel plates. These can also describe a joint where a structure has been lengthened. The rating should be selected using the relevant portion of the guidelines in Subsection 9.7.1.

ITEM 62.11 – WINGWALLS

Wingwalls are retaining walls on each side of the inlet and outlet designed to protect and retain the embankment slopes and prevent undermining.

ITEM 62.18 – EMBANKMENT

Embankment is the soil above the structure under the roadway and on the slope. Cracking or dips in the roadway and erosion of the embankment may be indicators of structural or hydraulic problems. Refer to Part 4, Chapter 6 for additional information on the inspection of the roadway approach and embankment.

N Not Applicable
9 Excellent Condition – new
8 Very Good Condition – no problems noted
7 Good Condition – some minor problems
6 Satisfactory Condition – cracking in isolated locations on roadway and slight erosion
5 Fair Condition – noticeable erosion of embankment; slight dips in roadway and cracking in 10 percent of pavement
4 Poor Condition – considerable erosion of embankment; noticeable dips in five percent of roadway and cracking in 20 percent of pavement

3 Serious Condition – severe erosion of embankment; large dips in 10 percent of roadway and cracking in pavement with one inch of differential movement

2 Critical Condition – extreme erosion of embankment; large and deep dips in 20 percent of roadway and cracking in pavement with three inches of differential movement

1 Imminent Failure Condition – roadway is closed to traffic due to erosion of embankment, dips in the roadway, and cracking in pavement

0 Failed Condition – beyond corrective action

Subsection 9.8.2 Subjective Appraisal Items

Subjective items to be rated for state-owned bridges are listed below. Each item shall be rated as a stand-alone item, assessing its condition independently and not how it might relate to Item 62, the National Bridge Inspection Standards (NBIS) condition rating. Each item shall be rated as follows unless noted:

N Not Applicable
9 Excellent Condition – new
8 Very Good Condition – no problems noted
7 Good Condition – some minor problems and insignificant impact damage from drift
6 Satisfactory Condition – minor impact damage with no effect on structure function
5 Fair Condition – moderate impact damage having a small effect on structure function
4 Poor Condition – major impact damage having a moderate effect on structure function
3 Serious Condition – severe impact damage having a major effect on underfill structure function, such as noticeable live load deflection, vibration, impact, or noise from roadway above
2 Critical Condition – impact damage preventing function of the structure, excessive live load deflection, vibration, impact, or noise from roadway above
1 Imminent Failure Condition – roadway is closed to traffic
0 Failed Condition – beyond corrective action
ITEM 59A.53 – DEFLECTIONS

Underfill structures do not typically deflect under live load from the roadway above, and live load deflection would be an indication of a serious problem. Unless there is live load deflection, the deflection rating should be the same as the alignment rating, Item 62.02.

ITEM 59A.54 – VIBRATIONS

Underfill structures are dampened by the overburden, so there should be no vibration. Vibration from live load on the roadway above is an indication of a serious problem.

ITEM 59A.55 – IMPACT

Rate any impact noticeable in the underfill structure from traffic on the roadway.

ITEM 59A.56 – NOISE

Underfill structures are dampened by the overburden, so there should be no traffic noise coming from the roadway. Noise from live load on the roadway above is an indication of a serious problem.

Subsection 9.8.3 Inventory Data

Inventory data to be collected for the Central Database is listed below. Each item shall be measured as follows unless noted:

ITEM 62.12 – DESCRIPTION OF CELLS/BOXES/PIPES

The description of the cells, boxes, or pipes should include the quantity of cells and the shape, orientation, and material for each cell.

ITEM 62.13 – FILL HEIGHT

The fill height is the depth of cover or overburden above the structure, as shown in Figure 4:9-21. The fill height is measured in feet, to the nearest tenth of a foot.
ITEM 62.14 – MINIMUM DISTANCE TO HEADWALL/COPING

Record the minimum distance from the headwall or coping to the edge of the roadway. The distance is measured perpendicular to the roadway and is in feet to the nearest tenth of a foot.

ITEM 62.15 – CULVERT BARREL LENGTH

The barrel length is the longitudinal length along the barrel, as shown in Figure 4:9-19. If there are multiple barrels with varying lengths, the barrel length of the longest cell should be used. The length is measured in feet to the nearest tenth of a foot.

ITEM 62.16 – CULVERT HEIGHT

The height is the clear distance from the bottom of the structure or the top of the footing, to the lowest point of the structure. The height is measured in feet to the nearest tenth of a foot.

ITEM 62.17 – CULVERT WIDTH

The culvert width is the width perpendicular to the length of the barrel, shown as NBI Item 49 in Figure 4:9-19. In the case of multiple pipes where the clear distance is less than half the smaller continuous opening, the width is equal to the distance between the outside walls of the outer most pipes, as shown in Figure 4:9-19. The width is measured in feet to the nearest tenth of a foot.

On structures perpendicular to the roadway, the barrel width will be the same as the span length. On skewed structures, these will not be the same.
Figure 4:9-22: Two-Celled, Reinforced Concrete Underfill Structure

Figure 4:9-23: Concrete Headwall Failure
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CHAPTER 10  STRUCTURES OVER ROADWAYS

SECTION 10.1  INTRODUCTION

This chapter discusses railway, pedestrian, and pipeline bridges over roadways. Although the inspecting agency does not own these bridges, their safety must be assessed and pertinent information must be inventoried.

The assessments discussed in this chapter are an additional safety check for the traveling public, and do not limit the ultimate responsibility of the structure owner to ensure a safe structure. Inspectors for state, toll road, county, or local agencies may perform the assessment of these structures through cooperative inspection efforts with the owner or through independent inspections. The level of effort for these structures will be owner and site-specific. Visual inspection using binoculars from the underside of the structure, as well as reviewing the owner's latest inspection report, may satisfactorily confirm the safety of the structure.

The owner should be notified in writing if a safety condition exists. For safety deficiencies that present a hazard to the public, the inspector should implement the emergency notification procedure outlined in Part 1, Chapter 7 of this manual.

All inventory route information and associated under records required for Item 5 of the Bridge Reporting for Appraisal and Greater Inventory (BRAGI) Coding Guide must be collected for all structures over roadways. Safety assessments are currently required for all structures over state-owned and toll road routes and are recommended, at this time, for structures over local agency routes.
SECTION 10.2  RAILWAY BRIDGES

Although railway bridges have much larger vertical, live, impact, centrifugal, and longitudinal (braking) loads than roadway bridges, the inspection of a railway bridge is similar to that of a highway bridge. Refer to Part 4, Chapters 4 and 5 of this manual for a discussion on the superstructure and substructure inspection. This chapter will focus on the inspection and evaluation of problems which are unique to a railway bridge. Refer to Figure 4:10-1 and Figure 4:10-2 for views of a typical railway bridge.

Figure 4:10-1: Railroad Bridge Top View

Figure 4:10-2: Railroad Bridge Elevation View
Subsection 10.2.1 Railway Bridge Inspection Reporting

Private railroad companies own most of the railway bridges in Indiana. The type and extent of railway bridge inspections may vary from one company to another. The American Railway Engineering and Maintenance-of-Way Association (AREMA) recommends a 12-month annual inspection program be completed by the owners of all railway bridges. At times, because of poor condition or low-rating capacity, inspections may often be scheduled at three-, four-, or six-month intervals. The owner of the railway structure is responsible for the safety associated with the bridge. Any additional inspections by others which are related to the safety of the traveling public under the bridge should be considered supplemental bridge inspection data.

During a Supplemental Inspection, the inspector should report indications of failure in any portion of the structure and any conditions that could contribute to a future failure. Loose or corroded elements in danger of falling onto traffic lanes or pedestrians below should be noted. If possible, structures should be observed during the passage of a train so the effects of vibrations and deflections may be noted. All pertinent defects should be noted and recorded.

Subsection 10.2.2 Railway Bridge Approach Inspection

The railway track approach immediately adjacent to the abutment and backwall is one of the most important areas of a railway bridge. When the approach surface is uneven, large forces are applied to the backwall and bridge seat by passing trains. This can cause broken backwall ties, cracked and failed backwalls, or damaged bridge seats.

When inspecting railway bridges, the approaches should be observed for the following serious conditions:

- The approach is excessively low, out of cross-level, or both.
- Broken track and backwall ties are present in the approach area.
- Mud in the track at the approach and backwall is present which suggests approach settlement.
- Bent or broken rails are present.
- Missing or broken track components, such as angle bars, bolts, or spikes are present.
SECTION 10.3 PEDESTRIAN BRIDGES

The inspection of a pedestrian bridge is similar to that of roadway bridges. Pedestrian bridges over roadways should be inspected at a 24-month maximum interval with interim inspections for problem areas.

Since pedestrian bridges will not encounter the same loadings that vehicle or railway bridges encounter, some pedestrian bridges are constructed with a nonredundant girder system. The inspector should pay extra attention to any nonredundant girder system to ensure excessive corrosion or cracking is not occurring. Fencing may make it difficult for the inspector to see critical areas clearly and access equipment may be necessary. Refer to Figure 4:10-3 for an elevation view of a pedestrian bridge.

![Figure 4:10-3: Elevation View of Pedestrian Bridge](image_url)
SECTION 10.4 PIPELINE BRIDGES

The inspection of a pipeline bridge is similar to that of the other bridges discussed in this manual. Pipeline bridges should be inspected at 24-month intervals with interim inspections for problem areas.

Pipeline bridges typically are owned by either a transport company that moves a bulk product, or a distribution company that sells the product. The company’s product normally consists of a fuel, such as gasoline, fuel oils, propane, or natural gas in either liquid or gas form.

The inspector should familiarize him/herself with the products carried in these pipelines and be aware of the signs of a leak, including hissing sounds and dripping liquids. Many of these products lack an easily recognized identifier. For example, bulk natural gas does not have the telltale odor added until it is processed by the distribution company. If a leak is detected, the inspector should immediately leave the site by foot, and then call 9-1-1. It is important to leave the site without introducing an ignition source, such as a cigarette or sparks created by starting a vehicle or using a cell phone. The inspector should also be familiar with safety procedures with respect to leaks involving these fuels. The inspection should not continue until the owner has contained the leak and given notice to proceed.

Pipelines and pipeline bridges should be inspected for material deterioration and any loose bolts or pieces of material that could fall on to the roadway below. In addition, the inspector should look for sags in the pipe or pipeline bridge and inspect any supporting cables and foundations. Refer to Figure 4:10-4 for an end view of a pipeline bridge.

Figure 4:10-4: End View of a Pipeline Bridge
Pipelines are most often connected to a bridge using a clamping system. Refer to Figure 4:10-5 for a view of a typical pipeline-to-bridge connection. This bridge uses U-bolts to hold the pipeline to the bridge. All connections should be inspected to ensure the pipeline is securely fastened. Any loose or missing connections should be noted in the inspection report.

Figure 4:10-5: Pipeline to Bridge Connection
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An important aspect in inspecting and evaluating a steel bridge is to determine if the bridge has a potential for fatigue and/or sudden fracture. Fatigue and fracture may occur under loads or conditions below the original design requirements and result in an often sudden, brittle failure of a portion of, or the entire, bridge. These failures often occur in a relatively short period of time and the defects may spread rapidly prior to the failure. Fatigue details and damage occur in both redundant steel bridges, as well as fracture critical bridges.

Due to these potential conditions, it is imperative that bridges be identified as fracture critical in accordance with the National Bridge Inspection Standards (NBIS) and that the fracture critical elements are properly inspected. An extra degree of caution and detail must be exercised during the inspection of fracture critical bridges. Fatigue-prone details must be properly identified and thoroughly inspected. The potential for failure warrants the added level of effort and detail required for monitoring and reporting any potential defects throughout the life of the bridge. The detailed inspection reports also permit the owner of the bridge to make any necessary repairs before any major problems occur, and assist future inspectors at the bridge.

Figure 4:11-1: Girder Failure Due to Brittle Cracking at Intersecting Weld
Figure 4:11-2: Girder Failure Due to Brittle Cracking
SECTION 11.2  FATIGUE- AND FAILURE-PRONE DETAILS

One of the major causes for fracture failure is fatigue. Fatigue is defined as the tendency of a member to fail at a stress level below yield stress when subjected to cyclical loading. Fatigue cracks and damage can develop in steel bridges as a result of repeated loading. Fatigue cracks initiate from points of stress concentrations in structural members or details. Stress concentrations often result from:

- Material flaws.
- Connection details.
- Out-of-plane distortions.
- A change in a member cross section.

Most cracks in steel members occur in the tension zones, generally at a flaw or defect in the base material. Frequently, the crack is a result of fatigue occurring in the areas of stress concentrations mentioned above. Recognizing and understanding the behavior of connections and details are crucial if the inspector is to properly inspect steel bridges and fracture critical members, because connections and details are often the locations of the highest stress concentrations. It is the inspector's responsibility to have adequate knowledge, resources, and the ability to clearly identify and inspect fatigue-prone details and material flaws. Numerous references are available that provide excellent guidance on fatigue-related issues. The Manual for Inspecting Bridges for Fatigue Damage Conditions (Yen, Huang, Lai & Fisher - 1990) and the Bridge Inspector's Reference Manual (Publication No. FHWA NHI 03-001) (BIRM) are recommended references for fatigue inspections.

The American Association of State Highway and Transportation Officials (AASHTO) bridge specifications have categorized the susceptibility of various steel bridge details to fatigue cracking. These details were categorized for beam or girder in-plane bending and axial loading of members or member components. See Appendix A, Fatigue Prone Details, for more detailed information. The progression of a Fracture Critical Inspection should be in the order of the susceptibility to fatigue crack propagation and fatigue life cycle, ordered from the highest susceptibility (E') to the lowest (A). Of all the details, those of Categories D, E, and E' are the most susceptible to fatigue crack growth. These details must be thoroughly examined at every inspection, and consideration must be given to fatigue-causing factors such as traffic counts and vehicular loadings.
Figure 4:11-3: Sheared-Off Diaphragm Bolts Due to Fatigue

Figure 4:11-4: Fatigue Crack Through the Line of a Connection Angle
Figure 4:11-5: Unarrested Fatigue Rivet Crack
SECTION 11.3 WELDS

Metal bridges, particularly those that are welded, can contain material flaws. Flaws can vary in size from undetectable, nonmetallic inclusions, to large cracks. Material flaws may exist as external flaws such as pits, or internal flaws such as nonmetallic inclusions or lamellar tears.

Flaws can also be introduced during fabrication, material handling, or erection. These flaws can include:

- Damage at the edges of drilled or punched holes.
- Gouges/notches from flame-cutting, grinding, or impacts.
- Sharp corners at coped or blocked details.
- Incomplete welding fusion.
- Slag inclusions.
- Porosities.
- Blow holes.
- Undercuts.
- Craters.
- Weld cracks.
- Back-up bars or tack welds left in place.
- Plug welds.
- Arc strikes.
- Nicks.
- Notches.
- Indentations.
- Tears.
- Chain marks.
- Pitting from corrosion.

Most weld cracks start at either the weld toe or the weld root. Cracks at the weld toe can generally be detected using visual nondestructive testing (NDT) methods such as dye penetrant. Cracks at the weld root, often caused by a weld defect, will not be visible until they have grown large enough to break the surface of the weld.
Figure 4:11-6: Fatigue Cracks in Weld Due to Out-of-Plane Distortion

Figure 4:11-7: Typical Weld Details

Figure 4:11-8: Rust Line at Weld Toe Indicating a Fatigue Crack
Figure 4:11-9: Fatigue Cracks in Weld After Rehabilitation

Figure 4:11-10: Fatigue Cracks in Weld Due to Stresses After Rehabilitation
SECTION 11.4 GUSSET PLATES

Gusset plates transfer loads from one member to another and should be inspected carefully for section loss. Corrosion of gusset plates can be difficult to quantify because of the limited access to these plates in tightly configured connections, or those where the members framing into the gusset plates are closely spaced.

Inspectors should identify the primary truss gusset plates where corrosion is evident, and visual inspections with traditional measurement devices (calipers, depth probe, tape measure, etc.) may not detect or adequately quantify section loss due to corrosion for the entire plate.

At these locations, inspectors should use an appropriate NDT technology to assess the gusset plate condition, quantifying the plate thickness. The measurement location and dimension from each inspection should be documented and retained in the bridge file. The measurement locations should be identifiable from readily reestablished reference points.

Ultrasonic testing methods for thickness measurement are recommended for this testing in combination with a visual inspection.
SECTION 11.5 OUT-OF-PLANE DISTORTION

Many fatigue cracks result from out-of-plane distortion across a small gap, usually a segment of a girder web. The problem of distortion-induced fatigue cracking has been observed in the following types of bridges:

- Trusses
- Suspension bridges (floor system)
- Two-girder bridges
- Multi-beam and multi-girder bridges
- Tied arch bridges
- Box girder bridges

![Out-of-Plane Bending at Floor Beam Connection Plate](image1)

**Figure 4:11-11: Out-of-Plane Bending at Floor Beam Connection Plate**

![Double Fatigue Cracks in Girder Web, Top of Connection Plate](image2)

**Figure 4:11-12: Double Fatigue Cracks in Girder Web, Top of Connection Plate**

(Out-of-Place Bending)
SECTION 11.6  FATIGUE REPORTING

Adequate documentation is crucial in the monitoring of fatigue damage. Once fatigue damage is located, all similar fatigue details on the bridge should be re-evaluated and examined. The inspector should give strong consideration to reducing the inspection frequency due to the potential for rapid deterioration or failure. The Federal Highway Administration (FHWA) suggests that approximately 95 percent of the fatigue life has been surpassed with the presence of a fatigue crack. Suitable documentation is mandated so the fatigue areas can be closely monitored across inspection cycles and by different inspectors. When a fatigue crack or suspected crack has been detected, the following relevant information should be recorded:

- Date the crack was detected, confirmed, and re-examined
- Relation of the crack to the areas of tension stresses
- General location of the crack, such as “at panel point L4 of the west truss,” or “at the upper end of the connection plate of the L4 floor beam,” etc.
- Detailed sketches of the location, orientation, length, and width of crack; extra care should be given to determine the location of the ends of the crack; limits of the crack should be clearly marked and dated on the member
- Dimensions and details of the member containing the crack
- Any noticeable conditions at the crack when vehicles traverse the bridge, such as opening and closing of the crack, visible distortion at the local area, etc.
- Any configuration and geometrical conditions of the other members or components adjacent to, or near, the cracked member, which may have deviated from the expected, or which may have been altered after erection of the bridge
- Condition of the corrosion, accumulation of dirt and debris, etc., at the general location of the crack
- Weather conditions when the crack was discovered or inspected
- Testing performed at the location of the crack or similar locations
Note the documentation shown in Figure 4:11-13.

The following is a list of some of the bridge superstructure types that have been identified as susceptible to fatigue cracking. However, other steel bridges are still at risk for failure and Fracture Critical Inspections are not limited to the structure types provided in this list. The bridges are listed in order, with the most susceptible first:

- Suspended spans with two girders
- Bar-chain suspension bridge with two eyebars per panel
- Welded, tied arches with box-shaped tie girder
- Simple span truss with two eyebars or single member between panel points
- Simple-span, single-welded box girders with details such as termination of longitudinal stiffeners or gusset plate
- Simple-span, two-girder bridges with welded partial-length cover plates on the bottom flange
- Continuous-span, two-girder system with cantilever and suspension link arrangement and welded partial-length cover plates
- Simple-span, two-girder system with lateral bracing connected to horizontal gusset plates which are attached to webs
- Single-welded I-girder or box girder pier cap with bridge girders and stringers attached by welding
PROPER IDENTIFICATION, CLASSIFICATION, INSPECTION, AND REPORTING OF ALL CRACK CRITICAL BRIDGES AND THE SUBSEQUENT MEMBERS ARE CRUCIAL TO THE LONGEVITY OF INDIANA’S BRIDGES AND THE SAFETY OF THE PUBLIC. UNIFORMITY IN REPORTING PERMITS THE INSPECTORS TO ACCURATELY AND CLOSELY MONITOR ANY PROBLEMS THROUGHOUT THE LIFE OF THE STRUCTURE. DETAILED AND ACCURATE REPORTING ALSO PERMITS THE BRIDGE OWNER TO MAINTAIN AND REPAIR THE BRIDGE BEFORE MAJOR PROBLEMS EVOLVE.

SUBSECTION 11.7.1 CLASSIFICATION OF CRACK CRITICAL MEMBERS

THE FHWA DEFINES A CRACK CRITICAL MEMBER AS A STEEL MEMBER IN TENSION, OR WITH A TENSION ELEMENT, WHOSE FAILURE WOULD PROBABLY CAUSE A PORTION OF, OR THE ENTIRE, BRIDGE TO COLLAPSE. A CRACK CRITICAL BRIDGE IS ONE THAT CONTAINS A CRACK CRITICAL MEMBER. THE FHWA PRESENTS TWO CRITERIA FOR IDENTIFYING A CRACK CRITICAL BRIDGE:

- STEEL MEMBERS MUST BE IN TENSION, OR ELEMENTS/FIBERS OF THE MEMBER MUST BE IN TENSION. THESE LOADING CONDITIONS MAY INCLUDE TENSILE FORCES, SHEAR, FLEXURE, AND TORSION. LOAD ANALYSIS RATINGS MAY INDICATE SOME MEMBERS EXPERIENCE A STRESS REVERSAL (VARIES FROM TENSION TO COMPRESSION) UNDER VARIOUS LOADS. SUCH MEMBERS ARE TO BE INCLUDED UNDER THIS CRITERIA.

- THERE MUST BE NO LOAD PATH REDUNDANCY OF THE BRIDGE, IN WHICH NO OTHER STRUCTURAL ELEMENTS ARE CAPABLE OF CARRYING THE LOAD IF A MAIN LOAD-CARRYING MEMBER FAILS. FOR A BRIDGE TO BE DEFINED AS NON-LOAD PATH REDUNDANT, IT MUST HAVE TWO OR LESS LOAD PATHS.

SOME TYPICAL BRIDGES THAT MAY BE CONSIDERED CRACK CRITICAL INCLUDE, BUT ARE NOT LIMITED TO, THESE TYPES:

- TRUSS BRIDGES CONTAINING TWO MAIN LOAD-CARRYING MEMBERS
- THROUGH GIRDER BRIDGES
- TWO-GIRDER BRIDGES
- TIED ARCH BRIDGES
- BOX GIRDER
- CABLE-STAYED BRIDGES
- SUSPENSION BRIDGES
- STEEL RIGID FRAME BRIDGES
- BRIDGES CONTAINING STEEL CROSS-GIRDER OR STEEL PIER CAPS
• Bridges with pin-and-hanger systems (will always be classified, at a minimum, as a special detail inspection, Item 92C)

• Movable bridges

See Appendix B for examples of fracture critical bridges, components, bending diagrams, typical crack locations, and typical pin-and-hanger parts. Timber covered bridges (trusses) with steel vertical tension hangers are not coded as fracture critical (Item 92A). Unless a structural analysis indicates these are primary members, they are to be considered a secondary member (non-fracture critical).

Once a bridge is designated as fracture critical, each individual member and connection must be identified for the inspection. Any attachment connected to the tension area of a fracture critical member and having a length in the direction of the tension stress greater than four inches shall be considered part of the tension component and, therefore, shall be considered fracture critical. For definition purposes and uniformity in reporting, the portions of the fracture critical member within a minimum of 12 inches of the entire connection (gusset plates, connection plates, etc.) shall be considered a fracture critical connection, whereas the portion of the tension member beyond the 12-inch window shall be considered a fracture critical member. See Figures 4:11-14 through 4:11-16 for examples of this definition. The Inspection Team Leader shall use sound judgment to expand the minimum 12-inch criteria to include additional fatigue details, and also consider the scale of the bridge and associated members. Floor beam connections, lateral bracing connections, bearings, gusset plates, connection angles, pins, hangers, etc. are all typically considered as part of the fracture critical connection.
In the event that original design plans of a fracture critical bridge clearly indicate that a tension member is not fracture critical due to internal redundancies within the bridge, these members will still require a detailed Fracture Critical Inspection. These tension members may only be omitted from the Fracture Critical Inspection if permission is given by the owner and the State Program Manager prior to the inspection.
Subsection 11.7.2 Inspector Qualification

All Inspection Team Leaders for fracture critical bridges must meet the following requirements:

- Qualified Inspection Team Leader, as defined in Part 1, Chapter 2
- Successful completion of FHWA-NHI-130078, Fracture Critical Inspection Techniques for Steel Bridges, within the last ten years
- Adequate knowledge and understanding of how a fracture critical bridge functions, and where possible defects may occur; must also possess suitable knowledge of the function of the specific bridge undergoing the inspection and, subsequently, the more complex bridges will warrant more knowledgeable, experienced inspectors; knowledge includes the understanding and ability to perform testing or recommend advanced testing procedures at problem areas; must be current on issues with the type of bridges being inspected
- Physical ability to provide a hands-on inspection of all fracture critical members and connections in the individual bridge, as defined in Section 11.2.5

For complex bridges that contain fracture critical members, additional requirements for the inspection of complex bridges are required as directed in Part 1, Chapter 2.

Subsection 11.7.3 Inspection Interval

Fracture Critical Inspections shall be performed at a regular interval not to exceed 24 months. If necessary, the inspection interval may be reduced. The inspection may be a supplemental inspection to the Routine Inspection. An entire bridge may require a 24-month Fracture Critical Inspection while several elements are identified for a six-month inspection cycle. The fracture critical Plan of Action must describe all fracture critical elements and their frequency of inspection that differ from the 24-month inspection cycle or the inspection cycle for the entire bridge.

Subsection 11.7.4 Inspection Preparation

The fracture critical Plan of Action must be developed and/or reviewed and updated prior to performing a Fracture Critical Inspection. The inspection Plan of Action plays a crucial role in assisting all current and future inspectors at the bridge. The Plan of Action serves as an important first step in performing a thorough and complete investigation of all fracture critical members, while identifying necessary means, methods, and equipment required to perform this inspection. The inspection Plan of Action is a required element for every fracture critical report. Although, these minimum requirements must be met for acceptance of the report by the Indiana Department of Transportation (INDOT), the inspecting agency may provide alternate inspection plan formats meeting internal guidelines, provided the criteria set forth in this chapter are met. A full sample report, including the inspection Plan of Action is included in Appendix C.
At a minimum, the inspection Plan of Action shall include the following:

- Sketch(es) of the superstructure with locations of all fracture critical members and connections clearly identified; primary members that are not fracture critical should be clearly identified, as well
  - An elevation view for trusses with locations labeled by letters and numbers similar to the nomenclature indicated in Figure 4:11-17
  - Use a framing plan and elevation view for a through girder with detail locations labeled by letters and numbers similar to the nomenclature indicated in Figure 4:11-18
  - A north arrow
- A general listing of all fracture critical members
- A brief historical fact statement, such as a summary of repairs and rehabilitations or prior history of any problems
- All inspection tools and access equipment required/used for the inspection
- Traffic control requirements
- Method used to measure the thickness of primary truss gusset plates and which gusset plates were measured using each method shall be clearly identified
- Bridge cleaning requirements
- Inspection frequency and identification of any fracture critical elements that require an inspection frequency different than the inspection frequency for the entire bridge
- Other items that should be reviewed and made available to the inspector, if available, prior to the inspection include the following:
  - Existing bridge plans and any repair/rehabilitation plans
  - Historical data and maintenance history of the bridge
  - Prior load ratings or a preliminary load rating (invaluable in determining fracture critical members)
  - Prior inspection reports
Figure 4:11-17: Typical Inspection Plan Sketch (Truss)

Note: Panel points are typically labeled beginning from South to North or from West to East in Figure 4:11-17.

Figure 4:11-18: Typical Inspection Plan Sketches (Through Girder)
Subsection 11.7.5 Field Inspection

The FHWA requires a hands-on inspection of all fracture critical members and/or components. Hands-on is defined as being within arm’s reach (two feet) of these components. INDOT firmly enforces the hands-on requirement during inspections due to the relatively small size and difficulty in locating cracks and adequately inspecting fatigue and other details. The hands-on inspection requirement warrants the utilization of ladders, man lifts, free climbing, and snooper vehicles to inspect all fracture critical components and members. Cracks and other deficiencies cannot be adequately located and inspected with the utilization of binoculars or outside of the inspector’s reach from the member.

Primary compression members, floor beams, and secondary members such as lateral bracing, portal bracing, etc. are not considered fracture critical. These items require inspection and reporting during the Routine Inspection cycle. However, special consideration should be given to ensure that all primary and secondary members are inspected during the Routine or Fracture Critical Inspection and that no members have been missed during the entire inspection cycle. At a minimum, the Inspection Team Leader should perform a brief walkthrough of all secondary and non-fracture critical primary members during the Fracture Critical Inspection as a simple means to ensure all members have been inspected. When expensive equipment such as a snooper vehicle or man lift is utilized during the Fracture Critical Inspection, the Inspection Team Leader should strongly consider and plan to utilize this equipment for the inspection of any difficult-to-inspect, non-fracture critical members or problem areas on the bridge.

Many fracture critical members and connections are often covered in dirt and debris. The dirt and debris can contribute to the deterioration of these members, and the dirtiest areas are often in the worst condition. INDOT requires all fracture critical members and components to be adequately cleaned and free of debris prior to the hands-on inspection. Typical areas that warrant cleaning are bearings and lower chords. Power washers, hand brooms, brushes, and shovels are effective tools to provide for an adequate inspection of members. The Inspection Team Leader may wish to coordinate with state or local maintenance crews to perform this work prior to the inspection; however, it is the responsibility of the inspector to ensure that all components are clearly visible and adequately cleaned. Special consideration must be given to the presence of lead-based paint during any bridge cleaning. This may prove harmful to the inspector and the environment if disturbed.

It is imperative that the inspector adequately identify and inspect each fracture critical member and fatigue detail. The FHWA suggests inspection for fatigue cracks in welded bridges should be performed at, but not limited to, the following locations:
For out-of-plane distortion in welded bridges, inspect the following locations:

- Girder webs at floor beam and diaphragm connections
- Ends of diaphragm connection plates in girder bridges
- Box girder webs at diaphragms
- Lateral bracing gusset plates on girder webs at floor beam connections
- Floor beam and cantilever bracket connections to girders
- Pin-connected hanger plates and fixed-pin plates

For main members in welded bridges, inspect the following locations:

- Ends of welded cover plates
- Groove welds in flange plates
- Butt welds in longitudinal stiffeners
- Web plates with cut-outs and filler welds
- Intersecting groove welds
- Welded repairs and reinforcement
- Back-up bar splices
- Stress risers

For connections and attachments in welded bridges, inspect the following locations:

- Cut short flanges
- Coped beam ends
- Blocked flange plates
- Welded rigid connections of cross-girders at bents
- Welded flange attachments
- Intersecting welds at gusset plates and diaphragms
In general, the locations where fatigue cracks develop in riveted and bolted bridges are similar to those in welded bridges. The FHWA suggests inspection for fatigue cracks in riveted or bolted bridges should be performed at, but not limited to, the following locations:

- Rivets/bolts at end connections (check for cracking and prying)
- End connection angle
- Girder webs at floor beam connections
- Floor beam connections to girders
- Diaphragm connections to girders
- Cantilever bracket connections to girders
- Truss hangers
- Eyebars (see Figures 4:11-19 and 4:11-20)
- Tack welds
- Rivet heads and bolts made of certain types and ages of steel on older bridges may have fatigue issues, especially if pack rust has developed between connection members; additional stress may be placed on the nut or rivet head at these locations

The thickness of primary truss gusset plates should be measured as a part of a Fracture Critical Inspection. If the section cannot be adequately measured with traditional measurement devices, inspectors should use an appropriate NDT technology to assess the gusset plate condition and quantify the plate thickness.
Subsection 11.7.6 Field Inspection Reporting

Each bridge owner has unique requirements and preferences for bridge reporting. The guidelines listed in this section are the minimum reporting requirements for acceptance of a fracture critical report. Although these minimum requirements must be met for acceptance of the report by INDOT, the inspecting agency may provide alternate report formats meeting internal guidelines, as long as the criteria set forth in this chapter are met. An example inspection report has been provided in Appendix C. The following are minimum requirements for a Fracture Critical Inspection report:

- Inspection Plan of Action
- General statement discussing inspection procedures
- Date, temperature, and weather conditions of the inspection
- Time duration of the inspection
- Inspection Team Leaders and Inspection Team Members present at the inspection
- General summary of inspection results
- Testing performed, and locations of these tests
- Recommendations for repairs and maintenance, highlighting urgent repairs and listing programmed repairs
• Photographs of every fracture critical member, connection, or component assigned a condition rating of 4 or less

• Photographs of each fracture critical member at a frequency of not greater than 10 years (to be included in the bridge file)

• Photographs of any cracks inspected or discovered

• Recommended inspection interval

• Documentation of inspection results for each individual member and/or component, including the following:
  o Individual member rating
  o Noted section loss
  o AASHTO fatigue category
  o Brief statement discussing the presence of cracks (or lack thereof)

• Adequate documentation of fatigue damage

• A table of showing the primary truss gusset plates, the thickness measurement taken, the location of each measurement, and the inspection procedure used to take each measurement

Figure 4:11-21: Inspector Performing Hands-On Inspection
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<tr>
<td>B</td>
<td>FRACTURE CRITICAL DETAILS</td>
<td>8</td>
</tr>
<tr>
<td>C</td>
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<td>19</td>
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<tr>
<td></td>
<td>SAMPLE SPECIAL INSPECTION REPORT – 2010</td>
<td>19</td>
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## Appendix A
### Fatigue-Prone Details

<table>
<thead>
<tr>
<th>General Conditions</th>
<th>Situation</th>
<th>Kind of Stress</th>
<th>Stress Category</th>
<th>Illustrative Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plain Member</td>
<td>Base metal with rolled or cleaned surface. Flame-cut edges with American National Standards Institute (ANSI) smoothness of 1,000 or less.</td>
<td>T or Rev⁸</td>
<td>A</td>
<td>1,2</td>
</tr>
<tr>
<td>Built-Up Members</td>
<td>Base metal and weld metal in members of built-up plates or shapes (without attachments) connected by continuous full-penetration groove welds (with backing bars removed), or by continuous fillet welds parallel to the direction of applied stress.</td>
<td>T or Rev</td>
<td>B</td>
<td>3,4,5,7</td>
</tr>
<tr>
<td></td>
<td>Base metal and weld metal in members of built-up plates or shapes (without attachments) connected by continuous full-penetration groove welds with backing bars not removed, or by continuous partial penetration groove welds parallel to the direction of applied stress.</td>
<td>T or Rev</td>
<td>B’</td>
<td>3,4,5,7</td>
</tr>
<tr>
<td></td>
<td>Calculated flexural stress at the toe of transverse stiffener welds on girder webs or flanges.</td>
<td>T or Rev</td>
<td>C</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Base metal at ends of partial-length, welded cover plates with high-strength, bolted, slip-critical end connections (see Noteb).</td>
<td>T or Rev</td>
<td>B</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Base metal at ends of partial-length, welded cover plates narrower than the flange having square or tapered ends, with or without welds across the ends, or wider than the flange without welds across the ends.</td>
<td>T or Rev</td>
<td>B’</td>
<td>7</td>
</tr>
<tr>
<td>Groove-Welded Connections</td>
<td>Base metal and weld metal in or adjacent to full-penetration groove weld splices of rolled or welded sections having similar profiles when welds are ground flush with grinding in the direction of applied stress and weld soundness established by nondestructive testing.</td>
<td>T or Rev</td>
<td>B</td>
<td>8,10</td>
</tr>
<tr>
<td></td>
<td>Base metal and weld metal in, or adjacent to, full-penetration groove weld splices with 2-foot radius transitions in width, when welds are ground flush with grinding in the direction of applied stress and weld soundness established by nondestructive testing.</td>
<td>T or Rev</td>
<td>B</td>
<td>13</td>
</tr>
</tbody>
</table>
Base metal and weld metal in, or adjacent to, full-penetration groove weld splices at transitions in width or thickness, with welds ground to provide slopes no steeper than 1 to 2-1/2 inches, with grinding in the direction of the applied stress, and weld soundness established by nondestructive testing:

(a) American Association of State and Highway Transportation Officials (AASHTO) M 270 Grades 100/100W (American Society for Testing and Materials [ASTM] A 709) base metal

(b) Other base metals

Base metal and weld metal in, or adjacent to, full-penetration groove weld splices, with or without transitions having slopes no greater than 1 to 2-1/2 inches, when the reinforcement is not removed and weld soundness is established by nondestructive testing.

---

Groove-Welded Attachments—Longitudinally Loaded:

<table>
<thead>
<tr>
<th>Description</th>
<th>T or Rev</th>
<th>Code</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal adjacent to details attached by full- or partial-penetration groove welds when the detail length, L, in the direction of stress, is less than 2 inches.</td>
<td>T or Rev</td>
<td>C</td>
<td>6, 15</td>
</tr>
<tr>
<td>Base metal adjacent to details attached by full- or partial-penetration groove welds when the detail length, L, in the direction of stress, is between 2 inches and 12 times the plate thickness, but less than 4 inches.</td>
<td>T or Rev</td>
<td>D</td>
<td>15</td>
</tr>
<tr>
<td>Base metal adjacent to details attached by full- or partial-penetration groove welds when the detail length, L, in the direction of stress, is greater than 12 times the plate thickness or greater than 4 inches:</td>
<td>T or Rev</td>
<td>E</td>
<td>15</td>
</tr>
<tr>
<td>(a) Detail thickness &lt; 1.0 in</td>
<td>T or Rev</td>
<td>E'</td>
<td>15</td>
</tr>
<tr>
<td>(b) Detail thickness ≥ 1.0 in</td>
<td>T or Rev</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base metal adjacent to details attached by full- or partial-penetration groove welds with a transition radius, R, regardless of the detail length:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--With the end welds ground smooth:</td>
<td>T or Rev</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>(a) Transition radius ≥ 24 in</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) 24 in. &gt; Transition radius ≥ 6 in</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) 6 in. &gt; Transition radius ≥ 2 in</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) 2 in. &gt; Transition radius ≥ 0 in</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--For all transition radii without end welds ground smooth.</td>
<td>T or Rev</td>
<td>E</td>
<td>16</td>
</tr>
<tr>
<td>Groove-Welded Attachments—Transversely Loaded&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>Detail base metal attached by full-penetration groove welds with a transition radius, R, regardless of the detail length and with weld soundness transverse to the direction of stress established by nondestructive testing:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>--With equal plate thickness and reinforcement removed:</td>
<td>T or Rev</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>(a) Transition radius $\geq$ 24 in</td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) 24 in. &gt; Transition radius &gt; 6 in</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>(c) 6 in. &gt; Transition radius $\geq$ 2 in</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) 2 in. &gt; Transition radius $\geq$ 0 in</td>
<td>E</td>
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<tr>
<td>--With equal plate thickness and reinforcement not removed:</td>
<td>T or Rev</td>
<td>16</td>
<td></td>
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<tr>
<td>(a) Transition radius $\geq$ 6 in</td>
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<td>(b) 6 in. &gt; Transition radius $\geq$ 2 in</td>
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<td>(c) 2 in. &gt; Transition radius $\geq$ 0 in</td>
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<tr>
<td>--With unequal plate thickness and reinforcement removed:</td>
<td>T or Rev</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>(a) Transition radius $\geq$ 2 in</td>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) 2 in. &gt; Transition radius $\geq$ 0 in</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--For all transition radii with unequal plate thickness and reinforcement not removed.</td>
<td>T or Rev</td>
<td>E</td>
<td>16</td>
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</table>

<table>
<thead>
<tr>
<th>Fillet-Welded Connections</th>
<th>Base metal at details connected with transversely loaded welds, with the welds perpendicular to the direction of stress:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Detail thickness $\leq$ 0.5 in</td>
<td>T or Rev</td>
<td>C</td>
</tr>
<tr>
<td>(b) Detail thickness &gt; 0.5 in</td>
<td>T or Rev</td>
<td>See Note&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>Base metal at intermittent fillet welds.</td>
<td>T or Rev</td>
<td>E</td>
</tr>
<tr>
<td>Shear stress on throat of fillet welds.</td>
<td>Shear</td>
<td>F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fillet-Welded Attachments—Longitudinally Loaded</th>
<th>Base metal adjacent to details by fillet welds with length, L, in the direction of stress, is less than 2 inches and stud-type shear connectors.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal adjacent to details attached by fillet welds with length, L, in the direction of stress, between 2 inches and 12 times the plate thickness, but less than 4 inches.</td>
<td>T or Rev</td>
<td>D</td>
</tr>
<tr>
<td>Base metal adjacent to details attached by fillet welds with length, L, in the direction of stress, greater than 12 times the plate thickness, or greater than 4 inches:</td>
<td>T or Rev</td>
<td>E</td>
</tr>
<tr>
<td>(a) Detail thickness &lt; 1.0 in</td>
<td>T or Rev</td>
<td>E</td>
</tr>
<tr>
<td>(b) Detail thickness $\geq$ 1.0 in</td>
<td>T or Rev</td>
<td>E'</td>
</tr>
<tr>
<td>Base metal adjacent to details attached by fillet welds with a transition radius, R, regardless of the detail length:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--With the end welds ground smooth:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Transition radius ( \geq 2 \text{ in.} ) ( \text{T or Rev D} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) 2 in. &gt; Transition radius ( \geq 0 \text{ in.} ) ( \text{T or Rev E} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--For all transition radii without the end welds ground smooth.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \text{T or Rev E} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detail base metal attached by fillet welds with a transition radius, R, regardless of the detail length (shear stress on the throat of fillet welds governed by Category F):</th>
</tr>
</thead>
<tbody>
<tr>
<td>--With the end welds ground smooth</td>
</tr>
<tr>
<td>(a) Transition radius ( \geq 2 \text{ in.} ) ( \text{T or Rev D} )</td>
</tr>
<tr>
<td>(b) 2 in. &gt; Transition radius ( \geq 0 \text{ in.} ) ( \text{T or Rev E} )</td>
</tr>
<tr>
<td>--For all transition radii without the end welds ground smooth.</td>
</tr>
<tr>
<td>( \text{T or Rev E} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Base metal at gross section of high-strength, bolted, slip-resistant connections, except at axially loaded joints which induce out-of-plane bending in connecting materials.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal at net section of high-strength bolted bearing-type connections.</td>
</tr>
<tr>
<td>Base metal at net section of riveted connections.</td>
</tr>
<tr>
<td>( \text{T or Rev T A} )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Base metal at the net section of eyebars or pin plate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal in the shank of eyebars, or through the gross section of pin plates with:</td>
</tr>
<tr>
<td>(a) rolled or smoothly ground surfaces.</td>
</tr>
<tr>
<td>(b) flame-cut edges.</td>
</tr>
<tr>
<td>( \text{T or Rev T A} )</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Appendix A</th>
<th>Fatigue-Prone Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal adjacent to details attached by fillet welds with a transition radius, R, regardless of the detail length:</td>
<td></td>
</tr>
<tr>
<td>--With the end welds ground smooth:</td>
<td></td>
</tr>
<tr>
<td>(a) Transition radius ( \geq 2 \text{ in.} ) ( \text{T or Rev D} )</td>
<td></td>
</tr>
<tr>
<td>(b) 2 in. &gt; Transition radius ( \geq 0 \text{ in.} ) ( \text{T or Rev E} )</td>
<td></td>
</tr>
<tr>
<td>--For all transition radii without the end welds ground smooth.</td>
<td></td>
</tr>
<tr>
<td>( \text{T or Rev E} )</td>
<td></td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Fillet-Welded Attachments—Transversely Loaded with the Weld in the Direction of Principal Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal at gross section of high-strength, bolted, slip-resistant connections, except at axially loaded joints which induce out-of-plane bending in connecting materials.</td>
</tr>
<tr>
<td>Base metal at net section of high-strength bolted bearing-type connections.</td>
</tr>
<tr>
<td>Base metal at net section of riveted connections.</td>
</tr>
<tr>
<td>( \text{T or Rev T A} )</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Mechanically Fastened Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal at gross section of high-strength, bolted, slip-resistant connections, except at axially loaded joints which induce out-of-plane bending in connecting materials.</td>
</tr>
<tr>
<td>Base metal at net section of high-strength bolted bearing-type connections.</td>
</tr>
<tr>
<td>Base metal at net section of riveted connections.</td>
</tr>
<tr>
<td>( \text{T or Rev T A} )</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Eyebar or Pin Plates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal at the net section of eybar head or pin plate.</td>
</tr>
<tr>
<td>Base metal in the shank of eyebars, or through the gross section of pin plates with:</td>
</tr>
<tr>
<td>(a) rolled or smoothly ground surfaces.</td>
</tr>
<tr>
<td>(b) flame-cut edges.</td>
</tr>
<tr>
<td>( \text{T or Rev T A} )</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>a “T” signifies range in tensile stress only. “Rev” signifies a range of stress involving both tension and compression during a stress cycle.</td>
</tr>
<tr>
<td>c “Longitudinally Loaded” signifies direction of approved stress is parallel to the longitudinal axis of the weld. “Tranversely Loaded” signifies direction of applied stress is perpendicular to the longitudinal axis of the weld.</td>
</tr>
<tr>
<td>d Transversely loaded partial penetration groove welds are prohibited.</td>
</tr>
<tr>
<td>e Allowable fatigue stress range on throat of fillet welds transversely loaded is a function of the effective throat and plate thickness. (See Frank and Fisher, <em>Journal of the Structural Division</em>, ASCE, Vo. 105, No. ST9, Sept. 1979.)</td>
</tr>
<tr>
<td>f Gusset plates attached to girder flange surfaces with only transverse fillet welds are prohibited.</td>
</tr>
</tbody>
</table>
SIMPLE SPAN TRUSS

- Imaginary Arch
- Compression Diagonal
- Tension Diagonal
- Imaginary Cable
Cracks being pulled open by tensile forces.
Fatigue Categories A, B (on eyebar body), or E (on net section of eyebar head)
Fatigue Category A, B (on hanger plate body), or E (on net section of hanger or pin plate)
Fatigue Categories E and E’
Web Out-of-Plane Bending at Floor Beam Connection Plate
Fatigue Category

LONGITUDINAL STIFFENERS

Tension Flange

Fatigue Category E

Crack

COMPRESION

M

Girder

Longitudinal Stiffener

Crack

Tension Flange
SAMPLE SPECIAL INSPECTION REPORT – 2010

The inspecting agency may provide alternate report formats meeting internal guidelines, as long as the criteria set forth in the manual are met. The following sample report is intended to serve as a guide for how the report may be set up. Alternate reporting formats may be provided subsequent to the review and approval by the Indiana Department of Transportation (INDOT).

Reviewing Owner Representative:

Name – County Engineer or Commissioner: __________________________________________________

Prepared by: _________________________________________________________________________

Certified: __________________________

(Name, P.E.)

Date: ________________________________
<table>
<thead>
<tr>
<th>Erection</th>
<th>Inspect</th>
<th>Underwrite</th>
<th>Specia</th>
<th>Load</th>
<th>Name and Title</th>
<th>Qualifications</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>-</td>
<td>Name</td>
<td>PE, BScEng, BE, MScCE</td>
<td>Project Supervisor</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BScCE XXX University, SGX</td>
<td>Team Leader</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NCT Certified Bridge Team Leader, MScCE</td>
<td>Special Detail Inspection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XX years Bridge Inspectors</td>
<td>Field Inspector</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>XX years Bridge Design</td>
<td>Final QC Review of Team Inspection Report</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>x</td>
<td>Name</td>
<td>PE, BScEng, BE, MScCE</td>
<td>Team Leader</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BScCE XXX University, SGX</td>
<td>Final Review Load Ratings</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>NCT Certified Bridge Team Leader, MScCE</td>
<td>Special Detail Inspection</td>
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<tr>
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<td></td>
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<td></td>
<td>XX years Bridge Inspectors</td>
<td>Field Inspection</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>XX years Bridge Design</td>
<td>Final QC Review of Team Inspection Report</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td>x</td>
<td>Name</td>
<td>PE, BScEng, BE, MScCE</td>
<td>Team Leader</td>
</tr>
<tr>
<td></td>
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<td>BScCE XXX University, SGX</td>
<td>Special Detail Inspection</td>
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<td></td>
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<td>XX years Bridge Inspectors</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>XX years Bridge Design</td>
<td>Special Detail Inspection</td>
</tr>
</tbody>
</table>

Team Leaders: name, name and name were present and were actively involved in the field inspections of the special detail bridge in Unnamed County.

<table>
<thead>
<tr>
<th>name</th>
<th>name</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>name, Quality Control Officer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
I. INTRODUCTION

A. Location and Description

Bridge No. 001 is located 0.1 miles east of State Road 99. Map location is at D-3. The bridge carries traffic on Main Street over Nameless Creek. The bridge is located at latitude of 39°00'01.1" and longitude of 86°00'01.1".

Bridge No. 001 is a single-span, timber, covered, burr arch, truss bridge that is on the National Register of Historic Places. The structure has no skew, has a length of 190 feet, and a maximum span length of 182 feet. The structure has a clear roadway width of 14.4 feet, which categorizes it as a “One-Lane Bridge.” The average daily traffic was estimated to be 100 vehicles per day in 2010. The bridge has an H rating of five tons, an HS Inventory Rating of 9, and an HS Operating Rating of 12.

B. History

The estimated year of construction for Bridge No. 001 is 1888 and it has been reconstructed in 2003 and repaired in 2008.

II. FIELD INVESTIGATION

A. Members and Connections to be Inspected

Inspect all main load-carrying members, including splices and panel points, timber through arch truss, and all connections.
B. Inspection Procedures

An up-close, visual inspection was performed to locate possible problem areas of the superstructure. Borings for determining decay of members was not warranted at this location due to the condition of the members.

C. Equipment Required for Inspection

Tools and equipment used to inspect each member or connection included a hard hat, safety glasses, hammer, tape measure, camera, and a flashlight. A drill for borings was available for a more detailed inspection of rotting members if needed. A 20’ extension ladder was used to inspect the upper chord connections and various members, and lower chord connections and various members were inspected from the bridge deck.

D. Bridge Cleaning Requirements

The bearings contained heavy dirt and roadway debris. A shovel and hand brush were utilized by the inspector to clean these locations.

E. Traffic Maintenance Requirements

Due to the low vehicular speeds and average daily traffic (ADT) of the bridge, no temporary roadway closures were required. A flagger and temporary signage was provided during the inspection.

F. Date and Conditions of Inspection

Date: 6/27/2009
Temperature: 83° F
Conditions: Sunny

Inspection Duration: Three hours

G. Other Items

Original bridge plans were not available. Rehabilitation and repair plans, dated 2001, were provided by the county. The previous Inspection Consultant provided copies of load ratings, as well as previous inspection reports. Field notes tracking several deficiencies were made available by the previous Inspection Consultant in order to monitor the development of several deficiencies at the bridge.

III. SUMMARY OF INSPECTION RESULTS

The overall condition of the cover timber bridge deck is very good, while the superstructure is in fair condition, and the substructure is in good condition. The bridge was damaged by a tractor in 2007, and all damage was repaired in 2008. New floor beams, stringers, siding, and arch and truss members were added during the 2001 reconstruction. The structure is posted with a weight limit of five tons, and is posted as a one-lane bridge with a 12'-6" vertical height clearance.
A. Connections

All of the connections were in satisfactory to good condition with the exception of:

- SE L3U4 lower connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 2” from its original position. Minor cracking and splitting are present with no additional signs of overstressing or deterioration.

- E L3U4 upper connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 1/2” from its original position. Minor cracking and splitting are present with no additional signs of overstressing or deterioration.

- SW L3U4 lower connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 1 3/4” from its original position. Moderate cracking and splitting are present with some potential signs of overstressing.

- W L3U4 lower connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 3/4” from its original position. Minor cracking and splitting are present with no additional signs of overstressing or deterioration.

B. Members

All of the members are in satisfactory to good condition. Most members typically exhibit minor splitting at various locations. Minor vehicular damage is still present at the arch and SE L3U3, SE L2U2, and SE L2U3.

C. Floor System

The floor beam connections are in satisfactory condition and exhibit minor cracking and splitting at various members.

IV. NBIS CODING INFORMATION

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CODE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>92C: Special Inspection (Other)</td>
<td>Y24</td>
<td>Special Inspection every 24 months</td>
</tr>
<tr>
<td>93C: Special Inspection (Other) Inspection Date</td>
<td>0609</td>
<td>Inspection Date was June, 2009</td>
</tr>
</tbody>
</table>
V. SUMMARY OF RECOMMENDATIONS

Programmed Repairs: In general, the timber covered bridge requires routine maintenance such as re-nailing the deck. The bridge requires standard bridge rail, adequate approach rail with end treatments, and bridge end markers at all bridge corners.

Urgent Repairs: Repairs to connections SE lower L3U4, upper E L3U4, lower SW L3U4, and upper W L3U4 are recommended. These recommendations include repairing the movement of the members at the connections because there is a potential for failure at the connections if these locations are overstressed or deterioration persists.
### Panel Point at Southeast L0:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing</td>
<td>8</td>
<td>Heavy debris build-up. Member shows minor signs of rot with localized areas of moderate rotting at bearing beam. No signs of distress.</td>
</tr>
<tr>
<td>Floor Beam</td>
<td>8</td>
<td>Connection was replaced in 2001. No signs of deterioration or distress.</td>
</tr>
<tr>
<td>Vertical (L0U00)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Diagonal (L0U1)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (L0L1)</td>
<td>6</td>
<td>Minor splits and deterioration. Member shows minor signs of rot due to heavy debris build up. No signs of distress.</td>
</tr>
</tbody>
</table>

### Panel Point at Southeast L1:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Beam</td>
<td>8</td>
<td>Connection was replaced in 2001. No signs of deterioration or distress.</td>
</tr>
<tr>
<td>Vertical (L1U1)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Diagonal (L1U2)</td>
<td>6</td>
<td>Minor splits and deterioration. Connection appears to show minor signs of movement. Appears to have migrated approx. ¼&quot; from the original position.</td>
</tr>
<tr>
<td>Lower Chords (L0L1 &amp; L1L2)</td>
<td>6</td>
<td>Minor splits and deterioration. Member shows minor signs of rot due to heavy debris build up. No signs of distress.</td>
</tr>
</tbody>
</table>

### Panel Point at Southeast L2:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Beam</td>
<td>8</td>
<td>Connection was replaced in 2001. No signs of deterioration or distress.</td>
</tr>
<tr>
<td>Vertical (L1U1)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Diagonal (L1U2)</td>
<td>6</td>
<td>Minor splits and deterioration. Connection appears to show minor signs of movement. Appears to have migrated approx. ¼&quot; from the original position.</td>
</tr>
<tr>
<td>Lower Chords (L0L1 &amp; L1L2)</td>
<td>6</td>
<td>Minor splits and deterioration. Member shows minor signs of rot due to heavy debris build up. No signs of distress.</td>
</tr>
</tbody>
</table>

In order to avoid redundancy, several pages of the Sample Report have been deleted.
### East Truss Lower Chord Members:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch (Southeast A0A2)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Arch (Southeast A2A4)</td>
<td>7</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. Repairs are in good condition. No signs of distress.</td>
</tr>
<tr>
<td>Arch (Northeast A2A4)</td>
<td>7</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. Repairs are in good condition. No signs of distress.</td>
</tr>
<tr>
<td>Arch (Northeast A0A2)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast LOL1)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast L1L2)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast L2L3)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast L3L4)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast L3L4)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast L2L3)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast L1L2)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast LOL1)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L0U0)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L1U1)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L2U2)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L3U3)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (East L4U4)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
</tbody>
</table>

In order to avoid redundancy, several pages of the Sample Report have been deleted.
SPECIAL DETAIL INSPECTION REPORT

8/28/2009

REPAIRED ARCH MEMBER (TYP.)

REPAIRED TRUSS MEMBER (TYP.)

APPROACH LOOKING WEST

ELEVATION LOOKING NORTH

MOVEMENT AT LOWER SE L3U4 (TYP. SW L3U4)

MINOR VEHICULAR DAMAGE (TYP.)
SPECIAL DETAIL INSPECTION REPORT

8/28/2009 BRIDGE NO. 001

MOVEMENT AT UPPER E L3U4 (TYP. WL3U4)

MOVEMENT AT LOWER SW L3U4
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A movable bridge is a bridge across a navigable waterway that has at least one span which can be temporarily moved in order to increase the vertical clearance for vessels in the channel. Such a bridge is built where site conditions preclude constructing a fixed-span bridge with an acceptable vertical profile.

In the second half of the 19th century, the U.S. Congress prohibited the construction of bridges or other obstructions over navigable waterways. Only bridges authorized by an act of Congress could be constructed over a navigable waterway, and these had to be movable or have sufficient height to allow the passage of vessels. To this day, water traffic has the primary right of way at intersections of land and water traffic. Although an act of Congress is no longer required for the construction of a bridge, a rigorous permitting process is in place.

As of 2010, there are three movable highway bridges in the state of Indiana. Two are in East Chicago. The Indianapolis Boulevard Bridge is owned and maintained by the Indiana Department of Transportation (INDOT), and the bridge on Dickey Place is owned and maintained by Lake County. The third bridge, on Franklin Street in Michigan City, is owned and maintained by LaPorte County.

Movable bridges should receive the same inspections mandated for fixed bridges, including applicable specialized inspections such as Fracture Critical, Special, and Underwater Inspections. In addition, the operating systems need to be inspected on a routine basis. Inspection of the structural components is addressed in Part 4. Part 5 of this manual outlines the requirements for a Moveable Bridge Inspection, which is primarily concerned with the electrical and mechanical machinery for operating and stabilizing the movable span. The interaction between the movable bridge and the machinery will also be addressed here because an understanding of the mechanical/structural interaction is important for adequate inspection and maintenance of the machinery.
SECTION 1.2 INSPECTION DETAILS

Subsection 1.2.1 Inspector Qualifications

Movable bridges are large, complex, pieces of machinery. Each part of a movable bridge has a relationship to, and must interact with, many other parts. All functional systems must be inspected and evaluated by personnel experienced in that line of work.

Inspectors for movable bridges should have experience beyond that required for the inspection of fixed bridges. As with a fixed bridge, the structural members of a movable bridge must safely withstand the stresses imposed by the dead loads, live loads, and other loads typically encountered. In addition, many of the structural members must withstand the stresses imposed by the operating equipment and the movement of the bridge. It takes significant experience on movable bridges and with the applicable codes to adequately understand these relationships, evaluate the conditions of the various components, and recommend appropriate action.

The Inspection Team Leader for a Movable Bridge Inspection should be trained in the inspection of fixed bridges and all of the functional systems. He/she must be a Professional Engineer registered in the state of Indiana with experience in the inspection, design, maintenance, or construction of movable bridges. The Inspection Team Leader's experience must understand the inter-relationships inherent in these bridges.

The inspection team for a Movable Bridge Inspection should include structural, electrical, hydraulic, and mechanical lead inspectors. A single individual may serve as lead inspector in more than one of the areas if he/she has the necessary experience. Each lead inspector should have experience in the inspection, design, maintenance, or construction of movable bridges, including the inspection of at least three such bridges within the last five years. The experience should be in the specific systems for which the individual is leading the inspection. Each lead inspector must supervise and monitor any work performed by anyone assisting in the efforts. All inspectors assisting with the inspection should, as a minimum, have experience in the inspection of fixed bridges.

The Lead Structural Inspector must have completed Fracture Critical Inspection Techniques for Steel Bridges (FHWA-NHI-130078) class and must be a Professional Engineer registered in the state of Indiana.
Subsection 1.2.2  Operating and Maintenance Manual

Every movable bridge should have its own Operation and Maintenance Manual, although these documents may not be readily available at the bridge site. If the Operation and Maintenance Manual is available, the inspection team should review the manual to determine if there are any special conditions that should be addressed at the bridge. A copy of the Operation and Maintenance Manual should be scanned into the Central Database. If there is no Operation and Maintenance Manual, the inspection of a movable bridge must be in accordance with this Bridge Inspection Manual and sound judgment should be used where specific conditions are encountered that are not covered by this manual.

Subsection 1.2.3  Precision

Movable bridges are considered complex structures in Indiana and require a Special Inspection, described in Part 1, Chapter 3 of this manual. The Plan of Action for each inspection required for a movable bridge (Routine, Movable, Fracture Critical, and Special) should be written with enough detail to provide guidance on the frequency and specific requirements for each inspection.

The Plan of Action must include the following:

- A timetable for conducting each inspection
- Personnel requirements for each portion of each inspection
- A list detailing what is required to be inspected under each inspection
- Required access and testing equipment needed for each inspection
- Required traffic control for each inspection
- Required type and level of nondestructive testing (NDT) that may be needed for each inspection

Movable Bridge Inspections typically require that a high level of precision be taken with measurements. Mechanical tolerances should be obtained with feeler gauges. Electrical data is typically obtained with specialized devices. The measurement locations and the precision required should be clearly called out in the Plan of Action.

Subsection 1.2.4  Frequency

Movable bridges are normally inspected prior to the start of the navigation season in the spring so that any problems can be corrected before the bridge returns to normal operations. Annual maintenance functions are generally performed at this time, as well. This is a good time to flush the bridge with high-pressure water to remove the previous year’s accumulation of dirt, road salt, and debris. Cleaning the bridge in this manner makes the inspector’s job easier and makes it more likely that small defects will be found.
Various systems, subsystems, and components are normally inspected on a frequent basis to ensure their continued operation and reliability. Some of these inspections may be performed on a daily basis by the bridge operators, while other inspections may be performed by maintenance personnel as a part of normally scheduled maintenance. Operators should be trained to observe the indicators located on the console during each bridge operation. They should be able to recognize if any of the readings are changing over time and, if so, report the changes to supervisory personnel. Any changes in the way the bridge handles should also be reported. Maintenance personnel should be trained to observe the equipment and recognize basic indicators of wear, misalignment, and malfunctioning equipment.

Movable bridges should be thoroughly cleaned prior to any of the required inspections.

**Subsection 1.2.5  Bridges Closed to Traffic**

If a bridge is closed to traffic, the inspection team shall follow the steps outlined in Part 1, Section 3.3 of this manual.

*Figure 5:1-1: Movable Bridge Gearing*
Figure 5:1-2: Rolling Lift Gears
SECTION 1.3  INSPECTION SAFETY

Nothing is more important during a bridge inspection than the safety of the public, the bridge operating and maintenance staff, and the bridge inspection team. The inspectors need to be alert and aware of the safety issues in the work environment. They should not rely solely upon bridge operating and maintenance staff to create a safe environment. The Inspection Team Leader should take an active role in arranging pedestrian and vehicular traffic control and de-energizing electrical equipment. For basic safety requirements, refer to Part 1, Chapter 4. Potential personnel and public safety hazards are also discussed in Chapter 1.3 of the American Association of State Highway and Transportation Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual.

The traveling public must be prevented from accessing any movable bridge that is not in a stable, closed position. All warning devices must be operating. Ensure that no one can access the moving parts during the inspection.

![Franklin Street Bridge in Partially Open Position](image)

Figure 5:1-3: Franklin Street Bridge in Partially Open Position

Perform a test opening before beginning the bridge inspection to determine if the movable span is operable and if there are any serious defects which need special consideration, or that would preclude a safe inspection. Such issues should be resolved with the bridge maintenance and design groups if possible.
Following the test lift, the inspection team should:

- Meet with the bridge operation crew to ascertain any scheduled opening times and to establish direct communications with the operating staff.

- Tag and lockout the electrical service to the lift motors. If it is not possible to tag and lockout the electrical service, one member of the inspection crew should remain with the operator and have direct communication with the inspectors working on the bridge to ensure that all inspection crew members are clear of any movable parts prior to initiating a bridge opening.

- Upon completion of the inspection, meet again with the bridge operation crew to inform them that all inspection crew members are in the clear and that bridge operations may resume without interruption. If electrical tags and lockouts have been placed, the person placing the tag and lockout shall remove the tag and lockout and restore the power to the lift motors.

Inspectors must be cognizant of the mechanisms which are intended to move and stabilize the movable span. Do not disconnect any components that would create an unsafe condition. After completion of the inspection, the Inspection Team Leader should check the operating equipment to make certain that it is energized and ready for operation. A test opening should then be made to verify that the bridge condition has not been compromised.

![Figure 5:1-4: Movable Bridge Span Accessible From the Bank](image)

The inspector should verify that a panel or device is not powered from a second utility source or standby generator. Under this circumstance, removing power from a single source may be insufficient to de-energize a panel. An inspector should always test the equipment with a voltmeter or similar power detector to determine whether the equipment is safe to inspect.
Give special attention to all rotating or moving machinery. Portions of the inspection will require the inspector to observe the machinery and equipment while in operation. Be very careful not to come into contact with the machinery or let hair or loose clothing be caught in the machinery. Strict notification and communication procedures between the person performing the inspection and the bridge operation staff should be implemented to ensure that inspectors are in the clear when bridge operations are observed.

The inspection of a bridge should not be destructive and the inspector should always take care to seal all panels and equipment properly to prevent later damage. Before attempting to open any panel, the inspector should determine if the panel is warped or damaged. If the equipment is damaged, do not inspect it unless there is a maintenance crew readily available to repair or replace the damaged equipment. Otherwise, the inspector should note in his/her report that the equipment is inaccessible due to damage. Open or cracked panels can expose the bridge wiring to corrosion or damage and expose people to electrical contact. This could lead to permanent injury, disability, or death.

Inspectors should not attempt to repair or modify any bridge equipment. Accurately recording any deficiencies and notifying the appropriate maintenance authority immediately will enable the repairs to be made in a documented and orderly manner.

Inspectors should always use appropriate personal protective equipment while performing the inspection. This includes, at a minimum, the use of a hard hat, safety glasses, safety reflecting vest, appropriate footwear, and clothing that is not loose. Life vests and safety harnesses shall be used when inspecting over the water or areas with a fall hazard, as required by the Occupational Safety and Health Administration (OSHA) and U.S. Coast Guard regulations. Each inspector is responsible for his/her own safety and should take all necessary actions required to minimize risk.

Figure 5:1-5: Franklin Street Bridge
SECTION 1.4  EMERGENCY NOTIFICATION

Structural deficiencies may lead to localized failures or collapse of a bridge. Similarly, mechanical and electrical defects can cause a movable span to become unstable in the closed position, the open position, or both. In Part 1, Chapter 7, procedures are detailed for reporting serious structural defects and the actions to be taken to limit traffic or temporarily close the bridge.

The lead inspector must immediately report any defects of the span drive or stabilizing machinery that would render the operation of the bridge unsafe or leave the bridge in an unsafe condition for motor traffic or pedestrian use. If necessary, the lead inspector shall take all such actions as is necessary to prevent the operation of the bridge until emergency repairs are made. Such defects include cracked or damaged drive gears and pinion shafts, loose or missing keys, improperly operating tail locks, and improper balance. A movable span may be unstable in any position due to defects in the span drive or stabilizing machinery. Much depends on the type of bridge and the redundancy of the overall system. Because of the variations in movable bridge design, the lead inspector must rely on his/her experience when assessing the suitability of the bridge for continued operation.
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CHAPTER 2 BASCULE BRIDGES

SECTION 2.1 INTRODUCTION

Bascule bridges are modern versions of the medieval draw bridge. These medieval draw bridges had no counterweights so their size and utility was limited. Modern bascule bridge design can be traced to about 1893 with the construction of the Van Buren Street Bridge in Chicago, a rolling lift bascule, and the Tower Bridge in London, a roller-bearing trunnion bascule.

Bascules are often selected for narrow to moderately wide channels where unlimited vertical clearance is required for navigation. They have been built in many configurations. Usually, a bascule leaf is comprised of two longitudinal bascule girders, or trusses, which support the roadway deck framing. A wide leaf may be supported by multiple girders.

A bascule leaf is usually nominally balanced by a counterweight, which is fixed to the girders and located below the roadway. Counterweights reduce the size of the mechanical systems required to operate the bridge and provide an increased margin of safety in the event that a control system failure leads to a runaway condition.

Bascule bridges can be constructed with one or two leaves spanning the channel. Indiana's three highway bridges all have two leaves. A bridge with two leaves is called a double-leaf bascule. The two leaves usually meet at the center of the navigation channel. A span drive and stabilizing machinery is required for the moving of each leaf. A shear transfer device is provided between the leaves of the bridge to allow both leaves to share live load.

On a deck bascule bridge, the deck is located above the girders or trusses. Indiana’s bridges are all deck bascules.

All movable spans utilize a combination of rotation and translation. Rolling lift bridges utilize rotation about a horizontal axis with simultaneous translation. Indiana’s three highway bridges were all designed using the concepts in patents granted to William and Albert Scherzer starting in 1893. The Franklin Street Rolling Lift Bridge in LaPorte County, a double-leaf rolling lift bridge, is shown in Figure 5:2-1 below.
Figure 5:2-1: Franklin Street Rolling Lift Bridge

Figure 5:2-2: Rolling Lift Bridge Teeth
SECTION 2.2 ROLLING LIFT BASCULES – SCHERZER-TYPE

Scherzer-type bascules are characterized by cylindrically curved parts of the bascule girders or trusses at the ends over the bascule piers. Because of their large size, the girders or trusses of the early Scherzer bridges were assembled from segments and the girders were called segmental girders. Each segmental girder may be viewed as a segment of a wheel, rigidly attached to the bascule leaf. As the wheels roll along the tracks, the bascule leaf rotates to open or close the bridge.

Figure 5:2-3 depicts this movement for a double-rolling leaf deck type Scherzer bascule. As the curved ends of the girders roll away from the channel, the leaf tilts open to clear the channel. Slippage between the segmental girder treads and the tracks on which they ride is prevented by lugs or teeth that mechanically engage sockets. Typically, the protruding lugs are located on the track and the receiving holes or notches are in the segmental girder treads. Treads and tracks are described in more detail in Part 5, Chapter 3, Section 3.3. The rack is shown located above the pinion, as is common on many newer Scherzers, and is found on all of Indiana’s rolling lift bridges. The tracks on which the bascule leaf rolls may be mounted directly on the substructures, as is the case for the Indiana movable bridges, or they may be mounted on flanking spans. Span locks (also called center locks) are required to transfer vertical shear between the two leaves of a double-leaf bridge and to assure proper lateral and vertical alignment. Span locks are discussed in Part 5, Chapter 3, Section 3.3.
Figure 5:2-3: Motion of Rolling Lift Bridge
SECTION 2.3 BRIDGE WATERWAY PROTECTION

As with all bridges over navigable waters, the movable bridge structure must be protected from water traffic. The movable bridge piers are protected with a combination of protection cells, typically referred to as dolphins, and fenders. The protection cells are located immediately outside of the navigable channel and protect the bridge from direct hits by vessels. Along the face of the bridge piers, fenders are typically installed. The fenders protect the bridge from vessels as they pass through the bridge draw.

Navigation lights are provided on the movable leaf. These indicated whether the bridge is open or closed. The protection cells will also have lights installed to delineate the limits of the navigable channel. Properly operating navigation lights are critical to the safety of the water traffic.

The protection systems must be inspected as part of a Moveable Bridge Inspection.

Figure 5:2-4: Dickey Road Pier Protection Cell
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CHAPTER 3 FUNCTIONAL SYSTEMS

SECTION 3.1 INTRODUCTION

The functional systems of a movable bridge are classified as span drive machinery and span-stabilizing machinery. Span drives are the machinery needed to move the span. They also serve to stabilize the span when it is not in the fully closed position. Span drive machinery varies little with movable bridge types because the objective is the same: to convert the low-torque rotation of a motor (electric or hydraulic) to the high-torque or force required to move the span. In electro-mechanical drives and hydraulic drives, gearing is used to convert the low-torque, high-speed rotation of the motor to high-torque, low-speed rotation required to move the span.

Stabilizing machinery consists of the electro-mechanical and hydraulic components that support and restrain the span when it is in motion and when it is at rest. Some stabilizing components may be used to decelerate the span under certain conditions, but they do not accelerate the span.

This chapter describes the span drive and stabilizing machinery arrangements utilized on Indiana’s rolling lift bascule bridges.
SECTION 3.2 SPAN DRIVE MACHINERY

The span drive is the combination of electrical or hydraulic motors and mechanical components used to open and close a movable bridge. This can be accomplished in many ways. In this section, we describe the electro-mechanical or hydraulic-mechanical drives found on the Indiana rolling lift bascule bridges.

Subsection 3.2.1 Type 1 Span Drives

Span drives in which the motor outputs are connected mechanically to the drive gear are denoted as Type 1 Span Drives. Indiana’s Franklin Street Bridge span drive is designated as a Type 1 Active Differential (AD) span drive and is described in greater detail below. In all Type 1 arrangements, a motor is connected directly to the primary speed reduction gearing, usually through a shaft with a slip clutch to prevent damage to the gearing. On this bridge, all gearing is fully open. Power from the motor is distributed from the primary reduction gearing to two or more sets of secondary reduction gearing located at the sides or ends of the movable span. Through a series of progressively fewer gear teeth, the mechanical leverage is provided to move the span. The point of interface between the drive gears and the bridge is at the rack which is mounted to the bridge girder.

An active differential span drive is designated as Type 1 AD. On the Franklin Street Bridge, the motor drives a main gear from which planetary gears are driven. The arrangement is similar to that of the rear axle differential of a car. The arrangement of the planetary gears around the main drive gear from the motor permits the output shafts to rotate at slightly different speeds, but transmit equal torques. The active differential is located at the center of the machinery room of the Franklin Street Bridge. The active differential is shown on Figure 5:3-2.

Each side of the active differential has a drive shaft that extends to the gear train on each half of the bridge leaf. The shaft drives are attached to a large gear, which in turn drives a smaller gear with fewer teeth, which in turn drives another large gear, which in turn drives a smaller gear with fewer teeth than the first small gear, etc. This is the gear that engages the rack and provides the torque to raise and lower the bridge. Figure 5:3-1 illustrates the general arrangement of a Type 1 span drive system.
Figure 5:3-1: Type 1 Span Drive With Two Low-Speed, High-Torque Final Outputs

1. RACK
2. PINION SHAFT
3. BEARING
4. GEAR COUPLING
5. SECONDARY GEAR SPEED REDUCTION
6. MACHINERY BRAKE
7. FLOATING SHAFT
8. PRIMARY SPEED REDUCTION
   TYPE 1 – NO DRIVE: NO DIFFERENTIAL
   TYPE 1 – AD DRIVE: ACTIVE DIFFERENTIAL
   TYPE 1 – LD DRIVE: LOCKABLE DIFFERENTIAL
9. MOTOR BRAKE (WITH FLEXIBLE COUPLINGS)
10. MOTOR
11. FLEXIBLE COUPLING
12. TACH GENERATOR

Figure 5:3-2: Type 1-AD Span Drive
Subsection 3.2.2 Type 2 Span Drives

When each drive pinion gear is separately powered on a bascule bridge, the span drive is called Type 2. The Indianapolis Boulevard and Dickey Place rolling lift bascule bridges have Type 2 span drives. In the case of these bridges, hydraulic motors are directly connected to the various gears that drive each half of the leaf. The motors are connected to a small gear, which in turn drives a large gear, which drives a small gear, etc. With each transfer there are fewer teeth on the gears. This creates the mechanical leverage needed to move the bridge. The Indianapolis Boulevard and Dickey Place bridges also have a shaft that connects the two gear trains. This shaft is used to apply braking forces to control the up and down speed of the bridge. Figure 5:3-3 illustrates the general arrangement of a Type 2 span drive system. Figures 5:3-4, 5:3-5, and 5:3-6 illustrate the motor, gearing, and brakes used on these bridges. Also illustrated is the hydraulic pump used to drive the hydraulic motors.

1. RACK
2. PINION SHAFT
3. BEARING
4. GEAR COUPLING
5. SECONDARY GEAR SPEED REDUCTION
6. MACHINERY BRAKE
7. HYDRAULIC MOTOR
8. TORQUE ARM
9. HYDRAULIC LINES
10. MANIFOLD & VALVES
11. TANK
12. MOTOR
13. PUMP

Figure 5:3-3: Type 2 Span Drive
Figure 5:3-4: Hydraulic Drive Motor

Figure 5:3-5: General Gearing Arrangement With Brake
Figure 5:3-6: Hydraulic Pump, Reservoir, and Span Drive Brake
SECTION 3.3 STABILIZING MACHINERY

Stabilizing machinery supports the span when it is in motion and at rest. The machinery components and assemblies are usually mechanical, but fluid power (air and liquid) components are also utilized. Stabilizing components on rolling lift bascule bridges include treads mounted on segmental girders, tracks, live load bearings, tail locks, mid-span locks, centering devices, and buffers. Components found on Indiana rolling lift bridges are explained below. Additional details are discussed in Chapter 4, Electrical Systems, and Chapter 5, Mechanical Systems. Stabilizing machinery includes the following:

- **Tracks and Treads**: Each rolling lift bridge segmental girder rolls on a track which has upward projecting lugs equivalent to gear teeth. The lugs are usually rectangular protrusions of the steel casting, spaced from about 10 to 25 inches apart, depending on the radius of roll. Lugs are staggered in two lines along the edges of the track. Figure 5:3-7 depicts the lugs on the edges of a track of a rolling lift bridge. The gear segments are then bolted to the sides of the tread. The tracks and treads guide the segmental girder as it rolls forward and backward, closing and opening respectively.

![Figure 5:3-7: Segmental Girder and Track](image)

- (a) Tread
- (b) Socket
- (c) Joint Between Segmental Tread Castings
- (d) Track
- (e) Lug
• **Live Load Bearings**: The live load bearing supports the live load, a positive dead load from a desired span heavy imbalance, and the force due to residual torque in the span drive machinery. The live load bearings are found at the tail of the movable span and engage the roadway overhead. The live load bearings prevent the rolling lift span from literally “falling into” the draw. The live load bearings prevent excess force in the gear train from the vehicular loads on the bridge. When properly adjusted, the live load bearings should be nearly touching the reaction bearing of the overhead roadway.

![Figure 5:3-8: Live Load Bearing at Rear of Counterweight](image)

• **Span or Shear Lock (also called Center Lock)**: This lock is intended to maintain the toes of both leaves at the mid-span of the bridge, at the same elevation, and in proper lateral alignment when the bridge is in the closed position and subjected to live load. In order to accomplish this, the shear lock must transfer live load shear between the leaves. All Indiana rolling lift bridges employ a jaw-type lock. As the bridge closes, the jaw, shown in Figure 5:3-9, enters between the diaphragm side plates and the diaphragm casting is engaged between the upper and lower jaws. With time, the top and bottom edges of the sliding surfaces of the jaw strike plates wear. The rate
of wear depends on the number of bridge openings and the amount of traffic passing over the bridge. Shims are provided under the jaw plates in order to permit adjustment. Figure 5:3-11 is a detailed drawing of the mid-span lock parts shown in Figure 5:3-9 and Figure 5:3-10. In order to inspect the mid-span shear locks, the bridge must be in the partially open position. Special care is needed to be able to access the locks for full inspection.

Figure 5:3-9: Span Lock
Figure 5:3-10: Span Lock Jaw

Figure 5:3-11: Detail of Mid-Span Shear Lock
- **Tail Locks:** Tail locks provide for the upward reaction that occurs when the live load is located between the center-of-roll and the rear floor break. The tail lock must be retractable to accommodate the motion of the leaf. All Indiana rolling bascules have tail locks, although they do not appear to be used at the present time.

Indiana bridges use a retractable lock bar for the tail lock. The tail lock is mechanically withdrawn prior to the start of the opening sequence of the bridge. It is mechanically inserted under the counterweight at the end of the closing sequence of the bridge. Tail locks reduce wear on the gears of the movable bridge by preventing movement of the leaf under live loads.

![Image of Lever Tail Lock](image)

**Figure 5:3-12: Lever Tail Lock**

(a) Tail Lock Post in Driven Position  
(b) Actuator (Hidden by Enclosure)  
(c) Live Load (Uplift)  
Anchor (right)
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CHAPTER 4 ELECTRICAL SYSTEMS

SECTION 4.1 INTRODUCTION

All Indiana rolling lift bascules have relatively modern electrical equipment. These electrical systems are also in generally good condition, although some functionality has been lost, including the tail locks which are no longer operating.

A typical electrical system for a movable bridge includes four major groups of equipment:

- Power Distribution Equipment
- Electrical Machinery
- Control System
- Lighting Systems

Conduits, flexible cables, junction boxes, electrical cabinets, and other components common to electrical systems are found on these bridges. An indispensable tool for the inspection of the bridge electrical system is the wiring or circuit diagram. These diagrams allow the inspector to determine the function of various components and what circuits control which functions. Common electrical systems and the tools unique to these inspections are discussed in this chapter.
SECTION 4.2 INSPECTION TOOLS AND INSTRUMENTS

Tools that are necessary for an electrical inspection include a megohmmeter, a voltmeter, a live power indicator, an ammeter, a thermometer, and a receptacle tester. The megohmmeter is a cable voltage insulation tester used to inspect bridge wiring, cables, and specialty cables. A voltmeter can be used to check the voltage on equipment and help verify equipment is de-energized. An ammeter can be used to verify the current and direction of phasing to motors, and verify desk indicators.

The inspector should note all equipment on the bridge and the state of the equipment. Each piece of equipment should have a unique identifier. This name should be used to track the status of the equipment from inspection to inspection.

An Electrical Inspection should be done in accordance with the recommendations listed in this manual, the American Association of State Highway and Transportation Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual and the National Electric Code (NEC). Part 5 of the Indiana Bridge Inspection Manual is intended to augment the inspector's prior knowledge of the NEC by providing bridge-specific equipment information.
SECTION 4.3  POWER DISTRIBUTION EQUIPMENT

The power distribution equipment consists of electric power sources, protective devices, and distribution equipment.

The primary power source for movable bridges is a three-phase electric service from a local utility company. The typical three-phase electric service voltage used on the Indiana rolling lift bridges is a 277/480-volt, four-wire system.

The electric service from the utility company is delivered from pole-mounted or pad-mounted transformers typically owned and maintained by the utility. Feeders from the transformers extend to the service disconnect. The service disconnect is a circuit breaker or fused switch, owned and maintained by the bridge owner, which provides overload and short-circuit protection of the bridge electrical system. A utility energy consumption meter is located in the vicinity of the service disconnect or at the utility transformers.

A movable bridge electrical system may be provided with a secondary source of electric power should the primary electric source fail. To provide this redundancy in electric supply, a second electric service derived from a utility source independent of the primary electric service may be provided. The second electric service will be furnished with its own service disconnect and utility meter.

Electric power is supplied to the various motors and electrical equipment through protective devices, namely fuses and circuit breakers. Fuses and circuit breakers provide overload and short circuit protection to the electrical equipment they serve. These protective devices are typically housed in panel boards, motor control centers, and/or enclosed panels. Typically, fuses are cylindrical devices that prevent fault currents by melting and preventing any current flow. They are single use items and must be replaced when they have been used. Circuit breakers are used to protect the electrical equipment from a fault condition. Circuit breakers have elements that sense the current and are set to open the breaker if a certain limit is reached. Once tripped, the circuit breaker can be reset and used again.

A panel board contains a group of circuit breakers to distribute power to various electrical devices. Motor control centers house circuit breakers, fuses, motor starters, motor controllers, and other equipment required to control and distribute power to motors and other equipment. Motor control centers are modular in construction. In lieu of panel boards and motor control centers, circuit breakers, fuses, motor starters, motor controllers, and other motor control equipment may be installed on an enclosed, custom-built panel.

Transformers are commonly installed on movable bridges. Transformers convert voltage from one level to another, usually to serve lighting loads or to isolate electrical noise in the electrical system.
Electrical circuits are carried from panel boards, motor control centers, enclosed panels, and transformers to the electrical devices they supply power to through a raceway system. A raceway system typically consists of rigid, metal conduit and junction boxes. Electrical wires, or conductors, carry electrical current and are installed inside the conduit and boxes that make up the raceway system.

Figure 5:4-1: Dickey Road Panel Board
SECTION 4.4  ELECTRICAL MACHINERY

Electrical machinery refers to electro-mechanical devices that operate the movable span and auxiliary devices such as locks and traffic control equipment. For the Indiana rolling lift bridges, the electrical systems are designed with interlocks that prevent bridge operation without completing a pre-programmed sequence of operation. This fact must be kept in mind when inspecting the electrical systems for these bridges.

Subsection 4.4.1  Span Motors

The movable span is provided with one or more span motors that serve either as the prime mover for the span or provide the power to operate hydraulic pumps that are used to move the span. Span motors are the alternating current (AC) type on all Indiana bridges. Depending on the type of motor control equipment employed, the operating speed of the span motors is governed by the bridge operator or by a motor controller. A motor controller provides controlled motor speed and torque to ensure smooth movement of the movable span. The span motor and motor controller combination is commonly referred to as the electrical part of a span drive.

In an electro-mechanical drive system, the movable span is provided with electrically actuated span brakes to stop and hold the movable span. With modern motor controllers, the majority of braking during operation is accomplished by the span motor and motor controller. Thus, span brakes are typically utilized for holding the movable span and stopping it during emergency conditions.

Subsection 4.4.2  Auxiliary Motors

Some movable spans are equipped with a back-up motor for operation in the event the span motors fail or are out-of-service. These motors, called auxiliary motors, are generally smaller motors that take longer to open or close the span because of additional speed reduction gearing. The motor controller for an auxiliary motor is typically an across-the-line contactor.

The auxiliary motor will either be directly coupled to the main span machinery, or separated by a clutch. The auxiliary motor will either be selected by the operator at the control desk, or operated locally. The clutch, if present, will then be operated manually or electrically to connect the auxiliary motor.

Subsection 4.4.3  Locks

Locks are described in detail in Chapter 3, Section 3.3, Stabilizing Machinery. The electrical equipment is similar in each type, consisting of a motor directly coupled to the machinery and a series of limit switches to monitor the machinery. The motor controllers for locks are typically across-the-line contactors.
Subsection 4.4.4  Warning Gates and Barrier Gates

Traffic signals, lights, and gates are used to warn approaching cars and pedestrians and to provide physical protection, when required. Traffic signals, or red flashing lights, are used to initially stop the traffic. Once the traffic has come to a complete stop, the warning gates are lowered to indicate that no vehicles may enter. Gates are usually equipped with flashing lights.

Subsection 4.4.5  Gongs, Horns, Bells, or Sirens

Gongs, horns, bells, or sirens are used to alert traffic to changing conditions. They are sounded at the beginning and end of any bridge operation and used in tandem with flashing lights and warning signs.
SECTION 4.5 CONTROL SYSTEMS

The control desk is where the bridge operator controls the operation of the bridge and its associated equipment. There are push buttons, control switches, indicating lights, meters, and indicators on the desk, and often a foot pedal switch mounted on the floor at the control desk. Mirrors, cameras, and binoculars are used to help the operator see motor, pedestrian, and water traffic.

Figure 5:4-2: Franklin Avenue Control Desk

There are many types of motor controllers, ranging from simple contactors to motor drives. The equipment may be installed in a panel or motor control center.

A standard motor controller consists of a motor protector, a contactor, and a motor overload device. A motor circuit protector is either a circuit breaker or a fuse that has a trip setting to protect the motor controller and motor. Contactors are devices that make or break current to the motor. When the motor is connected to the current, it will operate, and when the current is removed, it will stop. Contactors can operate the motor in a single direction, or forward and reverse directions. An overload device is a sensitive, quick-acting device that will sense when the motor is drawing too much current and open the contactor to stop the motor. Motor overloads are intended to be faster in reacting to a motor fault than a circuit breaker or fuse, and more sensitive to minor faults that would not trip a circuit breaker.

Many specialty controllers, called motor drives, provide the same functions listed above, as well as speed, torque, and/or counter torque control of the motor. Motor drives use circuit boards and capacitors to generate a specific current amplitude and/or frequency to control the motor.
Limit switches provide an electrical signal to stop or change operation. There are several types of limit switches: lever arm, plunger-type, rotary, and proximity.

Relays are low-current switching devices that provide logical control of a bridge. They can be used independently or with a programmable logic controller (PLC). In order to provide control for an entire bridge, multiple relays are required. They are generally located in a panel or enclosure. When relays are used with a PLC, they are generally interposing relays. These relays are located between the PLC outputs and the equipment being controlled and serve as a means of isolation. Relays are also used as part of auxiliary systems, such as traffic gates, or control of local equipment.

Machine relays are larger relays that can be repaired and modified for various logical configurations. They are bolted to panel back plates and the terminals of the relay accept wire. “Ice cube”-style, plug-in relays are smaller relays covered with a clear plastic cover. They cannot be modified or repaired and must be replaced when damaged. They are plugged into a mounting strip and wires to the electrical equipment are terminated on the mounting strip.

Check all contact surfaces for signs of pitting or flashing. Contacts should not make any sounds.

PLCs are computers that provide the logical control of the bridge. They are generally rack-mounted in cabinets in the control room. There may be multiple PLCs in the cabinet and multiple input/output (I/O) cards in the rack. There may be multiple remote I/O drops. A remote I/O drop will consist of I/O cards and communication cards rack-mounted in a panel. PLCs processors can use communication networks to transmit information from a remote drop to the main processors.

The PLC generates electrical control signals through the PLC output cards. These output signals interface with the motor electrical controllers and equipment to control bridge equipment. PLC input cards supply the PLCs with information on the state of the equipment and provide the necessary interlocks for the processors to start and stop the bridge equipment.
Figure 5:4-3: Control Relay Labeling on Dickey Road Panel Board
SECTION 4.6 LIGHTING SYSTEMS

Service lighting and receptacles are provided throughout the bridge to enable work and inspection in dark areas or at night. Check that receptacles exposed to the elements are provided with covers and have ground fault circuit interrupters (GFCIs) as part of the outlet.

Navigation lighting and signals are provided to guide and alert the channel water traffic. Red lights mounted on the piers or fenders mark the channel for the boats. Alternating red and green lights mounted on the span notify the boat operator of the status of the bridge opening. When the light is red, the span is not fully open. When the light is green, the span is fully open. Navigation lights are installed in accordance with U.S. Coast Guard standards and guidelines. Proper maintenance of these lights is essential for the safety of the waterway traffic.

An air horn or similar audible device is used to warn the water traffic that a bridge operation is about to start.
SECTION 4.7 INSPECTION OF POWER DISTRIBUTION EQUIPMENT

Inspection of the electrical service should include the following:

- Locate all points of electrical service. Some bridges may have separate points of service on each side of the bridge, or separate services for special equipment such as roadway lighting.

- Contact the utility and arrange for power to be disconnected. Have the utility verify, in the presence of the inspector, that electric power is removed.

- Perform a visual inspection of the incoming feeders. If the feeders are from overhead transmission lines, they can be easily viewed. Underground feeders will not be visible except at the point of entry.

- Check for damaged wires and missing or broken supports.

- Verify that all equipment is firmly mounted.

- Check for blown line jacks.

- Inspect the panels where service is terminated for damage, rust, debris, or fluid build up.

- Check the wiring and terminations.

- Check the insulation resistance of the cables while they are de-energized.

- Look for any scorch marks or evidence of faults in the panel.

- Inspect the main ground terminal. Request that the utility take a measurement of the resistance to ground to verify that the incoming service is solidly grounded.

- Inspect the bridge grounding system thoroughly if the grounding at the utility is not acceptable.

Inspection of the transformers should include the following:

- Inspect the exteriors for damage, corrosion, lost paint, or scratches.

- Verify that the hinges and latches of panel doors or bolt on covers operate properly, are sufficiently lubricated, and make a tight seal when the doors/covers are sealed.

- Verify there is a gasket between the door/cover and the panel. The gasket should be continuous, springy, and compressible to the touch. Note if the gasket is brittle, permanently deformed, or missing in areas.

- Verify that the panel mount is secure and vibration-resistant. The panel may be free-standing and bolted to the floor, wall-mounted and bolted to the wall, or wall-mounted and mounted to a metal strut support.
Note any loose bolts or other deficiencies.

Listen to the transformer for any unusual noises during bridge operations. Transformers normally have a low, quiet, buzzing sound.

Take the temperature of the transformer and compare it to the specified normal range. Record the operating temperature.

Inspect oil-filled transformers for leakage.

Test older transformers for polychlorinated biphenyls (PCBs).

Motor control centers (MCCs) are cabinets where electrical power is controlled and distributed to end devices. Equipment is arrayed in units called buckets. Each bucket will contain one or more of the following: an overcurrent protection device, a motor controller, an overload relay, or metering equipment.

Inspect the panel, motor controllers, circuit breakers, fuses, and wiring.

Panel boards are panels with distribution circuit breakers and, on older bridges, relays. Inspection of the panels should include the following:

Inspect the panel, circuit breakers, and wiring.

Inspect the exterior of all panels for damage, corrosion, lost paint, or scratches. Inspect panel doors or bolt-on covers to verify that the hinges and latches are properly lubricated and make a tight seal when the door or cover is sealed.

Verify there is a gasket between the door/cover and the panel. The gasket should be continuous, springy, and compressible to the touch.

Note if the gasket is brittle, permanently deformed, or missing in areas.

Verify the panel mount is secure and vibration-resistant. The panel may be free-standing and bolted to the floor, wall-mounted and bolted to the wall, or wall-mounted and mounted to a metal strut support. Note any loose bolts.

Determine if any temperature control equipment, such as a heater, ventilation grate, and/or fan is operating properly. Verify that the ventilation grate filter is clean and free of dust and debris.

Check that each panel is solidly grounded by a conduit fitting or ground bar located in the panel.

Inspect other equipment located within the panel.
The raceway system consists of conduits, conduit fittings, junction boxes, and terminal boxes. Conduit is used to protect wire and route it from one location to another. Typically these are 10- or 20-foot sections of rigid galvanized steel (RGS) conduit, polyvinyl chloride- (PVC-) coated RGS conduit, and PVC nonmetallic conduit. Inspection of the raceway system should include the following:

- Ensure raceways are properly coupled and supported.
- Ensure all conduit is tightly connected. If a coupling becomes loose, the conduit sections may separate, and the wires inside may become damaged.
- Verify that required supports are present and securely mounted. Check each support for loose screws or bolts. RGS conduit should have secure support at intervals not exceeding 10 feet. Nonmetallic conduit should have a support every three to seven feet.
- Check the wall-mounted conduit runs for dirt and debris between the conduit and the walls. Dirt and debris should not be allowed to build up on any conduit runs.
- Note any areas that require cleaning.
- Check that conduit fittings are in good condition. Conduit fittings are in-line enclosures in conduit that provide bends or taps in conduit runs. Check the gaskets for a tight seal. Check the conduit fitting for any debris or fluid.
- Check that junction and terminal boxes (enclosures for the routing of wires) are in good condition. The boxes will be rated by the National Electrical Manufacturers Association (NEMA) for various exposure conditions, including watertight, dust-proof, and corrosion-proof. For all junction and terminal boxes:
  - Inspect the wires and terminals.
  - Verify that that seals around the access panels provide a watertight seal.
  - Check the boxes for debris or fluids.
  - Check that the drain and breather valves are operational.
  - Check the exterior of the boxes for rust or chipped paint.
  - Check the conduit bushing and fittings to verify a solid and tight fight.
  - Verify that any grounding fittings are properly installed and the ground wire is bonded to the fitting.
Bridge wires are copper conductors that carry electrical power and control to the electrical devices. Occasionally, aluminum is used in lieu of copper. Wires are either solid cylindrical shapes, or composed of several strands. Conductor sizes are based upon the amount of electrical current, or ampacity, of the load device. The more current required, the larger the conductor. The wire is covered with insulation, rated for electrical voltage, and jacketed to protect the wire. A cable contains several insulated wires within the same outer jacket. The insulation and jacket are selected based upon the electrical voltage of the system and the environmental conditions to which the wire/cable will be exposed. Inspection of the wire and cable should include the following:

- Confirm that the bridge is wired in accordance with the as-built documents of the electrical system. Each wire should be designated with a wire number that is referenced on the as-built drawings.
- De-energize high- and medium-voltage cables before inspecting. Only personnel trained on such equipment should perform the inspection.
- Check for insulation failure when the jacket and insulation of the conductor wears away, causing electrical faults or wire failure. Failure may be caused by overloading, physical wear and tear, exposure to water or corrosive materials, or age.
- Note any signs of abrasion or cracking over the entire length of the cable.
- Note any signs of discoloration and overheating.
- Note any signs of excessive bends or kinks in the wire.
- Note any signs of water or other moisture on the cables.

Wires and cables are usually installed in conduits. The conduits provide additional protection for the cables. When the cable is inside conduit, it cannot be visually inspected for the entire run. The wire and cable should then be inspected at accessible points, such as conduit fittings, terminal and junction boxes, and equipment panels.

Wires and cables are terminated at terminal strips in panels and lugs on equipment. There are three types of terminations to terminal strips: compression, fork-tongue, and ring-tongue. A compression terminal is simply a screw that presses onto the bare wire to make a contact. A fork-tongue or ring-tongue terminal is compression-clamped onto the wire. The screw in the terminal strip will compress onto the tongue portion. Vibrations that occur on a bridge will cause the terminals to loosen over time. Compression terminals traditionally have the least resistance to vibration and the wires may become loose. Ring-tongue terminals provide the best resistance to vibration, as the compression screw travels through the ring on the cable. If the screw becomes loose, the ring will still maintain contact.
The inspector should examine the terminations and note:

- Loose terminals.
- Any wires not tagged with a wire number.
- Any wiring not in accordance with the as-built drawings.
- Terminals not marked with the wire number of the terminated wires.
- Any movement or vibration between the panel and wires.
- Corrosion or rust on the terminals.
- That the exposed copper conductor will not come into contact with exposed metal.
- That the wire is isolated from power and sensitive equipment and perform an insulation megohm resistance to ground test on each individual wire. Record the wire number and the phase-to-ground resistance, and a phase-to-phase resistance with an adjacent disconnected wire in a table. If the resistance value is below one kilo-ohm, the wire is close to failing. If the resistance is zero, the wire has failed. Compare the results to previous results to determine if there are trends in the insulation resistance or the cable test results. This may indicate a problem in the run of wire.

Specialty cables, including flexible cables and submarine cables, are installed in areas that cannot be serviced by wire in conduit. Flexible cables are cables routed between fixed portions and movable portions of the bridge, such as cables from the rest pier to the bascule leaves. Flexibility comes at the cost of reduced jacket protection. In order for the cables to bend and move with the bridge, the jacket must be softer and more flexible. This means that they may wear more quickly from rubbing and abrasion.

Submarine cables are cables that are routed into the channel through the water from one side of the bridge to the other. The cables are usually trenched into the riverbed. They are exposed to a much harsher environment than regular cables. The portions of the cables that remain continually underwater, or continually out of the water, usually remain undamaged. The portions of the cables that are exposed to fluctuations in water level due to wet and dry periods, and the wear and tear of moving in response to the changing water level, require the closest inspection. Submarine cable is typically manufactured with a steel armor wire wrapping and polyethylene covering to protect it from the harsh conditions. Submarine cables are usually terminated in panels where the wiring is transitioned to normal wire and conduit.
The inspection of specialty cables should include the following:

- Check that the armor is terminated and grounded at the submarine cable terminal panels in special fittings.

- Verify the range of motion of flexible cables during an operation of the bridge. Cables should swing freely and move freely during the entire operation of the bridge.

- Check for sharp bends or kinks in the cables during operation.

- Note any cables that snag or rub against the structure or equipment.

- Test the insulation of the individual wires of the flexible cables using a megohm meter and record the values.

- Note the effects of wind on the cables during operation.

- Check the cable grips and supports at each end of the cables. They must have a firm grip on the cables and be solidly attached to the structure.

- Inspect submarine cables during low-water conditions if possible.

- Note any deterioration of the cables.

- Verify panel terminations and cable supports.

- Inspect the clamps of armored cable to make sure the cable is supported and grounded.

- Use a megohm resistance test to check the insulation of the individual wires of the submarine cables and record these values.
SECTION 4.8 INSPECTION OF ELECTRICAL MACHINERY

The inspection of all motors should include the following:

- Verify that the motor shaft is free from oil and grease from the bearings. Leaking oil can indicate a poor seal or misalignment of the shaft.
- Verify all keys, bolts, and pins are in their proper positions. Check all bolts along the motor housing for proper tightness.
- Check any space heaters for proper operation by touching the motor to determine if it is warm before operation.
- Check all surfaces for signs of corrosion.
- Observe the operation of each motor during opening.
- Check motor shafts for normal end play.
- Verify that all motors are smooth-running and free from vibration.
- Check motors and bearings for overheating.
- Note any unusual noises heard during operation. If the motor is fan-cooled, check for proper operation of the fan and that the motor is being properly cooled.
- Check that each motor is wired in accordance with the NEC.
- Verify there is a disconnect switch within sight of each motor.
- Check the internal equipment after disconnecting the motor from its power supply.
- Check electrical connections on the motor for proper attachment.
- Test insulation resistance values on all motors using a megohm meter. Megohm measurements should be taken from phase-to-ground and between phases for all AC, three-phase motors.
- Take megohm measurements at the collector rings to detect cracked or otherwise defective bushings. Readings should be taken using a 500-volt direct current (DC) hand crank or battery-operated megger. Record the results of the megohm meter tests and compare these to prior inspection findings. Any large changes may indicate motor deterioration.
- Recommend overhauling a motor when megohm values for phase-to-ground values are projected to reach 2.0 or less before the next scheduled inspection.
- Recommend that the motor be overhauled as soon as possible if the megohm values are 1.0 or less.
Check the phase currents in motors under loaded conditions with a clamp-on ammeter for motors of one horsepower or larger. Record the results and compare them to the nameplate data and prior inspection results.

With the power disconnected, open the inspector ports of the motor to check the interior of the motor. Check that collector rings (slip-rings) are free of carbon, metal dust, discoloration, and deformation. The wearing surface of the collector rings should be smooth, highly polished, and free of dirt, oil, grease, and moisture. Try to determine the source of any detrimental conditions.

Wound rotor AC motors and synchronous AC motors use brushes to carry current to rotating parts of the motor. For all AC motors:

- Check that all brushes have free movement within their holders. Each brush holder should be set so the face of the holder is approximately 1/8 inch from the collector ring. Each brush must be reinserted into its original holder and in its original orientation after inspection. It may be helpful to scratch a mark on one side of the brush when removing it to indicate its proper location and alignment.

- Inspect all brushes for wear. If the remaining portion of any brush within its holder is 1/4 inch or less, the inspector should recommend that all brushes on the motor be replaced.

- Verify that the entire surface of the brush that rides on the collector ring displays a polished finish, indicating full-surface contact. If a brush is not making full contact over its entire surface, recommend that the brush be re-seated.

- Inspect the springs that push the brushes against the collector rings. All brushes should be held firmly on the collector ring with approximately the same pressure. Improper spring pressure may lead to collector ring wear or excessive sparking. Recommend that the springs be replaced if this is found.

- Look for evidence of excessive heat, such as annealed brush springs.

The inspection of electrical span brakes should include the following:

- Check that span brakes are equipped with covers to prevent debris or grease from affecting brake operation.

- Check the mounting and location of limit switches on the brake. Generally, a brake will have a set switch, a release switch, and a hand-released limit switch. Follow the inspection methods listed in Section 4.9.

- Check the wiring in the limit switches.
• Manually operate the hand-release arm to verify that the linkages work properly.
• Check the clearances between the brake shoes and the drum when the brake is released.
• Observe the drum to note the wear pattern. The entire drum should be shiny if it is wearing evenly. Note any uneven wear.
• Make sure no grease, oil, water, or dirt is on the brake drum, as this will reduce braking capacity.
• Check the length of time it takes for the brake to fully release and the brake to set.
• Monitor the brake shoe and drum during operation. If the shoe and drum are not aligned, they will come into contact during operation. This contact could produce smoke and damage the brake.
• Test the insulation of the brake motor with a megohmeter and record the results.

The inspection of warning and barrier gates should include the following:

• Check the exterior of the gate housing for any damage.
• Check the access panels for proper operation.
• Open the housing and inspect for fluid or debris accumulation.
• Closely inspect conduits entering the base of the housing. Oil leaks may flow into the conduits and damage the wiring and environment.
• Inspect the internal equipment.
• Observe the gate arm or barrier during an operation.
• Verify that the flashing lights blink for the duration of the arm's movement. The lights should operate from the time the locks are engaged until the gates are raised.
• Observe the cables powering the flashing lights on the arms.
• Verify the cable is not rubbing against or catching on the gate housing during movement.
• Check the arm for any frayed wire or exposed terminal on the flashing lights. This could pose a danger to a pedestrian.

Gongs are mounted on traffic gates for oncoming traffic. They should be loud. The inspection of gongs should include the following:

• Check that gongs start operating when the warning signals are activated to stop traffic and continue to operate until the locks are released. They should operate again from the time the locks are engaged until the gates are raised.
• Inspect the cables powering the gongs for abrasion or tears.
SECTION 4.9 INSPECTION OF CONTROL SYSTEMS

The inspection of the control desk should include the following:

- Verify that the switches or pushbuttons used to test the indicator lights on the control desk work. Note any light that operates improperly.
- Operate the bridge several times to verify that all pushbuttons, control switches, indicating lights, meters, and indicators operate properly.
- Record all voltmeter, ammeter, and kilowatt meter readings as the bridge is operated. Compare these readings to the records from previous inspections. Dramatic changes in readings may indicate problems and aid with the inspection.
- Interview several of the bridge operators to determine if they have experienced any problems with the controls or other systems.
- Examine the interior of the control desk. Verify that the interior light is working. Check for any loose wires and inspect the wiring. Look for any scorching or discoloration that could indicate a faulty piece of equipment. Inspect all interior equipment.
- Check all relays, especially plug-in types, to verify that they are firmly installed.
- Check for a strip heater and verify that it is operational.

The inspection of the interlocks should include the following:

- Verify that the interlocks in the control system are operating properly with a series of tests. Extreme care must be taken while verifying the interlocks. Vehicular traffic must be stopped by flagmen while testing roadway equipment. River traffic must be made aware of the testing and any potential delays. The testing must be performed in accordance with the AASHTO Movable Bridge Inspection, Evaluation, and Maintenance Manual, as follows:
  - With the bridge in the closed position, perform the following:
    - Attempt to lower the traffic gates prior to sounding the horn or activating the warning lights.
    - With the traffic gate open to vehicular traffic, insert the gate arm hand crank into the traffic gate housing and try to operate the gates from the console. The gate should not operate. Record the results and repeat for all gates.
    - With the locks in place, attempt to operate the bridge span. The span should not operate. Record the results.
During the bridge operation, perform the following:

- For all devices, confirm the motor will not operate if a hand crank is inserted into that device.
- Confirm that the main motors cannot be started prior to the release of the brakes. The main drive motor starters should not engage. Record the results.
- Test the limit switches at fully open.
- Attempt to raise the gates and turn the traffic signals to green before the locks or jacks are fully driven and the bridge span is secure.
- Verify that the traffic signals cannot be changed to green until all gates are raised.

Note any problems in the interlocking and clearly notify the operators. The operators in control of the bridge must be aware of any issues found in the inspection.

The inspection of the fuses should include the following:

- Verify the fuses are the proper current rating. The fuse ampacity printed on the side of the fuse should match the ampacity on the as-built wiring diagrams.
- If the fuse ratings do not match the as-built documentation, check the load equipment. If the equipment protected by the fuses has changed, the new equipment may require a different fuse size.
- Verify that the fuse ratings are accurately documented. Inspect the fuse terminals for a tight electrical fit.
- Look for corrosion or scorch marks on the fuse blocks.
- Check for wire used to jumper a fuse, leaving the equipment unprotected, but operational. This condition is not acceptable and must be reported. Note any missing fuses.

The inspection of the circuit breakers should include the following:

- Verify that the trip settings on the circuit breakers are accurate. Compare settings to as-built documentation and equipment ratings.
- Molded-case circuit breakers are not accessible due to their plastic cover. Air circuit breakers should have their arc chutes inspected for debris, missing hardware, and damaged chutes. Check the contact surface for corrosion, pitting, and damage. Operate the circuit breaker to determine whether the contacts make and break contact.
- Check the wiring and terminations.
There are many types of motor controllers ranging from simple contactors to motor drives. The equipment may be installed in a panel or motor control center. The inspection of the circuit breakers should include the following:

- Review the manufacturer’s specific written information on the drives on the bridge and follow the inspection recommendations.
- Inspect the motor control panel for any fluid or debris buildup.
- Note any damage to the panel exterior.
- Check the wiring and terminations.
- Inspect the circuit breakers and fuses.
- Inspect the individual contacts for corrosion and scorching.

The inspection of limit switches should include the following:

- Check the wiring and enclosures.
- Note any scratches or damage to the switch exterior.
- Where accessible, open the limit switch and inspect the wiring.
- Inspect the seal of the limit switch and verify that no fluid or debris have accumulated in the housing.
- Check that the limit switches are securely mounted and have little movement or play.
- Lever arm limit switches and plunger-type limit switches have arms that move to trigger the electrical contact. Lever arms rotate around a pivot point in the housing, and plunger-types are pushed into the housing.
  - Inspect the arms for debris, corrosion, and a buildup of dirt.
  - Verify that the arms move freely and do not stick in place. The making and breaking of the limit switch contacts should be audible when testing the arm.
  - Watch the limit switch during a bridge operation.
  - When safe, manually operate the switch to test whether the operation will stop or if the appropriate indicating light energizes.
- Proximity limit switches are generally magnetic sensors that make electrical contact in the presence of a metal trigger.
  - Check the limit switch magnetic sensor for a buildup of magnetic filings that may provide a false indication.
  - When safe, manually operate the switch to test whether the operation will stop or the appropriate indicating light energizes.
- Open the rotary limit switches and inspect the contacts for any corrosion or scorching. Check the bearings for proper lubrication. The rotary limit switch is coupled to the span drive gearing. Inspect these couplings for proper connection.
- Position indicators, selsyn transmitters, resolvers, and tachometers are all feedback devices that provide position or speed information to the operator or to the motor drives. Inspect the enclosures, wiring, and mountings.

The inspection of relays should include the following:
- Verify that relays, especially plug-ins, are securely mounted.
- Verify that all wires and terminals are tagged and identified.
- Check for any jumper wires that are not part of the logical control system. These wires are added to bypass logical control temporarily and should be removed when the equipment has been repaired.
- Note any wiring without tags or wiring that is not documented on the as-built drawings.
- Determine what equipment the relays with jumpers control, and pay close attention to the interlock testing on the control desk when testing that equipment. Relay identifiers should be on nameplates mounted adjacent to the relays and should match the as-built wiring diagrams.
- Inspect the individual relays for contamination, scorch marks, or discoloration and record any relays with these problems.
- Monitor the relays during a bridge operation to verify proper operation. The inspector will be able to hear a short, sharp, click sound as the relays pull in or become engaged.
- Note chattering relays.
- Use a clock to determine if timing relays are operating properly.
The inspection of PLCs should include the following:

- Review any manufacturer’s manuals for specific maintenance issues with the particular type of PLC installed on the bridge.

- Small switches on the processor and I/O cards, called dip switches, are configured to allow proper operation. Never change these switches.

- Inspect the processors, I/O cards, and remote racks for any dust, dirt, debris, corrosion, or fluid on the equipment.

- Check the PLC diagnostic lights to see if there are any failures in the equipment.

- Inspect all terminals and wires.

- Inspect the cabinet for debris and fluid, and clean air filters on the fans.

- Check the PLC batteries and make sure they are fully charged.

- Check other equipment in the PLC panel, including fuses, circuit breakers, the heater unit, lights, fans, and relays. Verify proper fan, heater, and light operation. Inspect the filter on the fan for an accumulation of dirt and debris. Inspect other equipment as described in this chapter.
SECTION 4.10 INSPECTION OF LIGHTING SYSTEMS

Test the service lighting throughout the bridge. Note any damaged or inoperative light. Check that lights in machinery areas are equipped with guards and globes. Determine whether the fixture or the bulb is inoperative. Carry a typical light bulb during the inspection to test the fixture.

Use a receptacle tester to verify that the lighting receptacles work and are wired properly. Note any damaged receptacles or any exposed receptacles lacking covers.

Navigation lights will be located along the piers or fender system of the bridge and on the span. The fender navigation lights are red fixtures, while the lights on the span may vary between red only and red and green alternating fixtures.

Check each navigation light for damage, broken lenses, loose mounting, corrosion, and functionality. A night inspection may be necessary. Each light should be clearly visible when lit. Note any fixture that is inoperative or damaged. Inspect any rotating lights for proper range of motion.

Navigation signals consist of horns or public address equipment used to alert waterway traffic. Inspect the equipment for any damage, corrosion, or opened enclosures. Inspect the wiring and verify operation. Inspect all signal devices.
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CHAPTER 5  HYDRAULIC SYSTEMS

SECTION 5.1  INTRODUCTION

The Indianapolis Boulevard and Dickey Place bridges utilize closed-loop hydraulic systems. In a closed-loop circuit design, a single hydraulic pump is used to drive one or more hydraulic motors. The closed-loop circuit is not viable for hydraulic cylinder applications because of the different fluid volume displacements during extension and retraction. The fluid that passes through the actuator is returned directly to the low-pressure side of the pump. For proper operation, the pump must receive the same quantity of oil at its inlet as it is pumping from its outlet.

A charge pump is always used in a closed-loop hydraulic circuit. The charge pump is usually a small, fixed displacement pump with approximately 15 percent of the displacement of the main pump. The charge pump works on the low-pressure leg of the main loop, pumping filtered fluid into the loop. The pressure in the low-pressure leg is maintained between 100 to 300 psi by a relief valve.

During operation, the main pump control can cause the pump's displacement to “go over center.” This means that the main pump can pump high-pressure oil from either of its two main ports, causing a clockwise or counterclockwise flow of fluid through the main loop plumbing. This allows the actuator to rotate in either direction.

In closed-loop systems, pressure, flow, and directional control are all achieved by the controlling elements of the pump. Cross-port relief valves are incorporated to protect the actuators from load-induced pressure peaks.

High horsepower, closed-loop systems are compact, operate with a minimum amount of excess fluid storage, and are highly efficient. The pump controls direction, acceleration, deceleration, speed, and torque of the motor actuator so pressure and flow control components are not needed. These systems also provide excellent dynamic braking control, which is highly desirable in most movable bridge applications.
SECTION 5.2  HYDRAULIC CONTROL SYSTEMS

Hydraulic control systems determine how flow and pressure are regulated from the system's pumps. Three types of hydraulic system controls are commonly used in movable bridge applications: constant horsepower control, electronic proportional control, and hydraulic cylinder control. Each is described below.

Subsection 5.2.1  Constant Horsepower Control

Constant horsepower control, also known as horsepower-limiting control, uses an electric motor connected to the pump and drives the pump at a constant speed. This keeps the pump motor working at a constant horsepower level. To maintain constant horsepower, the mathematical product of flow and pressure must be a constant value. Therefore, if the flow is high, the operating pressure must be low. Since the operating pressure level of a system is dictated by the load conditions, the flow must vary with changes in load-induced pressure to maintain the product of flow and pressure at a constant value.

Constant horsepower controls sense the load-induced pressure and regulate pump flow accordingly. The pump control holds the pump at its maximum displacement until the pressure reaches the point at which regulation or compensation begins. This type of system always uses a system pressure relief valve. Once the end of regulation is achieved, the slightest increase in system pressure will open the relief valve and bypass the minimum pump flow back to the tank.

Subsection 5.2.2  Electronic Proportional Control

Electronic proportional control utilizes a proportional solenoid to vary the pump displacement. The pump varies from minimum to maximum displacement in proportion to the current of a 24-volt direct current (DC) command signal. As DC power is applied to the proportional solenoid, the solenoid pushes the pilot spool with a specific force. When the current, and therefore the force, is high enough, the pump begins stoking and producing flow. Further increases in signal current will increase the pump’s output flow proportionally.
SECTION 5.3 INTERLOCKS

Control systems on movable bridges are provided with interlocking controls that allow the bridge to be operated in a manner that provides safety to the traveling public while protecting the equipment. The requirements for interlocking controls between the hydraulic span drive and other equipment such as span locks, traffic gates, and signals, are discussed in Chapter 4, Subsection 4.9.2, Interlocks.
SECTION 5.4 INSPECTION OF HYDRAULIC COMPONENTS

The inspection of hydraulic equipment requires special precautions due to the use of fluids for the system's operation. Leaks and spills cause slippery areas and special care should be taken when working in the area of the pumps and motors. Frayed or damaged hoses pose hazards since they convey fluids under high pressure. A burst hose can spew hydraulic fluids great distances and possibly cause injury. Hydraulic System Inspections should focus on the following:

- All components should be checked for cleanliness and leakage. Dirt and debris should not be allowed to build up on the components.
- Check the fluid level in the reservoir. Compare actual levels with the recommended levels specified in the bridge's maintenance manual.
- Inspect hoses and pipes for abrasion, kinks, and flattening. Damaged, kinked, or flattened lines restrict fluid flow and may damage pumps.
- Observe and record readings on gauges and compare them to recommended operating pressures found in the bridge's maintenance manual.
- Verify that the reservoir air filter has been cleaned and is free of clogs and contamination.
- Under operation, listen for the occurrence of "water hammering," which is the sudden stoppage of fluid that causes ramming in lines and pipes.
- Under operation, listen for cavitation or a loud rattling in the pump. Cavitation is caused by a lack of fluid passing through the pump and can cause serious damage to the impellers and other parts of the pump.
- Measure the surface temperature of the pumps. Temperatures above 140 degrees Fahrenheit indicate that the fluid may require replacement.
- After checking the temperature of the hydraulic fluid, smell and touch it. If the fluid smells burnt or feels gritty, it is time to change the hydraulic oil.
- Listen and feel for excessive vibration which may cause welds to fail or bolts to become loose.

Subsection 5.4.1 Accumulators

An accumulator stores energy in the form of pressurized hydraulic fluid. Although there are several different types of accumulators, gas-charged accumulators are the most common.
A gas-charged accumulator stores hydraulic fluid under pressure by compressing an inert gas, usually nitrogen. A rubber bladder separates the gas chamber and the oil chamber. Initially, the oil chamber is vented to atmospheric pressure and the gas chamber is pre-charged with nitrogen to a known setting through a gas valve.

Generally, accumulators are maintenance-free. The nitrogen pre-charge should be checked as a part of the inspection as follows:

- Close the isolation valve between the system and the accumulator.
- Slowly vent the accumulator using the venting needle valve.
- Watch the pressure gauge for a gradual decay in pressure as the fluid empties. The moment the accumulator rids itself of all the oil, the needle on the pressure gauge will immediately drop to zero. The pre-charge pressure is the pressure preceding this drop.

If the nitrogen pre-charge is below that value required by the system design, the inspector should recommend that the accumulator be recharged. Recharging an accumulator is dangerous and should only be performed by a qualified technician who is fully trained to properly and safely perform this procedure.

**Subsection 5.4.2 Valves**

Modern hydraulic system valves are very reliable. However, dirty system fluid or unintentional maladjustment could lead to problems with hydraulic valves. The inspector should perform the following for the system valves:

- Verify that pressure settings on all relief valves are correct.
- Check for leaks at the manifold interface.
- Verify that any directional control valve spools move freely.
- Verify that manual override pushbuttons are functional.
- If spools are sticking, disassemble the valve and inspect the internal components for wear, scoring, and fluid debris.
- Check the condition of pilot lines, if applicable.
- Inspect all shut-off valves and their connections to the system pipes for leaks.
- Verify that shut-off valves are fully open or fully closed as required by the system.
Subsection 5.4.3  Hydraulic Cylinders

Hydraulic cylinders are used for span motion or actuation of locking devices. Cylinders should be periodically inspected to ensure proper, safe, and long-term operation. The inspector should:

- Observe the extension and retraction of hydraulic cylinder rods. Span or locking device movement should be smooth.
- Inspect the condition of cylinder rod coating. Look for scoring, nicks, or other surface imperfections that could damage the rod seals.
- Inspect the area around rod seals for fluid leakage. A small amount of fluid is not cause for alarm. If leakage is excessive, recommend the replacement of the rod seals.
- Inspect the cylinder valve manifold blocks and pipe attachments for leaks. Verify that flexible hoses do not scrape anything due to cylinder movement.
- Inspect all connections of the cylinders to the structure or locking device. Verify that all bolted connections are tight. Verify that cylinder end-pin connections have freedom of movement. Verify that cylinder attachments have freedom of movement throughout the entire operating range.

Subsection 5.4.4  Pumps

Inspect system pumps and observe/listen during operation. Operation should be smooth. Verify that pumps equipped with a flow meter provide the required flow. The inspector should:

- Check the pump suction, high-pressure lines, and case drain lines for leaks. Verify that suction shut off valves are fully open, if equipped.
- Check the connections between the bell housing and the pump, and the bell housing and the motor for tightness.
- Check the tightness of the shaft-coupling assemblies.
- Check the tightness of other pump/motor mountings.
- Verify the temperature of the motor under operation. If the temperature is in excess of 140 degrees Fahrenheit, this indicates that the hydraulic fluid should probably be replaced.
- Listen to the pump when in operation. A loud rattling sound is the indication of cavitation, a serious condition which causes permanent damage to the pump.
Subsection 5.4.5  Rotary Motors

Observe and listen to the system’s hydraulic motors during operation. Operation should be smooth. The inspector should:

- Inspect the pressure line and case drain line connections for leaks. If loose, note the condition and recommend they be tightened. Check all housing joints for leaks. Verify that any suction shut-off valves are fully open.

- Check the tightness of the hydraulic motor to its support and mating equipment. Check the tightness of shaft-coupling assemblies, if applicable.

Subsection 5.4.6  Filters

Adequate and proper system filtration is the most important aspect of maintaining a movable bridge hydraulic system. Degradation or catastrophic failure could result from inadequate system filtration.

The abrasiveness of tiny particles wearing the close tolerance surfaces of internal components causes degradation failure. This type of failure spreads throughout the system and is usually not detected until the damage is irreversible. A sluggish system response, the loss of speed adjustment accuracy, the inability of the system to produce full load, and/or overheating, are all indications that degradation failure has occurred.

Catastrophic failure is the immediate failure of a system component and is usually related to large particles causing moving parts to jam or stick. In pumps, dirt can block lubrication passages and cause pump failure. Large debris can collect in orifices which supply oil to components such as the pilot circuit of the pilot-operated relief valve and pressure-compensated flow controls.

In a suction filtration system, the filtering element is located between the reservoir and the pump. The strainer is usually well below the minimum oil level within the reservoir, making servicing inconvenient. It is not unusual for these filters to go unserviced until they starve the pumps and cause cavitation damage.

If the system is equipped with suction filtration access holes, these filters can be serviced without draining the reservoirs.

Pressure filters are commonly used to protect high-pressure components such as directional spool valves and piston-type hydraulic motors. They are contained in a housing that is subjected to the full system pressure and flow. If a clogged pressure filter ruptures in service, a large concentration of contamination could dump directly into the components.

Return-line filtration is based on the assumption that a clean hydraulic system will remain clean if the contamination is filtered out of the fluid soon after it is ingested or created by the system.
Subsection 5.4.7  Pipes, Tubing, and Hoses

Plumbing systems for hydraulic movable bridge machinery often consist of complex arrangements of high-pressure pipes, stainless steel tubing, and hoses. Pipe runs usually contain many bends, elbows, fittings, and mountings due to the complex nature of the bridge structure. Vibration from operation of the equipment, vibrations from vehicular traffic, as well as movement of the equipment itself has the tendency to loosen pipe fittings and pipe supports. Inadequate support can also cause leaks or damage to the plumbing. The inspector should:

- Check for damaged, nicked, or worn hoses, which should be replaced immediately.
- Check all plumbing fittings for signs of leakage.
- Inspect pipe support systems. Check the tightness of hangers and mounting hardware.
- Visually inspect all pump and control valve pilot lines for leakage.
- Visually inspect inlet and outlet plumbing to main pumps.

Subsection 5.4.8  Hydraulic Fluids

Modern movable bridge hydraulic systems utilize either standard mineral oil or synthetic oil as their working fluid. The useful life of these fluids is not infinite. Several factors influence the expected life of hydraulic fluid including usage, operating temperature, system cleanliness, and water intrusion. Synthetic oils tend to oxidize after several years and require replacement. The inspector should touch and smell the hydraulic fluid. If the fluid smells burnt or feels gritty, the fluid should be replaced.
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This chapter discusses the basic inspection of mechanical components. All machinery components are related to, and function as, a system with the electrical and structural components. A deficiency found at one item would most likely affect other elements. Special care must be taken when inspecting mechanical components. Inspectors must make certain that the power is disconnected to motors and other drive mechanisms to prevent accidentally engaging the motor. Serious injury can result from clothing getting caught in the gears. The gears usually have a liberal application of grease to minimize wear. The grease is difficult to remove from hands and clothing and can cause skin irritation. Gloves should be worn when working around the gears and disposed of after use. Rags or paper towels are invaluable when cleaning gear teeth to obtain tooth wear.
SECTION 6.2  OPEN GEARING

Open gearing refers to gears that are not contained in a sealed housing. The gears are supported by shafting and bearings that are mounted onto fabricated or cast metal structural supports or framing. Distortion of the supports, deterioration of the fasteners, or deterioration of the shims may result in an abnormal alignment and/or wear of open gears. Wear of open gearing is compounded by the constant exposure to weather and the presence of abrasive, foreign materials that lodge in the gear mesh. The most common type of open gearing found on movable bridges is spur gearing. Spur gears transmit power and regulate the speeds of parallel shafts.

Subsection 6.2.1  Gear Alignment

Gears may be misaligned due to incorrect installation or deterioration of the supports. Misalignment may result in accelerated wear and undue stress on the gear teeth.

Inspection for gear alignment should include the following:

- View the grease patterns left behind during operation for even contact across the full tooth width at the pitch line. If the pattern is heavier on one edge of the tooth, or the pattern is not along the pitch line, the shafts are not parallel.

- Determine the amount of misalignment, indicated by grease patterns, by measuring the backlash between the mating gears. Backlash is the space between adjacent noncontacting teeth. Measure backlash to ± 0.003 inch using feeler gauges.

- Check the alignment of the bevel gears. Misalignment can show as heavier contact at the heel portion or the toe portion of the tooth.

Subsection 6.2.2  Gear Wear

Detailed examples of types of wear are described and pictured in the American Association of State Highway Transportation Officials (AASHTO) Movable Bridge Inspection, Evaluation, and Maintenance Manual.

Inspection for gear wear should include the following:

- Verify the tooth surface is smooth at the contact area. Scoring or deep gouges are evidence of deterioration of the tooth surface.

- Inspect the tooth roots for cracks. This is the area of highest bending stress.

- Inspect each tooth for fins that may form due to plastic flow of the steel.

- Verify that the teeth of one gear properly mesh with the teeth of the other gear and are properly aligned.
SECTION 6.3 BEARINGS

Two types of bearings are used on the movable bridges in Indiana: sleeve bearings and anti-friction bearings. These are discussed below.

Subsection 6.3.1 Sleeve Bearings

A sleeve bearing is a fixed cylinder in which a shaft journal rotates. The sleeve is usually made of bronze and is held to a fixed point within a steel housing. Housings are usually split in order to remove the shaft for repairs. The top half is bolted down to the base, and the base is bolted to the steel structure. Often, the sleeve bearing is provided with a flange that acts as a thrust surface to hold the shaft in the horizontal position.

A sleeve bearing requires lubrication between the sliding surfaces of the journal and bushing. Normally, one or more grease fittings are located at the top of the housing. A path is drilled through the housing and bushing and meets with grooves machined into the surface of the bushing. The groove is usually in a spiral pattern, which helps to lubricate the entire surface of the journal.

Inspection of sleeve bearings should include the following items:

- Inspect bearing supports, mounting bolts, and grout pads for cracks, damage, and deterioration.
- Inspect mounting bolts and cap bolts for tightness.
- Inspect bearing housing for cracks and damage.
- Inspect bushing and flange for cracks and damage.
- Confirm that old grease exits from the space between the journal and bushing during lubrication.
- During operation, note any movement of the bearing or support. This will indicate damage to the system that may need repair.
- During operation, note any movement of the shaft within the bushing. Any excessive radial movement indicates wear to the bushing. If excessive movement is found, other parts of the system may be adversely affected.
- Measure and record the clearance between the shaft and the bushing, using feeler gauges.
- Feel the exterior housing of the bearing after operation. The bearing should remain cool to the touch. Any heat generation may indicate improper lubrication or damage to the bearing.
Subsection 6.3.2 Anti-Friction Bearings

Anti-friction bearings include roller bearings and ball bearings. Typically, heavy-duty, spherical roller bearings are used to transmit power. Lighter-duty ball bearings are commonly used for instrumentation that drives electrical control feedback devices. In general, the clearances of the bearing are set during installation, and the unit is sealed for operation. Little wear occurs at these bearings, so wear measurements are not required. Overheating, unusual noises, and shaft or bearing vibration are indications of potential problems or the failure of an anti-friction bearing. Too much or inadequate lubrication, dirt, rust, or foreign materials in the bearing; a faulty ball or roller; seal failure; and loss of clearance or preloading can contribute to a failure.

Inspection of the anti-friction bearings should include the following:

- Examine bearing supports, mounting bolts, and grout pads for cracks, damage, and deterioration.
- Check the mounting bolts and cap bolts for tightness.
- Inspect bearing housing for cracks and damage.
- Note any movement of the bearing or support during operation.
- Listen to each bearing for any unusual noises during operation. Anti-friction bearings should operate smoothly and quietly.
- Inspect the seals for damage and proper sealing. Excessive lubricant may indicate a problem.
- Feel the exterior housing of the bearing after operation. The bearing should remain cool to the touch. Any heat generation may indicate improper lubrication or damage to the bearing.
- If possible, open the housing and visually inspect accessible portions of rollers and races. Check for internal contamination.
SECTION 6.4 SHAFTS AND COUPLINGS

Shafts transmit torque from one rotating part to another. Shafts ends are usually connected by couplings, which are secured to the shaft by an interference fit and key.

Inspection of shafts should include the following items:

- Inspect the keyways and shoulders for cracks.
- Check suspect cracks using nondestructive testing (NDT) methods.
- Inspect shafts for excessive radial movements and vibration during operation.

Couplings can be rigid, flexible, or adjustable. Rigid couplings are commonly found on older bridges, and are used to clamp shaft ends together. Flexible-type couplings are designed with internal elements that allow for misalignment during operation due to distortion of the bridge structure. The intent is to avoid bending the shafts. They also simplify shaft installation by allowing slight misalignment at the joints. Adjustable couplings are used when an angular adjustment, over time, is needed, or to monitor electrical control devices.

Inspection of couplings should include the following:

- Inspect the keyways for cracks.
- Look for corrosive deterioration and cracks.
- Check the flange bolts for tightness.
- Check for adequate lubrication of flexible couplings.
- Inspect all seals and gaskets of flexible couplings for leakage of lubricant.
- Make sure couplings rotate smoothly and are free of noise during operation. Noise indicates inadequate lubrication or misalignment of the shafts greater than the tolerances of the coupling.
- Disassemble the housings or covers. Inspect the internal flex grids and coupling hub teeth.
SECTION 6.5    LIVE LOAD BEARINGS

Live load bearings transfer vehicular live load from the span to the pier or approach span when the span is in the closed position. The bearings also prevent the span from rolling into the water in the closed position. The assembly consists of a shoe with a rounded surface (mounted to the span) and a flat strike plate mounted to the pier or other fixed structure. Both are secured with mounting bolts and are provided with shims for adjustment of the span position.

Inspection of the live load bearings should include the following:

- Determine if the mounting bolts are tight.
- Inspect the bolts and shims for deterioration.
- Check the contact surfaces of the shoe and the strike plate for deformations and wear.
- Confirm that firm contact exists between the shoe and the strike plate. If a gap exists, measure with feeler gauges and recommend re-shimming.
SECTION 6.6 SPAN LOCKS

A centering device called a span lock is located at the toe of each span to ensure roadway alignment of a rolling lift bridge. The two-part device consists of a tapered male upper and lower jaw and female diaphragm that gradually align the span horizontally during seating. The span locks also serve to transmit the live load shear between the two movable spans. The male jaws are faced with hardened steel shims that can be adjusted to nearly eliminate all movement between the spans under load.

Inspection of the span locks should include the following items:

- Inspect for adequate lubrication.
- Inspect for uneven wear that may indicate span misalignment.
- Inspect fasteners for tightness and deterioration.
- Inspect housing for cracks and damage.
- Observe the device during operation. Under normal conditions, the device should not encounter much sideward force.
SECTION 6.7  TREADS AND TRACKS

On rolling lift bridges, the weight of the leaf during operation is transferred from the curved segmental girders to the flat tracks through the treads. The treads are constructed with sockets that engage mating pintles or lugs on the tracks as the leaf rolls. These serve to position the span during operation and provide resistance against wind forces.

Inspection of the tread plates should include the following items:

- Inspect the mounting bolts that attach the treads to the girder.
- Inspect the contact surfaces for even wear across the width of the tread and track.
- Inspect the treads and tracks for cracks or surface deformation.
- Inspect the lugs, pintles, and sockets for wear and interference.
- Check the girders for cracks. Pay particular attention to the angles between web and flange.
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CHAPTER 1  OVERVIEW

SECTION 1.1  INTRODUCTION

Nondestructive testing (NDT) and partially-destructive testing (PDT) are used to investigate the material integrity of a bridge component and not the function of the component beyond material failure. NDT methods permit the inspection of an element without inflicting damage, while PDT typically causes minor, localized, repairable damage. NDT and PDT can be used when there is no observed defect, or when a defect is observed, but the extent of the problem is not known.

Part 6 presents an overview of NDT and PDT techniques as they apply to bridges. Although this testing is often performed by specialists, all structure inspectors should be familiar with available techniques so they can recommend appropriate testing procedures and recognize the limitations of the data.

Many NDT and PDT techniques have been developed and are commonly employed in the inspection of bridges. While the most common techniques are described in Part 6, the inspector should be aware that other methods are also currently available, and new techniques are constantly being developed. Refer to Figure 6.1-1 for a brief comparison of the techniques covered in Part 6.
### Figure 6:1-1: Summary of NDT and PDT Methods

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<td>In-situ, relative surface hardness of concrete.</td>
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**June 2010**
SECTION 1.2 NDT AND PDT TESTING INSPECTOR QUALIFICATIONS

NDT and PDT methods range from simple chain drags and timber coring, to complex testing such as ultrasonic or Windsor probe testing. It is important that the people conducting the test and interpreting the test data are properly trained in the applied method. These individuals must work together. The person interpreting the data must understand of the theory behind the test and have practical experience with the testing method.

All inspections should be conducted in accordance with applicable American Society for Nondestructive Testing (ASNT) procedures, American Society for Testing and Materials (ASTM) standards, and American Association of State Highway and Transportation Officials (AASHTO) specifications.

The testing technician must be trained and experienced to properly interpret the output data. Refer to Part 1 of this manual for the minimum qualifications for specialists performing NDT and PDT. Many tests particular to bridges, such as thermography and ground-penetrating radar testing of bridge decks, are not covered by ASNT certifications; however, these tests are covered by the ASTM standards and experience can be documented.

NDT personnel shall be qualified in accordance with ANST Level II or Level III. For all NDT work, other than dye penetrant, the NDT personnel must work hand-in-hand with a professional engineer, licensed in Indiana, who is qualified as an Inspection Team Leader.

Consultants, contractors, and their subcontractors performing magnetic particle testing, liquid penetrant testing, or ultrasonic testing on bridges must be prequalified by the State Program Manager prior to being allowed to solicit or perform these activities.
SECTION 1.3 DATA COLLECTION AND INTERPRETATION

For all NDT or PDT programs, a plan should be developed which details the type(s) of testing to be performed, amount of data needed, test locations, criteria for data interpretation, and follow-up procedures for handling unanticipated test results. All data should be entered into the Central Database or adequately documented in the bridge file.

Testing data should be interpreted by persons knowledgeable in both the test theory and the analysis or evaluation of the bridge being tested. For some tests, such as ultrasonic weld inspection, recognized criteria exists for evaluating any detected anomalies. However, for many test methods, the data must be evaluated based on the behavior of the bridge component.

Most NDT programs detect and assist in the evaluation of flaws and discontinuities, as well as determine the strength or serviceability by indirect methods. The tests typically indicate the existence, extent, and location of discontinuities. However, the influence of the discontinuity on the strength or serviceability of the structural component is often difficult to determine. The validity of any testing depends on good engineering judgment based on experience. The information collected by NDT/PDT is typically raw data and the specialist must interpret the information for it to be of use. Also, certain techniques may provide false data under certain conditions. The specialist must be familiar with a technique and be able to recognize the false readings. No inspector should recommend testing, or accept testing results, without being familiar with the technique.
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CHAPTER 2 VISUAL EXAMINATION

SECTION 2.1 INTRODUCTION

Visual examination is the most basic of the nondestructive testing (NDT) inspection techniques. It allows for detecting and inspecting a wide variety of surface flaws such as cracks, discontinuities, corrosion, and contamination. Detection of surface cracks is particularly important due to their relationship to failure mechanisms. NDT methods utilizing a visual examination, such as liquid penetrant testing, often supplement other nondestructive tests. Close visual examination requires proper access to the element being inspected and appropriate tools. Figure 6:2-1 shows an inspector conducting a visual inspection.

Figure 6:2-1: Inspector Conducting Visual Examination
SECTION 2.2 APPLICATIONS AND LIMITATIONS

Visual examination is applicable to all structures either as a Routine Inspection, or as the first step in any other type of inspection. It can identify where a failure is most likely to occur, and identify when a failure has commenced. Visual examination is often enhanced by other surface methods of inspection, which can identify defects that are not easily seen by the unaided eye. Furthermore, visual examination may be aided with magnifying equipment or tools.

Inspections should always proceed in a logical manner from element to element. Proper access is necessary so that the inspector can examine elements from a reasonable distance during Routine Inspections and from a maximum arm’s-length distance, approximately two feet, during Fracture Critical and In-Depth Inspections. Surfaces must be properly cleaned to expose the base material. The element being inspected should also be well-lit, either naturally, or by the use of a portable light source. The inspector should have good vision and color acuity. The inspector should also possess knowledge of the types of failures to look for. A variety of tools should be employed, when necessary, to aid the inspector. These tools may include binoculars, low-power magnifying glasses, crack gauges, and boroscopes to view inaccessible areas.

Because visual examination can only detect defects visible to the eye, the internal condition of an element remains unexamined. In addition, some small surface flaws may be difficult to locate or, once found, it may be difficult to accurately determine their extent. Badly deteriorated elements may be difficult to examine effectively due to heavy corrosion buildup. Furthermore, access to visually examine an item may be difficult even with the use of specialized equipment.
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CHAPTER 3 AUDIBLE INSPECTIONS

SECTION 3.1 INTRODUCTION

The most common types of Audible Inspections are chain dragging, hammer sounding, and listening under load. Chain dragging is normally used on large concrete surface areas, such as bridge decks, while hammer sounding can be used on a number of materials in random locations. Listening under load is used for all types of bridges. These methods rely on the experience of the inspector to differentiate the relative sounds of similar materials.

Chain dragging requires an inspector to drag several lengths of heavy chain over a concrete surface. The chains contact the concrete surface and produce an audible indication of delaminated areas, much like tapping with a hammer. These areas are marked and mapped for further evaluation.

Hammer sounding can aid in detecting impending spalls and existing delaminations which, when struck with a hammer, give off a dull sound or loud pop as opposed to the sharp ring of hard concrete without any internal discontinuities. This sound is easily noted when progressing from solid areas to delaminated areas. Similarly, hammer sounding of bolts and rivets can serve as an aid in detecting loose fasteners. Bolts and rivets should be struck sideways, as well as on their ends. In the inspection of timber elements, hammer sounding is used to detect the presence of significant decay. When a seriously decayed member is struck with the hammer, a dull or hollow sound is produced. However, when suspected timber decay is encountered, it must be verified by other means such as boring or coring. Hammer sounding can be satisfactorily accomplished using a light hammer. Figure 6:3-1 shows an inspector hammer sounding a concrete abutment.

Listening under load can be used to detect many problems, including loose bars in steel grid decks, settled areas, and bad expansion joints. Inspectors listen for thuds, pops, vibrations, or other unusual sounds when traffic is passing to help identify and locate problems.

Figure 6.3-1: Inspector Hammer Sounding a Bridge Abutment
SECTION 3.2 APPLICATIONS AND LIMITATIONS

Chain dragging is most commonly used as an aid in inspecting concrete bridge decks, but it can be used on other horizontal surfaces. Large areas can be quickly examined utilizing several chains in each drag. This method is most efficiently conducted using a two-person team.

Hammer sounding is most commonly used as an aid in inspecting concrete, but can also be used on metal fasteners and timber members. This technique works well on both horizontal and vertical surfaces. Large areas can be inspected in a reasonable amount of time only if spacing is random. However, the inspector should take care to thoroughly cover the entire surface of the element since the hammer only provides information on the local area under the point of impact. A single inspector can conduct this method of investigation, but access equipment may be needed.

Listening under load can be used on any type of bridge, but is most commonly used to detect loose bars in steel grid decks, settled areas, and bad joints. This technique is supplemental to all bridge inspections.

Chain dragging is limited to locating areas of delamination in exposed horizontal surfaces. It is not effective on asphalt-overlaid decks, since there is no difference in sounds between delaminated concrete and debonded overlays. Hammer sounding is limited to areas visually identified for possible deterioration. Deterioration may include delamination and impending spalls in exposed concrete; rotting timber; and loosened fasteners. Although chain dragging and hammer sounding are inexpensive, they can be physically demanding and time-consuming, and the inspector must be familiar with the tonal differences between sound and delaminated concrete. Traffic control is often needed for utilizing these methods on bridge decks. Listening under load is inexpensive, but requires the attention of an experienced inspector. It is best suited for low-volume bridges.

The extent of any noted defects is subject to the inspector’s interpretation of the tonal differences in the produced sound. Areas with high levels of background noise, such as those with large traffic volume or adjacent airports, industry, or construction sites will make the tonal differences difficult to distinguish. Data recording must be done manually using field sketches and photographs. Refer to Part 6, Chapter 6 for an Audible Inspection method using acoustic emissions.
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CHAPTER 4   INFRARED THERMOGRAPHY

SECTION 4.1   INTRODUCTION

Infrared thermography is used to locate and map delaminations in bridge decks. Using an infrared scanner and a video camera, infrared thermography senses temperature differences between delaminated and nondelaminated areas. A delamination in a concrete deck creates a thermal discontinuity that acts as an insulator. Thermography operates on the principal that when the sun warms the deck, the delaminated area heats up at a faster rate and reaches a higher temperature than the solid areas.

A temperature difference between delaminated and solid areas is normally established only on sunny or partially sunny days. The deck must be dry and winds must be less than 25 mph. Temperature difference is primarily related to the amount of sun, not the ambient air temperature, so inspections can be undertaken under various temperatures. Generally, these inspections are made between March and November with the use of a moving vehicle. Figure 6:4-1 shows a schematic diagram of an infrared thermography scan.

![Figure 6:4-1: Illustration of Infrared Thermography of a Bridge Deck](image)

The bridge deck is scanned from a vehicle mounted with an infrared camera. The video signal is recorded on videotape for detailed analysis in the office. A single pass, with a vehicle speed of approximately five mph, is typically made for each lane and shoulder. A video control image of the bridge deck surface is recorded simultaneously. Distance footage is superimposed onto both videotape signals to locate defects. Figure 6:4-2 shows a view of the display images from an inspection.
Field confirmation of the infrared data consists of sounding several suspect deteriorated areas and measuring surface temperatures of both suspect and solid areas. Select deck cores are taken for confirmation. The proposed core locations are typically marked at the time of the inspection.

![Figure 6:4-2: Video Control Image (Left) and Infrared Image (Right)](image)

Analysis of the infrared data is completed with the aid of a computer digitization program. During the analysis, the recorded temperature variations are interpreted to identify specific, delaminated areas. Each delamination is identified and plotted onto plan view drawings of the bridge deck. Square footage and percentage of delaminated deck are calculated. The video control data is examined to make sure that temperature variations were not caused by concrete spalls, discoloration, patches, tar, or debris. In addition, the video control data is used to plot patches or spalls.

SECTION 4.2 APPLICATIONS AND LIMITATIONS

Infrared thermography is most commonly used on concrete bridge decks with or without overlays; however, it can also be used on other concrete components. The method has proven to be accurate and easily repeatable.

Infrared thermography also provides for quick data collection, since the equipment can be vehicle-mounted and driven over the bridge deck. By mounting the equipment to a vehicle, the process typically results in minimal traffic disruption. Infrared thermography can be used in areas with high-traffic volumes or noise levels.

Data collection for infrared thermography is completed with the aid of computer logging software, and the image can be digitally processed for an overall assessment of the bridge deck.

Infrared thermography requires a temperature differential of approximately 0.9 degrees Fahrenheit (0.5° C) to identify the delaminated or debonded areas of a concrete deck. This typically requires that inspections be done on days when less than 50 percent of the sky is covered by clouds. Inspected areas must be dry, exposed to the sunshine, and without debris.

Thermography locates the delaminated areas in the horizontal plane and does not provide any information on the depth layer where the defect occurs. If confirmation on depth is desired, cores can be taken from the deck.

Cost may be a prohibitive factor for using this on a small number of structures since the scanning equipment and data processing software are expensive. Also, the vehicle must typically be operated by at least two inspectors. When compared to manually sounding a large deck or several smaller decks, thermography may be cost-effective and it may require less traffic control.
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CHAPTER 5 GROUND-PENETRATING RADAR

SECTION 5.1 INTRODUCTION

Ground-penetrating radar can be used on bridges to evaluate the condition of the bridge deck, measure the thickness of an overlay, detect voiding under bridge approach slabs, locate reinforcing steel, investigate foundations, and for underwater profiling. This chapter will discuss the use of ground-penetrating radar on bridge decks and approaches, while Chapters 18 and 19 will discuss additional uses of ground-penetrating radar.

A radar system typically consists of a control unit, radar antenna, and display unit. The control unit generates a radar pulse and sends it through a cable to the antenna. The antenna transmits the pulse into the surface. When this energy encounters an interface between two materials of differing dielectric properties, such as reinforcing steel, air, moisture, or the base-course material, a portion of the energy is reflected back to the radar antenna. The received pulse is sent back to the control unit for processing/storage. The display unit (video or chart recorder) presents the data.

The reflected energy is received by the transducer, amplified, and recorded. The electromagnetic pulse is repeated at a rapid rate and the resultant stream of radar data produces a continuous record of the subsurface. The radar system creates a linear profile of the materials beneath the antenna pass. Figure 6:5-1 shows an example of radar output on a typical pavement section.

![Figure 6:5-1: Typical Radar Output Image With Notations](image-url)
Two different types of transducers, contact or horn types, can be mounted on a data collection vehicle, or hand-towed. Refer to Figure 6:5-2 for views of two types of vehicle-mounted transducers.

The location of the transducers can be varied across the width of the pavement and, if additional information is required, a number of passes with the antenna in different locations can be made.

For the majority of surveys, the antennae are mounted over the wheel tracks. The data is normally collected at a vehicle speed of five mph or less. Faster speeds are attainable, but the longitudinal and vertical resolution of the system is reduced. Horizontal data positioning is accomplished by using a distance transducer connected to the drive train of the data collection vehicle.

An event mark is automatically placed on the data at user-defined intervals, allowing defects to be located accurately. Once the survey is completed, a computer processes the data and the results of the survey can then be presented in a variety of formats.

SECTION 5.2 APPLICATIONS AND LIMITATIONS

Ground-penetrating radar is most commonly used on concrete bridge decks with an overlay surface. This allows for an inspection of the concrete deck surface, which is hidden by the overlay surface. Ground-penetrating radar is not often used on bare concrete decks since it is not as accurate or rapid as thermography.

The ground-penetrating radar system can be used to determine the following:

- Pavement and/or overlay thickness
- Locating and/or determining the depth of reinforcing steel or mesh
- The thickness of pavement cover above reinforcing steel
- Pavement or joint types
- The size of voids beneath pavements

Ground-penetrating radar identifies areas of a concrete deck with different dielectric properties or conductivities. Some concrete, such as dry, low-permeability concrete, affect the accuracy of ground-penetrating radar to detect areas of delamination. Ground-penetrating radar is also sensitive to the presence of water and chlorides on the deck and between overlays and the base concrete, as well as the presence of debris on the deck surface. These conditions can significantly influence the accuracy of the data.

Ground-penetrating radar must be scanned perpendicular to the top layer of reinforcing steel. Therefore, inspection of some structures will require the survey to be conducted perpendicular to the flow of traffic. This will require traffic to be restricted or stopped altogether while the survey is being conducted. Frequently, several passes must be made on the deck area and the cost may be prohibitive.
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CHAPTER 6 ACOUSTIC EMISSION

SECTION 6.1 INTRODUCTION

Fatigue cracks, weld discontinuities, and many other failure-causing mechanisms produce sound energy. Although a portion of the sound produced by materials under stress may exist as audible sound, most is low-energy and inaudible. An example of an audible stress release occurred at the Mianus River Bridge in Greenwich, Connecticut, where newspapers reported loud noises were heard by nearby residents days before the actual collapse occurred. At the Hoan Bridge in Milwaukee, witnesses reported a loud noise at the time of the brittle fracture of the steel girders.

An acoustic emission is defined as inaudible sound energy released within a material undergoing deformation or flaw growth. An acoustic emission test is described as a method used to detect this sound energy. To detect acoustic emissions, one or more “listening” transducers are attached to the test object. Positioning of acoustic emission transducers in the path of anticipated sound propagation enables detection. The detected signals are then electronically processed to derive information on the location and severity of growing flaws. It should be noted that “guard” transducers are also used in conjunction with the “listening” transducers to differentiate the flaws from normal bridge noises. Figure 6:6-1 shows a schematic of a basic acoustic emission test.

![Figure 6:6-1: Acoustic Emission Test Configuration](image)

Note: The guard transducers are not shown for clarity in Figure 6:6-1.
The detected signal is produced by the test material, not by an external source. An acoustic emission transducer acts as receiver. Acoustic emission tests detect movement, where most other methods detect existing geometrical discontinuities. An applied stress is required to cause flaw growth and, hence, the acoustic emission. The applied stress can be the result of the bridge live and dead loads, or an induced load used specifically for the acoustic emission test. In many tests, a combination of the two is necessary.

Various American Society for Testing and Materials (ASTM) standards cover acoustic emission testing and are dependent on the material and type of structural component being tested.
Acoustic emission testing is used to detect cracks, corrosion, weld defects, and material embrittlement. This method can be used on a wide variety of materials, such as metal, timber, concrete, fiberglass, composites, and ceramic.

An entire structure can be monitored with acoustic emission testing from a few locations, reducing the amount of access required. Acoustic emission testing can be conducted while the structure is in service.

Acoustic emission testing is a real-time testing method. It monitors the actual condition of the component during the test. An acoustic emission test method can also be used to record an accumulation of damage within a structure. The data obtained can be used as history for a structure, and possibly to anticipate failure.

It is difficult to differentiate the sound energy released by a growing flaw from background noise. Many background noise generators such as bolts, joint friction, and traffic can mimic or mask the sound energy released from growing cracks. Some acoustic emission test methods avoid this problem by isolating areas known to contain background noise generators.

When a global acoustic emission test is conducted to determine areas where structural problems exist, additional nondestructive or partially-destructive testing methods may be required to identify the exact nature of the defect.
CHAPTER 7 COVERMETER TESTING

SECTION 7.1 INTRODUCTION

Covermeters, often referred to as pachometers or R-Meters, are electromagnetic devices that detect the reinforcing steel in concrete and measure its size and the depth of cover. The device produces a magnetic field and locates the reinforcing steel by measuring the distortion of the magnetic field created by the presence of the steel. The signal received increases with increasing bar size and decreases with increasing cover thickness. The covermeter can be calibrated to convert the signal into a distance, which indicates the depth of cover.

The depth of cover is important because of the relationship between cover depth and deterioration mechanisms. Inadequate cover can undermine the protection that the concrete provides to the steel reinforcement from corrosion. If the cover is too deep, there is the possibility of increased crack widths and decreased effective depth, which both affect design parameters on a concrete member. Figure 6:7-1 shows a basic covermeter.

Figure 6:7-1: View of a Basic Covermeter Unit
SECTION 7.2 APPLICATIONS AND LIMITATIONS

Covermeters can accurately measure the cover depth within 0.25 inches in the range of zero to three inches in lightly reinforced structural members. Covermeters can also locate reinforcing steel for the purpose of tying in a new structural member to an existing structure and is often used during rehabilitation.

The effectiveness of a covermeter is limited by several factors. A covermeter only locates the reinforcing steel and does not provide any actual information about defects or the material’s state of deterioration. The intensity of the signal may be misinterpreted and the cover depth can be incorrectly noted as less than the true depth if more than one bar is present at a location. This problem is common in heavily reinforced structures or when large steel objects, such as scaffolding, are near the test area. Some reports indicate that the epoxy coatings on reinforcing steel can distort the readings of a covermeter. Also, the relative material properties of the concrete must be assumed to utilize conversion charts for the reading.
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CHAPTER 8  REBOUND HAMMER

SECTION 8.1  INTRODUCTION

A rebound hammer, commonly referred to as a Schmidt hammer, is a mechanical device used to measure the compressive strength of in-place concrete. The device consists of a plunger and a spring-loaded hammer. When triggered, the hammer strikes the free end of the plunger that is in contact with the concrete, which in turn causes the plunger to rebound. The extent of the rebound is measured on a linear scale attached to the device. Figure 6:8-1 shows a standard rebound hammer.

This test is covered in the American Society for Testing and Materials (ASTM) publication C805-97, “Standard Test Method for Rebound Number of Hardened Concrete.”

![Figure 6:8-1: Standard Rebound Hammer](image)
SECTION 8.2  APPLICATIONS AND LIMITATIONS

A rebound hammer is used to assess the uniformity of in-situ concrete and to delineate zones of poor quality or deteriorated concrete. It is also useful to detect changes in concrete characteristics over time, such as hydration of cement, for the purpose of removing forms or shoring.

The rebound hammer is portable, easy-to-use, low-cost, and can quickly cover large areas.

The rebound hammer is valuable only as a qualitative tool since it measures the relative surface hardness of the concrete. Other tests, such as a compression test, must be used to determine the actual strength of the concrete. The rebound measurement is governed by several factors including the size, age, and finish of the concrete, as well as the aggregate type and the moisture content. A rebound hammer will give a false reading if used over exposed aggregate.
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CHAPTER 9 IMPACT ECHO TESTING

SECTION 9.1 INTRODUCTION

The impact echo method is a nondestructive testing (NDT) technique used for detecting internal flaws in concrete. It has been used on a variety of members, particularly slab, beam, and wall type members. The impact echo test method produces a transient stress pulse into a member by means of a point impact. This pulse produces a surface wave, as well as waves that travel into the element. These waves are reflected by internal defects and the boundaries of the element.

The testing apparatus consists of a handheld unit that generates an impact which produces a wave, and a receiving transducer which receives the reflected waves. A computer-based system is then used to process the data and display the echo wave form data. The operator interprets the data to determine the presence and extent of defects found. Figures 6:9-1 and 6:9-2 show an impact echo test unit and an inspector using a unit.

Figure 6:9-1: Impact Echo Test Unit
Impact echo testing is covered in the American Society for Testing and Materials (ASTM) publication C1383-98a; “Standard Test Method for Measuring the P-Wave Speed and the Thickness of Concrete Plates Using the Impact-Echo Method.”
SECTION 9.2  APPLICATIONS AND LIMITATIONS

The impact echo technique utilizes easily transportable equipment and can be performed by one individual. Testing is fairly rapid and only minimal surface preparation is needed to assure proper transfer of the impact energy to the structure. Tests are often made on a grid pattern, with the size of the grid determined by the suspected damage. The technique can be used to locate defects such as delaminations, honeycombing, cracks, and voids. It may also locate voids around reinforcing steel and within grouted prestressing strands and post-tensioned tendons.

The impact echo method requires interpretation of the wave form output for each test by the field technician. The technician must be trained and experienced to properly interpret the output data. Prior to testing, design plans should be carefully reviewed for embedded items or other details that may affect wave behavior and test results. The presence of reinforcing steel must be properly accounted for. The maximum element thickness for this test is approximately 6.5 feet.
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CHAPTER 10  PENETRATION METHOD

SECTION 10.1  INTRODUCTION

The penetration method utilizes a device that fires a probe into the concrete using a constant amount of energy. The probe is made of a hardened steel alloy specifically designed to crack the aggregate particles and to compress the concrete being tested. Once fired, the length of the probe projecting from the concrete is measured. A test typically consists of firing three probes and averaging the projecting lengths. Figure 6:10-1 shows a Windsor Probe test kit, one of the most commonly used tests for penetration testing.

This test is covered in the American Society for Testing and Materials (ASTM) publication C803/C803M-97C1, “Standard Test Method for Penetration Resistance of Hardened Concrete.”

Figure 6:10-1: Windsor Probe Test Kit
SECTION 10.2 APPLICATIONS AND LIMITATIONS

Penetration tests are used to assess the uniformity of in-situ concrete and to delineate zones of poor quality or deteriorated concrete. It is also well-suited for estimating compressive strength of concrete and the relative strength of concrete across the same structure. Penetration tests are commonly used to estimate early age strength of concrete for the purpose of stripping forms.

The penetration test method is a qualitative tool and, like the rebound hammer, it requires that other tests be conducted to determine the actual strength of the concrete being tested. The penetration method also damages the concrete at the test location. The probes must be removed and the holes patched.
CHAPTER 11  HALF-CELL TESTING

SECTION 11.1  INTRODUCTION

Steel reinforcement is typically protected from corrosion by the alkaline nature of concrete. If the alkalinity of the concrete is compromised, corrosion on the steel will commence if moisture and oxygen are present. The corrosion reaction will promote anodic and cathodic activity along the reinforcing steel. The corrosion of the reinforcement produces a corrosion cell caused by these differences in electrical potential.

The half-cell testing method is used to determine if the reinforcing steel is under active corrosion. This method utilizes a multimeter to measure the potential difference between the steel and a half-cell apparatus. The analysis of the potential difference can indicate if active corrosion is taking place on the reinforcing steel. Refer to Figure 6:11-1 for a schematic of a basic half-cell test.

This test is described in the American Society for Testing and Materials (ASTM) publication C876-91, “Standard Test Method for „Half-Cell” Potentials of Reinforcing Steel in Concrete.”

![Figure 6:11-1: Basic Half-Cell Test Configuration](image-url)
SECTION 11.2 APPLICATIONS AND LIMITATIONS

Although commonly used on bridge decks, the half-cell test can be performed on any reinforced concrete component, provided a direct electrical connection can be made to the reinforcing steel. Since the test can only detect corrosion directly under the device, a systematic grid of test points should be created to map the potential readings throughout the concrete component. This map can then be analyzed to determine the probable areas of active corrosion.

It is generally agreed that the potential measurements can be interpreted as follows:

- 0.00 to –0.20 volts indicates greater than 90 percent probability of no corrosion
- -0.20 to –0.35 volts indicates that corrosion is uncertain
- < -0.35 volts indicates greater than 90 percent probability that corrosion is occurring
- Positive number indicates that the moisture content of the concrete is insufficient and, therefore, test is not valid

Half-cell testing requires specialized equipment, typically including a copper/copper-sulfate half-cell apparatus and a multimeter. A connection with the reinforcing steel is required, so holes may need to be drilled in the concrete to connect to the steel. This test method only indicates the probability of corrosion present at the time of testing and does not indicate the extent or the rate of corrosion. Traffic control, access to electricity, and tools such as drills are required to perform this testing.
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CHAPTER 12  CHLORIDE ION TESTING

SECTION 12.1  INTRODUCTION

Chloride ions are the major cause of reinforcing steel corrosion in concrete. Chloride ions are most often provided from road salt, although they may also be available as contaminants in the original concrete mix. Chloride ions are not likely to cause problems unless they exist in unusually high concentrations. Since corrosion of steel reinforcing is generally considered to begin at a chloride ion content of between 0.025 percent and 0.033 percent by weight of concrete, knowledge of chloride content can aid in determining the likelihood of the onset or presence of corrosion.

A chloride profile must be developed to evaluate the concrete. The profile should show the percent of chloride concentration versus the depth below the concrete surface. This profile is important for assessing the future corrosion susceptibility of steel reinforcing and in determining the primary source of chlorides.

The chloride content in concrete is typically determined through laboratory analysis of powdered concrete samples. Field-collected, powdered samples are typically taken by drilling at different depths down to and beyond the level of the reinforcing steel. Extreme care should be exercised to avoid inadvertent contamination of the samples. Alternatively, core samples can be extracted and powdered samples can be obtained at different depths in the laboratory. The extraction of these samples destroys a portion of the component. However, since this test can be performed in the field and results obtained quickly, it has been separated from the Material Sampling section described in Chapter 13 of this part of the manual.

The chloride ion content of concrete is usually measured in the laboratory using wet chemical analysis. Although laboratory testing is the most accurate, it is time-consuming and often takes several weeks before results are available. As a result, field test kits have been developed. The use of field test kits allows rapid determination of chloride levels to be made on-site. Although the field kits are not as accurate as the laboratory method, they do provide good correlation with laboratory tests when a correction factor is used.

The detailed procedure for chloride sampling and testing is covered in the American Association of State Highway and Transportation Officials (AASHTO) publication T 260-84; “Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials,” and in the American Society for Testing and Materials (ASTM) publication C114-00; “Standard Test methods for Chemical Analysis of Hydraulic Cement.” However, both of these publications apply to testing in the laboratory, not in the field.
SECTION 12.2 APPLICATIONS AND LIMITATIONS

Chloride ion testing can be performed on any concrete component. Field kits allow inspectors to perform the test on-site and determine chloride levels immediately.

When samples are collected at different depths and plotted on a chloride profile chart, this method is a very useful tool in determining the depth of deck to be milled off prior to an overlay.

Collecting samples to perform this test requires the removal of a portion of the concrete member. Therefore, several samples cannot be taken from a single location to validate results. This method is also time-consuming and requires access to the member. In the case of a bridge deck, the bridge may need to be closed to traffic during the sampling process.
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CHAPTER 13  MATERIAL SAMPLING

SECTION 13.1  INTRODUCTION

To fully determine the condition of a structure, it may sometimes be necessary to extract material samples from the bridge so that laboratory tests can be used to determine the condition of the material, or the state of deterioration or damage. Typical laboratory tests include compressive tests and petrographic examination of concrete, tension tests, charpy tests, steel crack investigations, and integrity examination of timber.

The extent and purpose of the sampling must be determined prior to taking samples. The sample size is often stipulated by the specific test method used. In most cases, particularly where deterioration is present, it is advisable to take samples from both good and bad areas so that a comparison can be made. Once the number and location of samples is determined, they should be plotted on a drawing of the structure to aid in fieldwork and to serve as a record for the evaluation of the test results.
SECTION 13.2  APPLICATIONS AND LIMITATIONS

All materials can be sampled and tested either in the field or in a laboratory to provide useful information about the extent of deterioration and the material characteristics. Specimens should come from representative areas of the structure and typically three samples are required.

All material samples should be collected, and tests conducted, in accordance with applicable American Society for Testing and Materials (ASTM) and American Association of State Highway and Transportation Officials (AASHTO) methods for the respective materials.

The removal of material should only be used when a specific piece of information is required for the evaluation of the structure.

Repairs are required for the sample extraction holes or voids in the tested component. Concrete and timber repairs are relatively easy, but steel repairs may be more complex. Care must be taken to minimize any residual stresses or the creation of any fatigue-prone details when making a repair.
SECTION 13.3  CONCRETE TESTING

Concrete material sampling most often consists of drilled cores, though sections may also be obtained by sawing or breaking off a portion of the component. The core size should be determined by the tests to be run; however, in most cases, a four-inch diameter core is extracted. Core holes are normally filled with grout; other sample areas should also be repaired with a suitable mortar material.

Samples should be marked for location and orientation and packed to prevent damage during transport. As part of the sampling operation, reinforcing steel is typically located and marked to avoid cutting it during the sample extraction. In some instances, it may be desirable to include reinforcing steel as part of the sample. In these cases, it is necessary to confirm that the cut reinforcing steel will not jeopardize the structure’s integrity. Figure 6:13-1 shows a view of a concrete coring machine and core sample.

Concrete tests that require samples include:

- Carbonation.
- Permeability.
- Cement content.
- Percent air content.
- Moisture content.
- Steel reinforcing yield strength.
- Concrete compressive strength.
- Modulus of elasticity (static & dynamic).
- Concrete splitting tensile strength.

Figure 6:13-1: Concrete Coring Machine (Left) and Core Sample (Right)
SECTION 13.4 STEEL TESTING

Material coupons for steel members are usually obtained by sawing, coring, or by collecting drill shavings. Flame cutting should be avoided because the heat induced by the cutting operation alters the material’s properties in the vicinity of the cut, both in the sample and remaining base material. These heat-affected areas must then be removed by grinding prior to testing and repair to the base material is also often required. Coupon locations should be carefully selected because the properties of steel members vary over the cross-section as a result of varying rates of heat loss due to fabrication techniques and rolling/production practices. The orientation of the steel samples must be recorded prior to removal.

Steel tests that require samples include the following:

- Brinell hardness test
- Charpy impact test
- Chemical analysis
- Tensile strength test

Figure 6:13-2 shows a Charpy impact testing machine.
SECTION 13.5 TIMBER TESTING

Drilling, boring, and probing are most often used to assess the presence of voids, the extent of rot, and the depth of preservative penetration. An incremental borer is usually used to extract cores for timber sampling, although sections may also be obtained by sawing off a portion of the component. Core holes should be plugged with a treated hardwood dowel. Figure 6:13-3 shows several incremental borer core samples.

Timber cores are assessed to determine if bacterial or fungal decay is present, the extent of interior rot, and to determine the species of timber, if required. These methods typically do not produce a global sample specimen. Several local specimens from random locations can be used to get an overall picture of a member. Any holes should be plugged with a treated hardwood dowel.

Moisture content and rot can also be assessed on specimens using electrical devices, such as the Shigometer. These devices require electrodes to be driven into the timber or that small holes be drilled to insert probes into the timber. These detect the presence of timber rot; however, drilling or coring should be conducted to determine the extent of the rot.

Figure 6:13-3: Typical Incremental Borer Core Samples
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CHAPTER 14  ULTRASONIC TESTING

SECTION 14.1  INTRODUCTION

Ultrasonic testing is used to evaluate the internal (volumetric) condition of materials. Specifically, it is used to confirm suspected discontinuities or cracks, as well as check questionable material thicknesses or lengths. Typical discontinuities, which are detectable by use of ultrasonic testing, include laminations, surface cracks, and many surface and subsurface weld-related discontinuities, such as lack of fusion or porosity.

The use of sound to determine the internal properties of a member is not new; audible sound has been used as a nondestructive testing (NDT) method for centuries. For instance, striking a porcelain bowl to listen for either a ring or dull tone is an old way to detect a crack. Today, shear stud connectors used for composite bridge beams are still tested by striking them with a hammer and listening to the change in ringing note.

With ultrasonic testing, the transducer can be thought of as replacing both the hammer and ear. The transducer directs a wave of high frequency vibrations, inaudible to the human ear, into the test specimen, and then receives the returning echoes. The ultrasonic instrument provides the necessary electronics to produce these waves and display the returning echoes for interpretation.

A transducer is a device that is capable of converting energy from one form to another. In the case of ultrasonic testing, electrical energy is changed to mechanical energy and vice versa. Ultrasonic testing transducers convert electrical energy into mechanical vibrations, which in turn produce high-frequency sound waves. They also convert high-frequency sound back into electrical energy upon receiving the return echoes.

The most common ultrasonic technique currently in use in the United States is called pulse echo. The pulse echo method employs short bursts, or pulses, of waves which are transmitted into the specimen by the transducer, which must be in integral contact with the specimen. Any returning, unexpected echo from these pulses is evaluated to determine the location and size of the reflector.

The signal height or amplitude is related to the amount of reflected sound energy. Large reflectors, causing total reflection of sound, produce signal responses of higher amplitude than smaller reflectors, which only reflect a portion of sound energy. Larger return echo amplitudes suggest larger-sized flaws. Echo indications are normally retested from another position to confirm flaw size and position. Refer to Figure 6:14-1 for an illustration of pulse echo ultrasonic testing.

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Basic ultrasonic pulse echo systems include the following:

- Power supply
- Pulser
- Receiver/amplifier
- Oscilloscope
- Timer (clock)
- Transducer

Power for the testing equipment is supplied by portable battery packs or by an external alternating current (AC) source. The pulser, also called the pulse generator, produces the short duration burst of voltage, which is applied to the transducer. The rate of these voltage bursts is controlled by a clock or timer. Sound echoes returning to the transducer are relayed to the receiver, amplified, filtered, and sent to the display screen. Pulse echo methods include compression, shear, and surface wave modes.

Compression wave testing, also called straight beam testing, is used for flaw detection, particularly laminations, and for thickness measuring. It directs waves into the material perpendicular to the specimen's surface. Refer to Figure 6:14-2 for a schematic of the compression wave mode.
Shear wave testing, also called angle beam testing, is ideally suited for weld testing. Waves are directed into the material at an angle other than 90 degrees to the specimen surface. The shorter wavelength (lower velocity) increases sensitivity, and angular capability allows for weld examination at predetermined angles. Refer to Figure 6:14-3 for a schematic of the shear wave mode.

American Society for Testing and Materials (ASTM) standards cover ultrasonic testing dependent on the material and type of structural component. American Welding Society (AWS) standards cover ultrasonic testing of welds.
SECTION 14.2 APPLICATIONS AND LIMITATIONS

Ultrasonic testing allows an examination of the internal structure of a material when accessibility is limited to one side. It is an ideal method for the detection of flaws, which are not readily detectable by visual means. It is used to inspect a variety of both metallic and nonmetallic members, such as welds, forgings, castings, plastics, ceramics, concrete, steel sheeting, aluminum tubing, fiberglass, and timber. Since ultrasonic testing is capable of economically revealing subsurface discontinuities (variation in material composition) in a variety of dissimilar materials, it is an extremely effective and useful tool. Relatively thick specimens can be examined. Ultrasonic testing results are definitive for both bare and covered concrete slabs. Penetration of asphalt thicknesses of up to six inches has been successful. The length and integrity of piles and caissons can be determined using ultrasonic testing.

Ultrasonic testing is most successful for detecting discontinuities, which are oriented perpendicular to the direction of propagating sound. It is also often used as a complimentary method to other NDT procedures such as radiography.

The method is readily adaptable to field testing, as portable lightweight units contain a rechargeable battery having a typical eight-hour battery life. Figure 6:14-4 shows an inspector conducting ultrasonic testing in the field.

Figure 6:14-4: Inspector Conducting Ultrasonic Testing on a Sign Structure Anchor Bolt
Ultrasonic testing should not be performed on rough surfaces, on parts with complicated geometries, or where the size of the discontinuity is expected to be smaller than one-half of the wavelength. Rough surfaces may require grinding. Ultrasonic testing requires properly trained personnel who understand the limits of the accuracy of the method. Clearly written test procedures are needed. A certified Level III NDT specialist should evaluate and develop written testing procedures for any uncommon applications. It is important that the ultrasonic testing equipment be calibrated prior to each use.
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CHAPTER 15 LIQUID PENETRANT

SECTION 15.1 INTRODUCTION

Liquid penetrant testing, also known as dye penetrant testing, is used to confirm the presence of a crack or flaw. It relies on the ability of a liquid to enter into a discontinuity. Therefore, it can only find discontinuities open to the surface of the material. It can be applied to any nonporous material that is not adversely affected by the penetrant material.

The material is cleaned to remove all surface contaminants before the penetrating liquid is applied. The penetrant will seek out and enter small surface openings. Excess penetrant is removed from the test surface by wiping or rinsing with water. A drying developer is then applied and the penetrant remaining in the discontinuity bleeds out, forming a highly visible, contrasting indication on the test surface.

The characteristics of a good penetrant relate to the ability of the fluid to be drawn into small openings, even against gravity. This penetrating ability is affected by many variables, including surface tension of the liquid, wetting ability, surface condition, surface contamination, and temperature.

Two major types of penetrants used: visible dye penetrants and fluorescent penetrants. Visible dye penetrants are normally red, providing contrast with the applied white developer under visible light. Fluorescent penetrants contain dyes which fluoresce brilliantly when viewed under black light in a darkened area. Fluorescent penetrants provide better contrast than visible dye penetrants and are, therefore, more accurate. Figure 6:15-1 shows a casting with a visible dye and developer applied to the surface. Figure 6:15-2 shows a gusset plate with applied fluorescent penetrant.

The indications must be interpreted by trained personnel. Interpretation includes determining what caused the indication, evaluating the seriousness of the problem, and reporting the inspection results accurately and clearly.

Proper interpretation and evaluation of liquid penetrant indications require knowledge of the types, causes, and appearance of indications, knowledge of the test method and material fabrication process, adequate illumination, good eyesight, and experience.

This testing method is covered in the American Society for Testing and Materials (ASTM) publication E165-95 “Standard Test Method for Liquid Penetrant Examination” and the ASTM publication E1417-99 “Standard Practice for Liquid Penetrant Examination.”
Figure 6:15-1: Visible Dye Penetrant and Developer Applied to a Casting

Figure 6:15-2: Gusset Plate With Fluorescent Penetrant
SECTION 15.2 APPLICATIONS AND LIMITATIONS

Liquid penetrant tests can be conducted on a wide variety of nonporous materials, including those that are metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive. This method is highly sensitive to small surface discontinuities and produces indications directly on the surface of the component, providing a visual representation of the flaw.

The penetrant materials typically come in aerosol form, making them portable and well-adapted to field use. This also allows large areas of a component to be tested rapidly, even if the component has a complex geometric shape. Powder penetrant materials are also available, but are typically cumbersome to use in the field.

Penetrant materials and the associated equipment are relatively inexpensive, especially when compared to most other nondestructive testing methods.

This method only works on nonporous materials. Also, surface finish and roughness can affect the sensitivity of the test.

It can only detect discontinuities which are open to the surface. Discontinuities filled with contaminants, paint, rust, oxidation, or corrosion products may not be detected. Therefore, pre-cleaning is critical. The process also requires multiple steps: cleaning, applying the dye/fluorescent, cleaning off the dye/fluorescent, applying the developer, and cleaning off the developer after the test is completed. This effort requires the safe handling of chemicals and the proper disposal of saturated cleaning rags and empty aerosol cans.

The test sensitivity is lowered at reduced temperatures since crack widths are typically reduced and the test medium is less fluid.
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Magnetic particle testing is used for testing ferromagnetic materials such as steel, wrought iron, and cast iron. Magnetic particle testing is used to confirm suspected cracks or test suspect details. Magnetic particle testing is highly sensitive in detecting tight surface cracks and other small discontinuities. Cracks, lack of fusion, weld-related surface discontinuities, and base metal discontinuities are easily detected.

The magnetic particle method utilizes the principle that magnetic lines of force, when present in a ferromagnetic material, will be distorted by a change in material continuity, such as a sharp dimensional change or a discontinuity. If the discontinuity is open to, or close to, the surface of a magnetized material, flux lines will be distorted at the surface causing a condition termed flux leakage. When fine magnetic particles are distributed over the area of the discontinuity when the material is magnetized, they will be held in place and the accumulation of particles will be visible.

In magnetic particle testing, one must apply a magnetic field of sufficient strength and predetermined direction to cause flux leakage if discontinuities are present. The inspector detects these leaks by sprinkling the test area with iron filings, blowing away the excess, and observing areas where the filings have accumulated. Accumulations indicate a surface, or possibly, a subsurface discontinuity.

Magnetic particle test methods and implementation procedures are described as follows:

- In the dry method, the iron filing powder used as an indicating medium is dry. Commercial powders are available in various colors including red, black, grey, or yellow. The color should be selected to maximize the contrast with the material to be tested. Figure 6:16-1 shows a sample of test powder colors. Dry, fluorescent particles are also available for use with a black light. Dry particles are finely divided, ferromagnetic material with high permeability and low retentivity. The powder consists of a mixture of particle sizes, smaller ones being attracted by weak leakage fields, and larger ones for detecting larger discontinuities.
If the test powders or particles are suspended in oil or water, the method is considered wet. Wet suspensions are also available in various colors and fluorescent. They can be sprayed onto the part, or the part can be bathed in a suspension. Wet fluorescent particles provide maximum sensitivity if used with the proper current, lighting, and surface preparation. Wet particles are mixed with the suspension in predetermined concentrations and particle sizes. The concentration will affect the test sensitivity. Light concentrations will produce faint indications, and heavy concentrations may provide too much coverage. They are generally smaller in size and lower in permeability than dry particles.

The term continuous procedure is used if a magnetizing force is applied prior to the application of the particles, and terminated only after excess powder has been blown away.

The term residual procedure is used when the particles are applied after the part has been magnetized, and the magnetizing current terminated.
A portable unit is used for the field testing of bridges. These units include a small, portable prod or yoke units with alternating current (AC) or half-wave direct current (HWDC) capability. Portable prod equipment is commonly available in amperages up to 1,500 amps. However, it can also be powered from a 115-volt, single-phase, alternating current. Direct current (DC) prods may cause arc strikes and, therefore, and should never be used on fracture critical members.

Yokes are lightweight portable units easily carried to the job site. On some yokes the legs are fixed at a set distance. On others, the legs are adjustable for various pole spacings. Yokes operate with 115-volt AC. Refer to Figure 6:16-2 for a view of a portable field kit.


Figure 6:16-2: Magnetic Particle Inspection Kit
SECTION 16.2  APPLICATIONS AND LIMITATIONS

Magnetic particle testing is a sensitive means of locating small and shallow surface cracks and has the ability to locate near-surface discontinuities with DC. Cracks filled with foreign material can be detected and no elaborate cleaning is necessary. This test is effective on painted surfaces.

This magnetic particle method is reasonably fast and inexpensive, and the equipment is very portable. There is also little or no limitation due to size or shape of the part being inspected. Refer to Figure 6:16-3 for a view of a magnetic particle test being performed in the field. Refer to Figure 6:16-4 for a view of a crack that was identified using magnetic particle testing.

Figure 6:16-3: Magnetic Particle Testing on a Built-Up Plate Bridge Girder Butt Weld
Figure 6:16-4: Crack Identified by Magnetic Particle Testing

This test will work only on ferromagnetic material and the magnetic field must be in a direction perpendicular to the principal plane of the discontinuity for best detection. Magnetic particle testing will not disclose fine porosity. The deeper the discontinuity lies below the test surface, the larger the discontinuity must be to provide a readable indication.

Electricity is required on-site, and must be alternating current for Fracture Critical members. DC prods should not be used on Fracture Critical members. Test surfaces should be clean and paint removed for highest sensitivity. Also, the residual magnetism may need to be removed. Experienced and knowledgeable operators are required.
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CHAPTER 17  MONITORING SYSTEMS

SECTION 17.1  INTRODUCTION

Monitoring systems provide continuous data over an indefinite time interval since the monitoring devices are typically mounted to the structure, connected to a data collection device, and left by the inspector to monitor the structure. These systems can monitor a specific component or section of the structure, or they can be designed to monitor the entire structure. The scope is dependent on the desired data, the potential problem areas of the structural components, and/or the potential areas of movement.

A monitoring system is generally comprised of a variety of sensors, a computer to collect data, and in the case of a remote system, a communication device, which transmits the data to the monitoring station for analysis. Figure 6:17-1 shows a view of a remote system computer and communication device.

![Figure 6:17-1: Remote Field Computer, Clinometers, and RF Link Mounted in an Enclosure](image)

Sensor types include strain gauges, clinometers or tilt meters, accelerometers, and thermocouples. The term strain gauge typically covers a wide range of devices that are used, as their name implies, to measure the strains of structural members under load. Clinometers measure the inclination or tilt of a bridge component. Accelerometers measure bridge dynamics under conditions such as high winds, seismic activity, and vehicular traffic. Thermocouples measure the temperature of a bridge or its environment.
Strain gauges are the most common sensor in use today. A variety of strain gauges are available, and their selection should be made based on the location of their use, as well as the type of data and the amount of data to be collected. A strain gauge will have an established initial set length, the gauge length, which is used as a datum. The gauge will electronically measure any elongation. The elongation divided by the gauge length yields the strain at that point. This calculation is typically performed automatically by the data acquisition system. Strain gauges can also be used to measure rotational strain. Groups of gauges are usually installed in patterns determined by the type of data desired. Strain gauges are typically small and flat and do not interfere with the use of the bridge. The strain gauges are connected to a data acquisition system which records the strain data. Under real-time loading situations, the acquisition system can automatically collect data at a given time interval (e.g., every 10 minutes) to record a strain-time history.

Strain gauges are often installed at carefully selected locations on a bridge to measure strains under live load conditions. These strains may be due to traffic, wind, temperature, or applied test loads. This strain data can be evaluated directly, or converted to stresses that can be compared to calculated design stresses. Strain data allows the real performance of a structure to be compared to the theoretical design, and can provide data for an analytical model to more accurately predict actual performance. Strain gauges are also often employed to study the performance of a local area or detail for which theoretical analysis may be difficult.

In field situations, strain gauges may also be used as monitoring systems at locations of great concern, where movement or changes in stresses may be present. Figures 6:17-2 and 6:17-3 show strain gauges attached to steel bridge components. This work may be required to verify the safety in areas of uncertain stability or strength. In a system of enough sophistication, movement beyond a certain range may cause alarms to sound at the structure or at an off-site monitoring station. Therefore, strain gauges may be used at locations where it is difficult or prohibitively expensive to replace an existing structure of uncertain strength, while still allowing safe use of the structure.
Figure 6:17-2: Strain Gauges Attached to the Steel Track Casting of a Movable Bridge

Figure 6:17-3: Strain Gauges Attached to the Tie Girders of a Tied Arch Bridge
SECTION 17.2 APPLICATIONS AND LIMITATIONS

Monitoring systems have many applications in the inspection of bridge components. The sensors are very versatile and can be applied to many materials. They typically are small and can be attached in tight fitting areas. Many have a high level of accuracy and can be applied in both static and dynamic situations. Once installed, the sensors can provide data for an indefinite period of time. The ability to continuously monitor structures or specific components allows the owner to record and clearly observe the performance and detect deterioration.

Monitoring systems do have limitations. The sensors, although typically inexpensive, are often one-time use devices. Once mounted to a particular structure, they cannot be removed and reused in another application. The sensors typically require a high level of expertise to install. The data collection and transmission devices can be expensive and require specialized individuals to gather and process the data. The data must also be analyzed and manipulated to provide useable information.

Figure 6:17-4: Strain Gauge on a Girder Flange
Figure 6:17-5: Strain Gauge Close-Up
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CHAPTER 18 UNKNOWN FOUNDATIONS

SECTION 18.1 INTRODUCTION

A large number of older bridges do not have any design or as-built plans on file to document the type, depth, geometry, or materials incorporated into their foundations. Bridges with unknown foundations potentially pose a scour safety problem. Since the undermining of bridge foundations poses a risk to the public safety, it is crucial to evaluate all bridges over or near water and determine their susceptibility to scour. Unknown foundations are also a concern when a bridge is considered for improvements.

The evaluation of unknown foundations can be conducted either by conventional methods, such as physically disruptive excavation, coring, or boring methods, or less invasive nondestructive testing (NDT) methods. Conventional methods are typically considered to be expensive, destructive, and limited in their application. Research emphasis has recently been placed on NDT methods that can inexpensively and reliably determine the foundation properties.

It is important to find the following:

- **Foundation Depth** – What is the bottom elevation of the footing, piles, or combined system?
- **Foundation Type** – Are there shallow footings, deep foundations such as piles or shafts, or a combined system?
- **Foundation Geometry** – What are the dimensions and locations of buried substructure units?
- **Foundation Materials** – Is the foundation steel, timber, concrete, masonry, or a combination?
- **Foundation Integrity** – What is the condition of the foundation?

The foundation depth and type are considered to be the most critical pieces of information in a scour evaluation. The foundation geometry, materials, and integrity are frequently desired when improvements are being considered.

In determining which NDT methods might be useful, the ability of the method to detect and to delineate the foundation components from the surrounding environment is often the deciding factor. The subsurface environment typically consists of a mixture of air, water, riprap materials, soil, and/or rock. Thus, the method needs to consider the wide range of substructure, geological, and hydrological conditions at a particular structure site.

The NDT methods used for unknown foundation investigation can be categorized into either surface methods or borehole methods. Surface methods are generally less invasive since they do not require soil disruption. Although the following list provides a brief sample of applicable methods, the inspector should be aware that other methods are also currently being researched and implemented.
Surface methods include the following:

- **Sonic Echo/Impulse Response Test**: The source and receiver are placed on the top and/or sides of the exposed pile or column. This test determines the depth of the pile or column using the identified echo time(s) for sonic echo tests, or resonant peaks for impulse response tests.

- **Bending Wave Test**: Two horizontal receivers are mounted a few feet apart on one side of an exposed pile, and then the pile is impacted horizontally on the opposite side a few feet above the topmost receiver. This method is based on the dispersion characteristics and echoes of bending waves traveling along very slender members such as piles. This method locates the bottom of the piles.

- **Ultraseismic Test**: An exposed substructure is impacted with an impulse hammer to generate and record the travel of compression or flexural waves down and up the substructure at multiple receiver locations. This test is used to evaluate the integrity and determine the length of shallow and deep foundations.

- **Spectral Analysis of Surface Waves Test**: This test involves determining the variation of surface wave velocity verses depth in layered systems. The bottom depths of exposed substructures or footings are indicated by slower velocities of surface wave travel in underlying soils.

- **Ground-Penetrating Radar**: This method uses a radio frequency signal that is transmitted into the subsurface and records the reflection echoes from the concrete/soil interface to locate the thickness and depth of a foundation.

Borehole methods include the following:

- **Parallel Seismic Test**: An exposed foundation substructure is impacted either vertically or horizontally with an impulse hammer to generate compression or flexural waves that travel down the foundation and are reflected by the surrounding soil. The reflected compression wave arrival is tracked at regular intervals by either a hydrophone receiver or geophone receiver to determine the depth of the foundation.

- **Borehole Radar Test**: A transmitter/receiver radar antenna is used to measure the reflection of radar echoes from the side of the substructure foundation. This locates the foundation bottom.

- **Induction Field**: A magnetic field is induced around the steel of the pile or reinforced concrete foundation to measure the depth of the foundation. The field strength will decrease significantly below the bottoms of the foundation.
Figure 6:18-1: Bridge With Unknown Foundations
Applications vary depending on the chosen NDT method. Refer to Figure 6:18-2 for a comparison of the NDT applications.

<table>
<thead>
<tr>
<th>Method</th>
<th>Applications</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sonic Echo/Impulse Response</td>
<td>Most useful for columnar structures. Best penetration attained in loose soils. Good for determining thickness and geometry of foundations.</td>
<td>Low-cost equipment and inexpensive testing. Data interpretation may be able to be automated. Theoretical modeling should be used to plan field tests.</td>
</tr>
<tr>
<td>Bending Wave</td>
<td>Most useful for determining the bottom of a purely columnar substructure. Best penetration attained in loose soils.</td>
<td>Low-cost equipment and inexpensive testing. Theoretical modeling should be used to plan field tests. Horizontal impacts are easy to apply.</td>
</tr>
<tr>
<td>Ultraseismic</td>
<td>Good for determining thickness and geometry of the foundation. Best penetration attained in loose soils.</td>
<td>Low-cost equipment and inexpensive testing. Can identify the bottom depth of foundation inexpensively for a large class of bridges. Combines compressional and flexural wave reflection tests for complex substructures.</td>
</tr>
<tr>
<td>Spectral Analysis of Surface Wave</td>
<td>Good for determining thickness and geometry of the foundation.</td>
<td>Low-cost equipment and inexpensive testing. Shows variation of bridge material and subsurface velocities verses depth and thickness of accessible elements. Must have access to the top of the footing.</td>
</tr>
<tr>
<td>Ground-Penetrating Radar</td>
<td>Can indicate geometry of inaccessible elements and bedrock depths.</td>
<td>Low testing costs. Fast testing times.</td>
</tr>
<tr>
<td>Parallel Seismic</td>
<td>Accurate for determining foundation bottom depths for a large range of structures. Under certain conditions, can indicate foundation orientation.</td>
<td>Low-cost equipment and inexpensive testing. Can detect foundation depths for largest class of bridges and subsurface conditions. Can be used to find the depth of complex foundations.</td>
</tr>
<tr>
<td>Borehole Radar</td>
<td>Good for determining foundation parameters. Sensitive to detecting steel or steel reinforced members.</td>
<td>Relatively easy to identify reflections from the foundation; however, imaging requires careful processing.</td>
</tr>
<tr>
<td>Induction Field</td>
<td>Highly sensitive to detecting steel or steel reinforced members that are electrically connected to the surface.</td>
<td>Low-cost equipment. Easy to test. Compliments Parallel Seismic in determination of pile type.</td>
</tr>
</tbody>
</table>

*Figure 6:18-2: Comparison of NDT Methods*
Refer to Figure 6:18-3 for a comparison of the limitations of the methods discussed.

<table>
<thead>
<tr>
<th>Method</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface</strong></td>
<td></td>
</tr>
<tr>
<td>Bending Wave</td>
<td>Response complicated by various bridge superstructure elements. Response complicated by stiff soils that may show only depth to the stiff soil layer.</td>
</tr>
<tr>
<td>Ultraseismic</td>
<td>Cannot image piles below the cap. Difficult to obtain foundation bottom reflections in stiff soils.</td>
</tr>
<tr>
<td>Spectral Analysis of Surface Wave</td>
<td>Cannot image piles below the cap. Use restricted to bridges with long, flat access for testing.</td>
</tr>
<tr>
<td>Ground Penetrating Radar</td>
<td>High-cost equipment. Signal quality is highly controlled by environmental factors. Adjacent substructure reflections complicate data analysis.</td>
</tr>
<tr>
<td><strong>Borehole</strong></td>
<td></td>
</tr>
<tr>
<td>Parallel Seismic</td>
<td>Difficult to transmit large amount of seismic energy from pile caps to smaller (area) piles.</td>
</tr>
<tr>
<td>Borehole Radar</td>
<td>Radar response is highly site-dependent (very limited response in conductive, clayey, salt water-saturated soils).</td>
</tr>
<tr>
<td>Induction Field</td>
<td>The reinforcement in the columns is required to be electrically connected to the piles underneath the footing. Only applicable to steel or reinforced structure. Requires a cased boring.</td>
</tr>
</tbody>
</table>

Figure 6:18-3: Comparison of Limitations
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CHAPTER 19  HYDROGRAPHIC SURVEY

SECTION 19.1  INTRODUCTION

Hydrographic survey is known as underwater profiling, bottom profiling, or water-depth sounding. This process is used to obtain underwater surface elevation data for evaluating the channel bottom surrounding a structure and the waterway in general. Similar to a topographic land survey, a hydrographic survey consists of a series of elevation measurements over a particular area in a waterway. Refer to Chapter 7 in Part 4 for discussions on scour inspections with hydrographic surveys. The level of accuracy in hydrographic surveying varies greatly based on the equipment and methods used. The United States (U.S.) Army Corps of Engineers has specifications and general requirements for hydrographic surveying. There is a process to become a certified hydrographic surveyor. However, scour inspections typically require the use of simplified methods performed by an individual familiar with the applications and limitations of water depth measurements near a bridge.

The inspector determines channel bottom elevations, and then compares the values to previous data. It is necessary to measure the water level at the time of the inspection against a benchmark or known elevation on the substructure. This location of the known elevation should be documented in the Central Database and should be permanently marked on the structure.
SECTION 19.2  APPLICATIONS AND LIMITATIONS

Hydrographic surveys evaluate channel bottom movement. The methods include: lead line, sounding pole, fathometer, multi-beam sonar, and other complex systems.

A lead line is a standard surveyor’s tape with a weight attached to the end. The inspector lowers the lead line until the weight comes to rest on the channel bottom. The inspector then pulls the line taut and records the reading from the channel bottom to the waterline or top of the deck. An inspector working from the top of the deck most often obtains lead line readings.

Lead lines are limited by the softness of the channel bottom. The swiftness of the current can introduce horizontal drift into the line or cause a lightly weighted tape to drift downstream. It takes a significant amount of time to lower and raise the tape for each new measurement position. This method is also prone to inaccuracies based on the experience of the inspector.

Figure 6:19-1: Inspector Using a Sounding/Range Pole
A sounding pole is an extendable, graduated rod. An inspector in the water or in a boat places the pole vertically on the channel bottom and records the measurement at the waterline. The inspector then records the distance from the waterline elevation to a known elevation on the structure. Refer to Figure 6:19-1 for a view of an inspector using a sounding pole.

Sounding poles are limited by the softness of the channel bottom. It can be dangerous and difficult to use this method in swift currents or where the bottom is uneven.

The most commonly used electronic sounding device is a 200 kHz black-and-white fathometer, most often referenced as fish finders. This device uses a transducer just below the waterline and repeatedly transmits sound energy through the water column. The time interval between the transmission of the sound pulse and the returning echo from the channel bottom is used to automatically calculate a depth measurement that is recorded onto the device. Figure 6:19-2 shows an example of a black-and-white fathometer reading.

A color fathometer works in the same fashion as a black-and-white fathometer, but it transmits at a lower frequency, usually 25 kHz, and will penetrate up to 10 feet into the channel bottom. The display will indicate materials of different densities as different colors. This can be useful in determining if any silt or timber debris infilling of previous scour holes has occurred.

Fathometers are limited by their ability to detect refilled scour holes. They are subject to false readings from heavy drift or heavy turbulence. Care must be taken to avoid a distorted scale on the readout due to varying boat speed. They provide only limited information about the sub-bottom.
Continuous seismic-reflection profiling (CSP) is a more complex system utilizing low-frequency sonar to transmit seismic energy from a transducer through the water column and into the channel bottom. It can be either fixed-frequency or swept-frequency. Fixed–frequency systems typically use a 3.5-, 7-, or 14-kHz signal, whereas the swept-frequency systems typically use a signal that sweeps from 2- to 16-kHz. The swept-frequency CSP system can be used in water as shallow as one-foot deep, can penetrate up to 200 feet in some silts and clays, and may be able to detect layers as thin as three inches. Exposed pier footings, scour depression geometry, and scour depression infill thickness can often be detected with this device.

The data collected by a CSP system can be affected by side echoes and by multiple reflections. Side echoes from the shoreline or piers will interfere with the true echo from the channel bottom. Water-bottom multiple reflections occur when the echo is bounced back and forth between the channel bottom and the surface, creating multiple readings. These are most evident when the water-bottom reflection coefficient is large, such as in a river with a hard bottom.

Ground-penetrating radar systems radiate short pulses of electromagnetic energy from a broad-bandwidth antenna. These systems typically use a signal of 80-, 100-, or 300-MHz. Scour depression geometry, scour depression infill thickness, and riverbed deposition can often be detected using this technique. Penetration up to 40 feet into resistive granular material can be attained and layers as thin as two feet can be detected. However, ground-penetrating radar systems will not work in soils or waters that are highly conductive due to chlorides or pollution.

Ground-penetrating radar is typically only useful in fresh water less than 20-feet deep with granular bottom and sub-bottom sediments.

Multi-beam sonar utilizes high-frequency sound waves to generate pictures of underwater elements. An ultrasonic transducer placed below water emits sound waves that travel through the water towards an object. These are reflected back to the transducer for processing by the computer software. Multi-beam sonar utilizes numerous sound beams side by side. The beams are stitched together by the software to create a continuous image, producing near-photo-quality images. The units operate at very high frequency, which provides good detail and resolution.

Multi-beam sonar provides highly detailed images of bridge substructures and the adjacent channel bottom. The resulting data can be used to evaluate channel scour and locate major substructure damage. The multi-beam equipment is expensive and requires specially trained personnel. It is difficult to use in high-velocity flow conditions.