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BRIDGE REHABILITATION

The State contains approximately 18 000 bridges on its public roads and streets. Over 5500 of these are on the State highway system. These bridges are designed and constructed to provide an adequate margin of safety and service life for the traveling public through the application of stringent design criteria and construction specifications. Nevertheless, all structural elements deteriorate over time, sometimes prematurely, and they will eventually present a hazard to the bridge users. Periodically, these bridges require repair and/or rehabilitation work which exceeds the scope of normal maintenance. In these cases, the bridge work is programmed as a capital improvement project. For the purpose of this Chapter, rehabilitation refers to the following:

1. restoration to its former state and/or capacity;
2. improving serviceability (structural and/or traffic);
3. strengthening; and/or
4. widening.

This Chapter describes procedures and design criteria for a bridge rehabilitation project. The Chapter addresses the following:

1. overall activities which may lead to a bridge rehabilitation project;
2. condition surveys and analyses;
3. rehabilitation techniques; and
4. widening.

72-1.0 BRIDGE INSPECTION/BRIDGE MANAGEMENT

72-1.01 National Bridge Inspection Standards (NBIS)

The National Bridge Inspection Standards (NBIS), a nationwide inspection and inventory program, is intended to detect structural problems to minimize the probability of structural failure. The Federal Highway Administration has promulgated regulations to establish the applicable criteria which must be met.

The following presents a brief discussion on the operational requirements of the NBIS:

1. Frequency of Inspections. Each bridge must be inspected at regular intervals not to exceed two years. Examples of structures requiring more frequent inspections include the following:

    a. new structure types;
    b. those with details without known performance history;
    c. those with potential foundation or scour problems;
    c. nonredundant structures; and
    d. bridges with structural problems.

    The NBIS, however, allows the State to inspect certain bridges at greater than a two-year interval, if properly justified by the State and approved by the FHWA.

2. Qualifications of Personnel. The key element of the State's bridge inspection program is the qualifications of its inspection personnel. This includes both the individual in charge of the overall organization and the field inspection personnel. The NBIS Federal Regulation lists the minimum qualifications for all bridge inspection personnel.

3. Inspection Procedures and Reports. The State must have a systematic strategy for conducting field inspections and reporting their findings. It must be clear to the inspection team which structural elements to investigate and what to look for. The bridge inspection report should accurately and clearly record all findings and should include photographs of the overall structure and of any significant defects.

4. Records. The State must have a systematic means of entering, storing and retrieving all bridge inspection data. The records must meet the requirements of the NBIS and the Structure Inventory and Appraisal (SI&A) data, They should contain a full history of the structure including the following:

    a. all inspections;
    b. recommendations for maintenance or repair work;
    c. any maintenance or repair work performed;
    d. calculations; and
    e. structure ratings.

5. Ratings. Each bridge must be rated according to its load-carrying capacity. This includes both the Operating and Inventory Ratings. See Section 72-1.02 for definitions. The ratings provide an indication of the bridge's capacity to safely resist the loads it is likely to be subjected to. This information assists in the determination of necessary posting, the issuance of special overload permits, and the scheduling for rehabilitation or replacement.

72-1.02 Definitions

The following definitions apply to the NBIS and its implementation.

1. Damage Inspection. This is an unscheduled inspection to assess structural damage resulting from environmental or man-inflicted causes. The scope of inspection should be sufficient to determine the need for emergency load restrictions or closure of the bridge to traffic and to assess the level of effort necessary to effect a repair.

2. In-Depth Inspection. This is a physical inspection of the bridge above and/or below water level (where applicable) to detect any deficiency not readily detectable using Routine Inspection procedures.

3. Interim Inspection. This is an inspection scheduled at the discretion of the individual in responsible charge of bridge inspection activities. An Interim Inspection is typically used to monitor a particular known or suspected deficiency, e.g., foundation settlement or scour, member conditions, the public's use of a load-posted bridge.

4. Inventory Inspection. This is the initial inspection of a bridge intended to determine the SI&A data and all other relevant information required by the Department and to collect basic structural data, e.g., identification of structure type, fracture critical members.

5. Inventory Rating. This is the load level which can be safely resisted by a structure for an indefinite period of time.

6. Operating Rating. This is the maximum permissible load level to which a structure may be subjected.

7. Routine Inspection. This is a regularly scheduled, intermediate-level inspection consisting of observations and/or measurements sufficient to determine the physical and functional conditions of a bridge; to identify any developing problems and/or changes from Inventory or previously recorded conditions; and to ensure that the bridge continues to satisfy present service requirements.

8. National Bridge Inspection Standards (NBIS). These consist of federal regulations establishing requirements for inspection procedures, frequency of inspections, qualifications of personnel, inspection reports, and preparation and maintenance of the State's bridge inventory. The NBIS apply to all structures defined as bridges located on all public roads.

9. National Bridge Inventory (NBI). This consists of the aggregation of structure inventory and appraisal data collected to fulfill the requirements of the National Bridge Inspection

Standards which require that the State prepares and maintains an inventory of all bridges subject to the NBIS.

10. National Bridge Inventory (NBI) Record. This consists of data which have been coded according to the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* for each structure carrying highway traffic or each inventory route which passes beneath a structure. These data are stored within the Program Development Division and are also furnished to the FHWA.

11. Structure Inventory and Appraisal (SI&A) Sheet. This consists of the graphic representation of the data recorded and stored for each NBI record in accordance with the *Guide*.

12. Sufficiency Rating. A numerical value from 0 to 100% which indicates a bridge's overall sufficiency to remain in service. The Rating is calculated from the SI&A data and reflects the factors as follows:

    a. structural adequacy and safety;
    b. serviceability and functional obsolescence;
    c. essentiality for public use; and
    d. any special considerations.

72-1.03 INDOT Bridge Inspection Program

The Program Development Division's Bridge Inspection/Inventory Unit is responsible for collecting, maintaining, and reporting bridge inspection information and also for ensuring that the Indiana Bridge Inspection Program is in compliance with the requirements of the NBIS.

72-1.04 Bridge Rehabilitation Project

As determined through the INDOT Bridge Inspection Program, the need for bridge rehabilitation may be based on any number of deficiencies. This may include the following:

1. deterioration of structural elements;
2. insufficient load-carrying capacity;
3. inadequate seismic resistance;
4. insufficient traffic-carrying capacity;
5. safety hazard, e.g., substandard bridge railing, substandard guardrail-to-bridge-railing transition; and/or
6. geometric deficiency (e.g., narrow bridge width, inadequate horizontal alignment).

The Design Division's Bridge Rehabilitation Unit is responsible for rehabilitation projects included in the Department's capital improvement program.

72-1.05 INDOT Bridge Management System (IBMS)

The INDOT Bridge Management System (IBMS) will be used as a planning tool to identify proposed projects with a recommended action, cost, priority ranking and optimized listing based on a set budget. Programming of bridge projects is based on recommended actions of the IBMS, district review and recommendations, and integration with other management systems. See Section 4-2.02 for more information on IBMS.

72-2.0 CONDITION SURVEYS AND TESTS

To identify the appropriate scope of bridge rehabilitation work, the designer should select and perform the proper array of condition surveys, tests, and analyses, as described below.

72-2.01 Selection of Surveys/Tests

The decisions on the type and extent of bridge rehabilitation are based on information acquired from condition surveys and tests. The selection of these condition surveys and tests for a proposed project is based on a case-by-case assessment of the specific bridge site. The structural factors to be considered are as follows:

1. age;
2. estimated remaining life (i.e., before bridge replacement is necessary);
3. size;
4. historic significance; and
5. potential investment in bridge rehabilitation.

The information normally available that may be requested if deemed pertinent is as follows:

1. original design plans and previous rehabilitation plans;
2. as-built plans;
3. shop drawings;
4. pile driving records;
5. geotechnical report;
6. previous surveys;
7. accident records;

8. flood and scour data, if applicable;
9. traffic data;
10. roadway functional classification;
11. bridge inspection reports;
12. structural ratings (sufficiency, operating, inventory); and
13. maintenance work performed to date.

The condition surveys and tests to be selected will be those are appropriate for the bridge site conditions based on an assessment of the structural factors and the available information

72-2.01(01) Materials and Tests Division's Involvement

The Materials and Tests Division may be consulted when the designer believes such consultation is warranted. The Materials and Tests Division can offer support in the following areas:

1. geotechnical evaluation/foundation recommendations;
2. pavement design/analysis;
3. subgrade design;
4. concrete corings/strength and chloride determination;
5. slope stability analysis and recommendations;
6. geologic information such as Karst or mine subsidence;
7. foundation geometry and type, if unknown;
8. existing loading conditions; and
9. cohesiveness of existing embankment.

Where little or no bridge widening is planned, the existing substructure condition, supplemented with the pile driving records, may be used to determine foundation types. Typically, foundations will be widened with the same system as the original construction. Spread footings will be designed next to existing spread footings, H piles will be driven to anticipated rock, and 356-mm shell piles will be used where friction piles exist. Friction piles of 355 kN may be used where existing timber piles were driven. The time and cost associated with geotechnical investigations do not normally justify their use when only one or two pile spaces will be driven outside the existing foundations. Where more extensive widening is required, foundation settlement is noted, additional pile capacity is sought, the existing foundation type cannot be determined, or any other unusual situation occurs, a geotechnical investigation will be requested.

Where more than 60 m of total pavement replacement beyond the RCBA is anticipated or where added lanes are included, a geotechnical investigation and pavement design will be requested. Where such pavement length is 60 m or less, the existing pavement section may be reproduced and the Geotechnical Section may provide the subgrade treatment requirements.

If it is determined after the preliminary field check that further information on the concrete strength or chloride content is needed, testing may be requested from the Materials and Tests Division. The designer and the testing engineer should work together to determine the number and location of samples needed. Additional traffic maintenance will be required for cores taken in the traveled way.

If any form of soil instability is observed on the preliminary field check, the Materials and Tests Division will be notified and given the opportunity to perform the necessary testing and analysis to make recommendations for remediation.

Many older bridge embankments were constructed with steeper sideslopes than would be used today. Narrow widening of these embankments may be necessary to meet modern roadside safety criteria. Geotechnical slope stability should also be considered when an existing slope is widened, especially when the widening is relatively narrow. Narrow widenings should include a benching detail. Figure 72-2A, Sideslope Acceptability, indicates slopes that are geotechnically acceptable based on slope inclination and Plastic Index of the existing embankment material. Any final slope-stability recommendations must be made by the Materials and Test Division.

If a new retaining wall is required, the Materials and Tests Division should be contacted to provide the appropriate soil design parameters. Also, if fill is added to an embankment where the designer is aware of underlying peat deposits, the Materials and Tests Division should be contacted for recommendations.

If the Materials and Tests Division is involved in a rehabilitation project, the schedule should be re-evaluated to account for the time required for the investigation.

For additional information on geotechnical investigations, see Chapter Eighteen and Section 3-1.04.

72-2.01(02) Field Surveys

If a rehabilitation project involves deck replacement, superstructure replacement, or widening of the substructures, a field survey will be made. A typical survey will involve a structure profile extending approximately 150 m from each end of the bridge and a check of features such as cap and bridge seat elevations.

The purpose of this survey is to verify elevations so that datum corrections can be made in the plans and do not have to be determined in the field during construction. The Bridge Rehabilitation Unit will approve the extent of any survey before field work begins.

Vertical and horizontal railroad clearances must be measured and included in the bridge inspection report if the project involves a railroad.

72-2.02 Bridge Decks

For the purpose of this Chapter, decks include the structural continuum directly supporting the riding surface, deck joints and their immediate supports, curbs, barriers, reinforced concrete bridge approaches, and utility hardware. The bridge deck and its appurtenances provide the services as follows:

1. support and transmittal of wheel loads to the primary structural components;
2. protection for the structural components beneath the deck;
3. lateral bracing for girders;
4. a smooth riding surface;
5. drainage of surface runoff; and
6. safe passageway for vehicular and bicycle/pedestrian traffic, e.g., skid-resistant surface, bridge railings, guardrail-to-bridge-railing transitions.

Any deterioration in these services warrants investigation and possible remedial action. The most common cause of bridge deck deterioration is the intrusion of chloride ions from roadway deicing salts into the concrete. The chloride causes formation of corrosive cells on the steel reinforcement, and the corrosion product (rust) induces stresses in the concrete resulting in cracking, delamination and spalling. Chloride ion (salt) penetration is a time-dependent phenomenon. There is no known way to prevent penetration, but it can be decelerated such that the service life of the deck is not less than that of the structure. Salt-penetration is, however, not the only cause of bridge deck deterioration. Other significant problems include the following:

1. Freeze-Thaw. This results from inadequate air content of the concrete. Freezing of the free water in the concrete causes random, alligator-type cracking of the concrete and then complete disintegration. There is no known remedy other than replacement.

2. Impact Loading. This results from vehicular kinetic energy released by vertical discontinuities in the riding surface, such as surface roughness, delamination, and inadequately set or damaged deck joints. Remedial actions are surface grinding, overlay or replacement of deck concrete, and rebuilding deck joints.

3. Abrasion. This normally results from metallic objects, such as chains or studs attached to tires. Remedial actions are surface grinding and/or overlay.

The objective of the condition surveys and tests is to quantify the extent of deterioration based on INDOT criteria to determine the appropriate remedial action. Methods are discussed in the following Sections to establish the level and extent of deterioration after the deterioration is visually detected. The first test to be performed is sounding. This may be followed by half-cell measurement. If permeability is measured, less than 2000 coulombs indicates that the concrete is capable of resisting intrusion of chlorides. Then, either by coring or by chemical analysis of pulverized samples, the chloride concentration profile is established. Other methods, such as thermographic (infrared) testing, are also becoming established as reliable tools for mapping delaminations.

72-2.02(01) Visual Inspection

1. <u>Description</u>. A visual inspection of the bridge deck should establish the following:

   a. the approximate extent of cracking, delamination, spalling and joint opening;
   b. evidence of any corrosion;
   c. evidence of efflorescence, discoloration, or wetness at the bottom of deck;
   d. deformation in the riding surface and/or ponding of water;
   e. operation of deck joints;
   f. functionality of deck drainage system;
   g. bridge railings and guardrail-to-bridge-railing transitions meeting current Department standards.
   h. deterioration and loss in wood decks; and
   i. geometric compatibility with design criteria.

2. <u>Purpose</u>. The visual inspection of the bridge deck will achieve the following:

   a. By establishing the approximate extent of cracking, corrosion, delamination, and spalling (and by having evidence of other deterioration), one can determine if a more extensive inspection is warranted.

   b. The inspector will identify substandard roadside safety appurtenances.

3. <u>When to Use</u>. Visual inspection should be used for each potential deck rehabilitation project.

4. <u>Analysis of Data</u>. Based on the extent of the bridge deck delamination, the following will apply:

   a. Five percent delamination of surface area is a rough guide for triggering remedial action.

b. Thirty to 40% delamination is a rough guide for triggering bridge deck replacement.

In addition, the following should be considered.

a. traffic control;
b. timing of repair;
c. age of structure;
d. AADT;
e. slab depth;
f. structure type; and
g. hazard potential to other traffic (vehicular, cyclist, pedestrian, etc.).

72-2.02(02) Sounding

1. Description: Sounding establishes the presence of delamination, based on audible observation by chain drag, hammer, or electromechanical sounding device. It is based on the observation that delaminated concrete responds with a hollow sound when struck by a metal object. See ASTM D 4580.

2. Purpose: Its purpose is to determine the location and area of delamination.

3. When to Use: Sounding should be used on each deck rehabilitation project, except where proper traffic control cannot be provided during the test.

4. Analysis of Data: Quantities are approximate for bid purposes only and should be rounded off to the nearest 5%.

72-2.02(03) Half-Cell Method

1. Description: Copper/copper sulphate half-cell method for the measurement of electrical potential is used as an indicator of corrosive chemical activity in the concrete. See ASTM C 876.

2. Purpose: Its purpose is to determine the level of activity of corrosive cells in the bridge deck.

3. When to Use: The method should be used if non-destructive testing is warranted.

4. Analysis of Data: A potential difference of -0.35 V or greater indicates active corrosion. A potential difference of -0.20 V or less indicates a state of no corrosion. The range between -0.20 and -0.35 V is considered questionably active.

72-2.02(04) Coring

1. Description: Cores of 100- or 150-mm diameter are taken by means of a water-cooled, diamond edged rotating shell. In an older deck with a large amount of reinforcement, it is difficult to avoid cutting steel if 150-mm diameter cores are used.

2. Purpose: Its purpose is to establish strength, composition of concrete, crack depth, position of reinforcing steel, delamination, and profile of chloride content and gradient.

3. When to Use: Coring should be done if questions exist relating to the compressive strength or soundness of the concrete, or if the visual condition of the reinforcement is desired. Also, coring should be done if compression or chloride analysis tests are requested.

4. Analysis of Data. Less than 50 mm of cover is considered inadequate for corrosion protection. Less than 21 MPa compressive strength of concrete is considered inadequate. Normally, if a 100-mm diameter core of undelaminated concrete is extracted intact, the concrete quality can be assumed to be accetable. Core locations can have a significant impact on the findings.

72-2.02(05) Chloride Analysis

1. Description: This consists of a chemical analysis of pulverized samples of the bridge deck concrete extracted from either slices of cores or in-place drilling. See AASHTO T 260.

2. Purpose: Its purpose is to determine the chloride content profile from the deck surface to a depth of about 75 mm or greater.

3. When to Use: This analysis should be used if a visual inspection does not clearly indicate the corrosive potential of the deck. The analysis is relatively inexpensive once cores have been obtained.

4. Analysis of Data: A chloride content of 0.9 kg/m^3 of concrete at the level of top reinforcement is a rough threshold value for indicating a potential for corrosion occurring

in the uncoated reinforcing steel of the deck. The locations of cores can have a significant impact on the findings.

72-2.03 Superstructure

For the purpose of this chapter, the superstructure includes all structural components located above the bearings, except the deck. For a bridge without bearings, such as a rigid frame, fixed arch, etc., this includes every visible structural component, except the deck. The following briefly describes those condition surveys and tests which may be performed on the superstructure elements to determine the appropriate level of rehabilitation.

72-2.03(01) Visual Inspection

1. Description: A visual inspection of the superstructure should include an investigation of the following:

    a. surface deterioration, cracking, and spalling of concrete;
    b. major loss in concrete components;
    c. evidence of efflorescence;
    d. corrosion of reinforcing steel or prestressing strand;
    e. loss in exposed reinforcing steel or prestressing strand;
    f. corrosion of structural metal components;
    g. loss in metal components due to corrosion;
    h. cracking in metal components;
    i. excessive deformation in metal components;
    j. loosening and loss of rivets or bolts;
    k. deterioration and loss in wood components;
    l. damage due to collision by vehicles, vessels, or debris;
    m. damage due to leakage through deck joints;
    n. ponding of water on abutment seats;
    o. state and functionality of bearings; and
    p. presence of low fatigue life details.

    Structural steel members should be checked to ensure that there are no intersecting welds. There should be a gap of 4 times the web thickness with 50 mm as the absolute allowable minimum between any two weld toes. If such welds are found, it should be noted in the inspection report, and the Program Development Division's bridge inspection engineer should be notified in writing.

2. Purpose: Its purpose is to record all deterioration and signs of potential distress for comparison with earlier records and for initiating rehabilitation procedures if warranted.

3. When to Use: It should be used on each bridge rehabilitation project.

4. Analysis of Data. Analysis should be made as required.

72-2.03(02) Fracture-Critical Members

A fracture-critical member is defined as a structural metal component in tension whose failure would render the bridge dysfunctional or cause its collapse. A major portion of this determination relates to redundancy. For example, loss of a girder in a multi-girder or continuous girder structure may not be critical, while inadequate welding of a stiffener in other situations may be critical.

If the issue arises, criticality should be investigated by an experienced structural engineer.

72-2.03(03) Tests for Cracking in Metals

These tests are used to determine the appropriate remedial action, if the visual inspection revealed the existence of cracking in a steel structure, the extent and size of cracks should be established. The following are the most common test methods used in locating cracks in a steel structure, and for measuring their extent and size:

1. Dye Penetration Test. The surface of the steel is cleaned, then painted with a red dye. The dye is wiped off. If a crack is present, the dye penetrates the crack. A white developer is painted on the cleaned steel and any cracks are indicated where the red dye "bleeds" from the crack.

2. Magnetic Particle Test. The surface of the steel is cleaned and sprinkled with fine iron filings while a strong magnetic field is induced in the steel. Magnetism is not resisted by the void in the cracks; therefore, the particles form a footprint thereof.

3. Acoustic Test. Although the above two methods require no special equipment, the acoustic method needs both a transmitter and a receiver. The method works on the principle that cracks reflect acoustic waves. It can only establish the presence of cracks.

4. Radiogram. This is a highly reliable but cumbersome and expensive test because it requires a medium for producing x-rays which penetrate the cracks and mark the film located at the other side.

5. Ultrasonic Test. This consists of the use of testing devices that use high-frequency sound waves to detect cracks, discontinuities, and flaws in materials. The testing depends a great deal on the expertise of the one conducting the test to interpret the results.

All tests must be conducted by, at a minimum, a Level II ANSI approved technician. For more information, see *FHWA-RD-89-167, Fatigue Cracking of Steel Bridge Structures*; AASHTO *Guide Specifications for Fatigue Evaluation of Existing Steel Bridges*; or *FHWA-NH1-90-043, Economic Design of Fracture Critical Members,*.

72-2.03(04) Fatigue Analysis

1. Description: Fatigue is defined as a progression in the crack size caused by cyclical loading to a critical dimension at which cracking is no longer effectively resisted, thus, leading to fracture of the component. The progression is a function of the following:

    a. crack size;
    b. location of crack (i.e., structural detail);
    c. energy absorbing characteristics of metal;
    d. temperature; and
    e. frequency and level of stress range (transient stresses).

2. Purpose: Its purpose is to establish type and urgency of remedial action.

3. When to Use: This analysis should be used where cracks, found by visual inspection, are believed to be either caused by fatigue or are progression prone under transient loading. It should also be used if members are known to have a low fatigue life.

4. Analysis of Data: For the analysis, fatigue characteristics of the metal should be established. For the stress range, the *LRFD Bridge Design Specifications* provides an upper-bound criterion of 75% weight of one design truck plus impact per bridge. The actual stress range of a given bridge component may be far lower than that specified by the *Specifications*, and it may be warranted to establish it by physical means. See Section 64-4.0 for further discussion.

72-2.04 Substructures/Foundations

Substructures transfer loads to the foundations such as rock or earth. Substructures include unframed piers, bents and abutments, footings, piles, and drilled shafts. Substructures including piles and drilled shafts are referred to as deep foundations. They also include fenders and dolphins used in navigable waterways. The following briefly describes those condition surveys and tests which may be performed on these elements to determine the appropriate level of rehabilitation.

72-2.04(01) Visual Inspection

1. Description: A visual inspection of the substructure components should address the following:

   a. surface deterioration, cracking, and spalling of concrete;
   b. major loss in concrete components;
   c. distress in pedestals and bearing seats;
   d. evidence of corrosion of reinforcing steel;
   e. loss in exposed reinforcing steel;
   f. deterioration or loss in wood components;
   g. leakage through joints and cracks;
   h. dysfunctional drainage facilities;
   i. collision damage;
   j. changes in geometry such as settlement, rotation of wing walls, tilt of retaining walls, etc.;
   k. compliance with current INDOT seismic design standards;
   l. accumulation of debris;
   m. erosion of protective covers;
   n. changes in embankment and water channel;
   o. evidence of significant scour; and
   p. underwater inspection (as needed).

2. Purpose: Its purpose is to record all deterioration and signs of potential distress for comparison with earlier records and for initiating rehabilitation procedures if warranted.

3. When to Use: It should be used on each bridge rehabilitation project.

4. Analysis of Data. Analysis should be made as required.

72-2.04(02) Other Test Methods

Other test methods described in Section 72-2.02 for bridge decks may be used to determine the level and extent of deterioration of the substructure components.

72-2.04(03) Scour Analysis

A scour analysis should be included for each bridge that crosses over water. INDOT's methodology for performing this analysis is discussed in Section 32-5.0. The specific performance criteria for this analysis are discussed in Section 32-3.02(06).

Scour analysis for a consultant-designed bridge rehabilitation project should be performed by the consultant. Scour analysis for an INDOT-designed project should be performed by the Design Division's Hydraulics Unit.

Scour countermeasures may be deemed necessary based on the results of the scour analysis. Any scour countermeasures must be approved by the Hydraulics Unit's engineer supervisor.

72-2.05 Bridge Field Inspection/Inspection Report

The procedures for the field inspection and the suggested format and content of the Bridge Inspection Report are described below.

72-2.05(01) Field Inspection

After assimilation of the relevant background material, e.g., as-built plans, SI&A data, traffic data, the designer will conduct a field inspection of the bridge site. The primary objective is to conduct the visual inspections for the various structural elements as described in the condition tests and surveys in Section 72-2.0. The following guidelines apply to the field inspection:

1. Attendees. If the project is consultant-designed, personnel from both the consultant and the Design Division will attend the field inspection. Depending on the nature of the bridge rehabilitation, attendees may include the representatives as follows:

    a. Consultant (not more than two representatives, unless there are special circumstances);
    b. Design Division's Bridge Rehabilitation Unit;
    c. Design Division's Railroads Unit;
    d. District office, construction area engineer;
    e. District office, operations engineer;
    f. District office, development engineer;
    g. FHWA (if bridge is subject to oversight); and/or
    h. Local public agency (if bridge is not on the State highway system).

2. As-Built Plans. The designer should request a set of the existing plans from the Design Division's Records Unit at least three weeks before the field inspection.

3. Schedule. The Bridge Rehabilitation Unit will schedule the date of the field inspection, and will notify all attendees by telephone, e-mail, or other means. For a project not on the State highway system, the consultant must notify the attendees.

4. Equipment. The items which should be available are as follows:

   a. plans for existing structure;
   b. inspection forms filled in with all available information;
   c. camera and film;
   d. clipboard, pencils, eraser, scale, and scratch pad;
   e. tape measure;
   f. hammer, cold-chisel;
   g. chain or other sounding device;
   h. safety gear; and
   i. other equipment as may be necessary.

5. Procedure. Before the inspection, the designer should perform the following:

   a. study the existing plans, maintenance/repair history, and other items described in Section 72-2.01;
   b. review the design standard requirements for the roadway classification; and
   c. note any areas of particular concern, e.g., fatigue-critical details, guardrail, width of structure, alignment, utilities (overhead), age of structure.

   After arriving at the site, the designer should perform the following:

   a. complete the Inspection Report, noting any unusual conditions not covered under general categories;
   b. take necessary photographs showing approaches, side view, all four quadrants of the bridge, the feature being crossed, and any deficient features to be highlighted in the report; and
   c. ensure that all information is gathered as necessary to complete the Bridge Inspection Report.

72-2.05(02) Bridge Inspection Report

The Bridge Inspection Report has the purposes as follows:

1. document the findings from the field inspection, including photographs;
2. make recommendations on the proposed bridge rehabilitation improvements;
3. provide a preliminary project cost estimate;
4. identify a proposed strategy for maintenance and protection of traffic during construction;
5. serve as design approval documentation including compliance with Level One design criteria; and
6. document findings from the scour analysis, if the bridge is over water.

The format, content, and order of the Bridge Inspection Report to be used should match that shown in Figure 72-2B. Not all features described therein will pertain to each project. However, unusual features will require more in-depth coverage in the Report than described as follows.

The following general guidelines will apply to the Bridge Inspection Report.

1. Structure. Prepare a separate Bridge Inspection Report for each structure, i.e., for each Des number.

2. Page Size. Prepare the Report on 216 mm x 279 mm paper.

3. Font. Use a 12-point font size. The font may be either Times Roman or Arial.

4. Page Numbering. Number the pages consecutively through the Report, including the pages with schematics and photographs. The page number should be at the bottom of the page.

5. Page Header. Place the bridge file number and Des number at the top of each page, including those with schematics and photographs.

6. Presentation of Information. The objective of the Report is to communicate critical information on the existing bridge and proposed scope of rehabilitation. Statements should be direct, clear, and concise. The Report should be formatted as shown in Figure 72-2B.

7. Timeliness. Prepare and submit the Report as soon as practical after the field inspection, but no later than 30 days after the field inspection, unless otherwise approved by the Design Division's project coordinator.

8. Number of Copies/Submission. Submit the required number of copies of the Report as stated in the project coordinator's letter to the Bridge Rehabilitation Unit.

72-3.0 BRIDGE REHABILITATION TECHNIQUES

As discussed in Section 72-2.0, the bridge condition surveys, tests, analyses, and reports will indicate the extent of the problems and the objectives of rehabilitation. This Section presents specific bridge rehabilitation techniques which may be employed to address the identified deficiencies. This Section is segregated by structural element. For each technique, Section 72-3.0 presents a brief description.

In addition, where applicable, several typical Department practices are presented which apply to each bridge rehabilitation project. The discussion in Section 72-3.0 is not intended to be all-inclusive, but it provides a good starting point on the more common bridge rehabilitation techniques used by INDOT. For eac individual projects and individual application, the designer is encouraged to review the highway engineering literature for more information. The INDOT *Standard Specifications* should also be consulted for more detailed information.

72-3.01 Bridge Decks

72-3.01(01) Indiana Design Manual Reference

Chapter Sixty-one provides an in-depth discussion on the design of the deck for a new bridge. Many of the design and detailing principles provided in the Chapter also apply to deck rehabilitation. Therefore, the designer should review Chapter Sixty-one to determine its potential application to a bridge rehabilitation project.

72-3.01(02) Typical Department Practices

The Department has adopted several typical practices for bridge deck rehabilitation. These are as follows:

1. Bridge Deck Overlay.

    a. Patching. Patching the bridge deck should be considered a temporary measure to provide a reasonably acceptable riding surface until a more permanent solution can be applied.

    b. Latex Modified Overlay. This is typically applied in conjunction with deck patching. Since the early 1970s, the latex modified overlay has been the most common bridge overlay technique used, and it has provided an average service life of 15 years.

c. Microsilica Concrete. A microsilica concrete overlay may be used if providing a low diffusivity concrete overlay is desirable. This method has been used since the early 1990s.

d. Asphalt Overlay with Sheet Membrane. This method was used in the 1960s and early 1970s with limited success. The difficult construction tolerances for surface preparation, membrane discontinuities and application temperature have caused poor results.

A damaged waterproofing system is counterproductive in that it retains salt-laden water and continues supplying it to the deck which, thus, never dries out. Also, rain water or washing efforts cannot remove the salt. Due to its low reliability, INDOT no longer uses this rehabilitation technique.

e. Low-Slump Concrete. Dense low-slump concrete overlays, 56 mm thick, have been specified as an alternative to latex modified overlays for over 25 years. Very few projects have actually used this option. Because this product has the same characteristics as the latex modified overlay and is more expensive, it is no longer specified.

f. Second Overlay. It is acceptable to remove an existing overlay and replace it with a new one. Department policy is to not allow a new overlay to be placed over an existing bridge deck overlay, because it is counterproductive and adds to the dead-weight of the structure.

2. Joints. The Department recognizes that the service life of bridge deck expansion joints is much shorter than that of the bridge, and leaking and faulty joints represent a hazard for the deck and the main structural components. Therefore, the standard procedure is to eliminate all expansion joints as part of a bridge rehabilitation project where practical. The elimination of joints may require substantial alterations and may have structural implications which should be investigated. Where applicable, the bridge deck rehabilitation should be consistent with the criteria described in Section 61-4.06(03) relative to the design of bridge deck expansion joints.

Compression seals (type BS joints) are not permitted on a bridge deck rehabilitation project. Therefore, all such existing joints should be removed.

3. Minimum Patching Quantities. In general, the quantity summaries for a bridge rehabilitation project only include an estimate of the percent of bridge deck patching. The exact amount of patching needed is determined in the field during construction. However, the minimum amount of bridge deck patching shown in the quantities summary will be either 5% of the bridge deck area, or 28 m^2, whichever is greater.

4. Additional Bridge Deck Overlay. The Estimate of Quantities will include a pay item for additional bridge deck overlay. The estimate for this quantity will be calculated as follows:

Additional Bridge Deck Overlay (m^3) =
(0.050) (Patching, m^2) + (0.00267) (Overlay, m^2)

72-3.01(03) Rehabilitation Techniques

Brief descriptions of bridge deck rehabilitation techniques which may be considered are shown below. The designer should review the technique, determine its applicability to the project, and discuss implementation of the technique with the Design Division's Bridge Rehabilitation Unit. The techniques include the following:

BD-1 Patching
BD-2 Epoxy Resin Injection
BD-3 Low Viscosity Sealants for Crack Repairs
BD-4 Concrete Overlay
BD-5 Cathodic Protection
BD-6 Deck Drainage Improvements
BD-7 Upgrade Bridge Railings
BD-8 Upgrade Guardrail-to-Bridge-Railing Transitions
BD-9 Joint Elimination
BD-10 Concrete Sealants
BD-11 Corrosion Inhibitors
BD-12 Prefabricated Bridge Decks

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-1
Title: Patching

Description:

The area to be patched is defined by sounding. The concrete is then removed by an approved method that will not damage any sound concrete. Any exposed reinforcing steel is cleaned and coated with a thick, viscous epoxy from a point where it projects from the existing concrete for a distance of about 450 mm. The existing concrete surface should remain free from this material because it will destroy the bond.

A bonding agent is then applied to the existing concrete surface. Usually, a sand-cement grout is brushed onto the concrete surface. If polymer concrete is used for patching, a coating of epoxy or other polymer is applied to prime the existing concrete surface.

Although conventional portland cement concrete is often used, many other materials have been developed to permit early opening of the deck to traffic, such as accelerators, fast-setting cements and polymer compounds. In all cases, it is essential that the manufacturer's specifications for mixing, placing, and curing be rigidly followed.

For inorganic concrete, wet curing with a vapor barrier should be used if possible. Overheating and excessive evaporation may cause debonding of the patch regardless of how well it is performed.

For a bridge deck, partial depth patching quantities are estimated during the field check and any subsequent testing. The estimated percentage of the deck to be patched should be shown on the general plan. Traditionally, more patching is needed during construction than is determined by chaining the deck on a field check. If partial depth patching is required, a minimum of 5% should be estimated. Full depth patching shall be estimated as the number of square meters to be replaced. A minimum of 3% of the deck area or 25 m^2 should be estimated if full depth patching is required.

If large contiguous areas of the structure should be replaced, consideration should be given to providing details including replacement of reinforcing steel. The remaining concrete should be capable of resisting its own weight, any superimposed dead load, live load (if the bridge will be repaired under traffic), formwork, equipment, and the plastic concrete.

Deck patching alone is usually only moderately successful, extending the service life of the deck from one to three years.

See INDOT *Standard Specifications* Sections 722.05 and 722.06 for construction and material requirements for patching of bridge decks.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-2
Title: Epoxy Resin Injection

Description:

Epoxy resin injection is seldom used in correcting delamination, because the liquid pressure applied in the process may increase the severity of the problem. Its primary use is to fill cracks in selected areas. Holes are drilled into the cracks between reinforcing bars (pachometer) to a depth as appropriate. A suitable epoxy system capable of bonding to wet surfaces is injected into the entry hole under pressure until it appears in the exit hole(s). A pumping system, in which the two components of the epoxy are mixed at the injection nozzle, is usually employed.

Epoxy resin injection can also be used for re-attaching loose non-composite decks to beams.

For selecting the epoxy resin and for the method of application, advice from the suppliers of the resin should be sought.

See INDOT *Recurring Special Provision* 727-B-012 for construction and material requirements and proper pay item descriptions for concrete repair by epoxy injection.

Bridge Rehabilitation Technique

BRIDGE DECKS
Reference Number: BD-3 Title: Low Viscosity Sealants for Crack Repairs
Description: A low-viscosity epoxy or other organic liquid compound is brushed into the crack, and it fills the crack by gravity. Accordingly, the success of this operation depends on the crack size, selection of the appropriate compound, temperature, contamination on the crack walls and the skill of the operator. Its success rate is typically low. These products are also known as sealer/healers. Acceptable products are included on INDOT's Approved List for conditions as described in Section 722.10 of the *INDOT Standard Specifications*.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-4

Title: Concrete Bridge Deck Overlay

Description:

Latex modified bridge deck overlays have been successfully used by INDOT since the 1970s. These overlays typically protect the bridge deck for 15 ± 5 years. The variation depends on the quality of the placement, annual truck traffic and amount of winter salting. Overlays protect the deck by providing a non-permeable sacrificial layer that prevents water and chlorides from penetrating to the reinforcing steel in the deck. Overlays are placed 44 mm thick after 6 mm of the deck is milled producing a net 38 mm grade raise. The grade is normally adjusted by adding an HMA wedge on each approach.

Overlays are not to be used over existing overlays. These layers must be milled off the deck prior to any other preparation. Prior to placing a bridge deck overlay, a 6-mm layer of the bridge deck shall be removed either by milling or hydrodemolition. This creates a clean, rough surface for the latex modified overlay to adhere to. After this removal, additional milling or patching may be required to create a sound base surface.

Microsilica-based overlays have been used on a trial basis by INDOT. These may be considered with the approval of an engineer from the Bridge Rehabilitation Unit.

For more information, see *INDOT Standard Specifications* Section 722.

Bridge Rehabilitation Technique

BRIDGE DECKS

Reference Number: BD-5

Title: Cathodic Protection

Description:

The advantage of cathodic protection is that it can halt the progress of corrosion without the removal of chloride-contaminated concrete. Corrosion requires an anode, a point on the reinforcing steel where ions are released. Cathodic protection is the application of direct current such that the steel becomes cathodic to artificial anodes located on the deck. These anodes usually consist of sheets of thin wire mesh. A relatively small DC rectifier operating on "AC" line voltage and a control panel are normally located beneath the bridge.

Cathodic protection systems do not need to operate 24 hours per day to be beneficial. Therefore, they can be powered by solar panels or in line with highway lighting systems.

Cathodic protection systems should be considered for locations where traffic maintenance costs are very high and where a few years of additional service between repairs would be advantageous.

Cathodic protection is seldom used because of several disadvantages, including:

1. need for expertise in design and construction,
2. need for periodic adjustment,
3. power requirement, and
4. possible debonding of overlay.

For more information, see *Guide Specifications for Cathodic Protection of Concrete Bridge Decks*, 1994, AASHTO Task Force 29.

Bridge Rehabilitation Technique

BRIDGE DECKS

Reference Number: BD-6
Title: Deck Drainage Improvements

Description:

The most common drainage problems are as follows:

1. Deterioration of and around drainage facilities.

2. An inappropriate number of facilities.

3. Clogging of facility due to lack of grating and insufficient size.

4. Spilling water onto other structural components or the roadway below and/or causing erosion.

Details should ensure positive attachment of the facility to the existing structure and permit proper consolidation of the new concrete in the deck. Abandoned drainage facilities should be permanently sealed such that no ponding will occur at their location.

For more information, see the following:

1. AASHTO *LRFD Bridge Design Specifications* Section 2, which contains information on drains. Its relevant provisions should be followed as practical.

2. Chapter Thirty-three.

Bridge Rehabilitation Technique
BRIDGE DECKS

<u>Reference Number</u>: BD-7
<u>Title</u>: Upgrade Bridge Railings

<u>Description</u>:

The evaluation and disposition of existing bridge railings will be as follows:

1. <u>Operational</u>. Section 61-6.01(02) describes those bridge railings which are operational. If the existing bridge railing is not operational, the designer must upgrade the railing to an operational type. If the system is operational, see the next step.

2. <u>Test Level</u>. Section 49-9.o presents the methodology for determining the required Test Level (TL) based on specific site conditions. If a new railing will be installed, its TL will be based on this methodology. If an existing bridge railing is operational and serviceable but does not meet the TL requirements of Section 49-9.0, then a decision on its replacement will be based on a case-by-case evaluation, considering the following:

    a. implications of other necessary work (e.g., need to upgrade guardrail-to-bridge-railing transition, bridge widening, curb removal); and

    b. other relevant factors, such as accident history.

Bridge Rehabilitation Technique
BRIDGE DECKS
Reference Number: BD-8 Title: Upgrade Guardrail-to-Bridge-Railing Transitions
Description: Section 61-6.01(05) describes those guardrail-to-bridge-railing transitions which are operational. All existing transitions should be upgraded to the current operational systems. This includes both the type of system and the location/design details shown in Section 61-6.01(05).

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-9
Title: Joint Elimination

Description:

The deck joint may often be eliminated by simply making the concrete deck continuous. This can be achieved by removing sufficient concrete on both sides of the joint to permit adequate lap joints in the longitudinal steel, then form and place the concrete.

Making the concrete deck continuous may sometimes not be likely to succeed because the new concrete is likely to crack due to the concentrated rotation at this point of the superstructure. For this situation, a properly conducted rehabilitation should include deck joint considerations as follows:

1. the beams or stringers supporting the deck be made continuous;

2. a portion of the deck concrete is removed to permit placement of negative moment steel;

3. the effects of additional longitudinal movements are investigated at the end of the non-continuous deck;

4. for an integrated superstructure, the effects of these movements on the substructures be considered;

5. the need for discontinuity in the barriers be considered at the points where the joints are eliminated; and

6. if two bearings are used, the effects be considered of increased eccentricity of reaction forces on the substructures.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-10
Title: Epoxy or Silane Seal

Description:

One method of preventing entry of chloride ions into the concrete is sealing its surface. This can be achieved by removing and rebuilding all deteriorated concrete in the surface, sandblasting the surface, and applying a thin organic compound with brooms or mechanical means. Then, the surface is "seeded" with hard granular aggregate to increase its skid-resistance and wearing resistance.

The success of this method depends on the adherence of the seal to the concrete. This can only be attained under ideal conditions and, therefore, the rate of success has been rather disappointing.

The useful life of this sealant is usually not more than three years. However, the minor costs associated with this technique give it a favorable cost-benefit ratio. It also adds protection during the early period of the concrete's curing which is very important.

INDOT maintains an approved list of other Portland Cement Concrete Sealers which includes information identifying the manufacturer, sealer designation, and additional requirements for specific sealers.

See INDOT *Standard Specifications* Sections 709, 909.09, and 909.10 for construction and material requirements and proper pay item descriptions for epoxy penetrating sealers and other portland cement concrete sealers.

Bridge Rehabilitation Technique
BRIDGE DECKS
Reference Number: BD-11 Title: Corrosion Inhibitors
Description: Corrosion inhibitors are added to the concrete mix. They bond to the chloride ions to stop or slow their migration through the concrete.

Bridge Rehabilitation Technique
BRIDGE DECKS

Reference Number: BD-12
Title: Prefabricated Bridge Decks

Description:

Lack of adequate detours, or seasonal or other time limitations may preclude traditional methods of rehabilitation including the use of cast-in-place concrete. There are a number of prefabricated deck systems available for these applications:

1. Solid Concrete Slabs. These are prefabricated as traditionally reinforced, prestressed, or a combination of the two. Panels are placed on the tops of the beams in a mortar bed with space or opening for shear connectors. Normally, panels are joined by wet joints wide enough to permit lapping of steel. If the deck is post-tensioned, epoxied match-cast joints may be used.

2. Steel Grids. Normally employed only on steel beams, these are lightweight and easy to install. They are, however, denying protection to other structural components, noisy, slippery when wet and can "lead" vehicular wheels. At the expense of cost and lightness, these problems can be rectified if the grid is partially or fully filled with concrete.

3. Exodermic Deck. This deck is similar to the filled-steel grids, except that the concrete slab is reinforced and is located on top of the steel grid to which it is connected by shear connectors.

72-3.02 Steel Superstructures

72-3.02(01) *Manual* Reference

Chapter Sixty-four rovides a detailed discussion on the structural design of steel superstructures for new bridges. Many of the design and detailing practices provided in that Chapter also apply to the rehabilitation of an existing steel superstructure. Therefore, the designer should review Chapter Sixty-four to determine its potential application to bridge rehabilitation projects.

72-3.02(02) Rehabilitation Techniques

Brief descriptions of steel superstructure rehabilitation techniques which may be considered are shown below. These include the following:

- SS-1 Grinding
- SS-2 Peening
- SS-3 Gas Tungsten Arc Remelt
- SS-4 Drilled Holes
- SS-5 Bolted Splices
- SS-6 Welding
- SS-7 Addition of Cover Plates — Strengthening
- SS-8 Introduction of Composite Action — Strengthening
- SS-9 Addition of New Stringers — Strengthening
- SS-10 Bearings
- SS-11 Post-Tensioning — Strengthening
- SS-12 Heat-Straightening

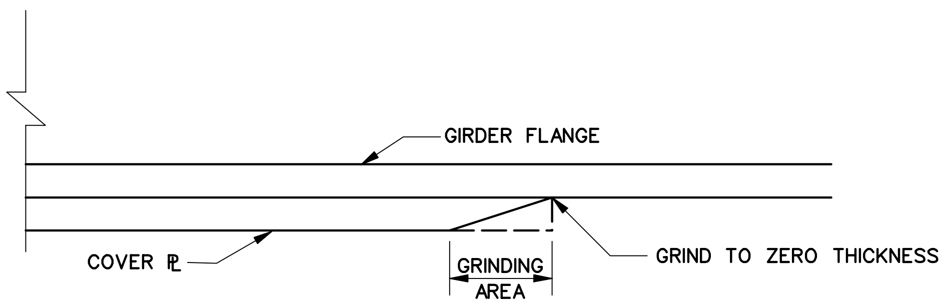
Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-1
Title: Grinding

Description:

If the penetration of surface cracks is small, the cracked material can be removed by selective grinding without substantial loss in structural material. Grinding should preferably be performed parallel to the principal tensile stresses, and surface striations should carefully be removed because they may initiate future cracking.

The most common application of grinding is to the toe of the fillet weld at the end of cover plates to meet fatigue requirements. Grinding can also be used when beams are nicked while sawing off old decks.



GRINDING
Figure 72-3A

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES
Reference Number: SS-2 Title: Peening
Description: Peening is an inelastic reshaping of the steel at the surface location of cracks, or of potential cracks, by using a mechanical hammer. This procedure not only smoothes and shapes the transition between weld and parent metal, it also introduces compressive residual stresses that inhibit the cracking. Peening is most commonly used at the ends of cover plates to reduce fatigue potential.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES
Reference Number: SS-3 Title: Gas Tungsten Arc Remelt
Description: This process remelts the metal at the toe of the weld and eliminates any cracks that are present. The tungsten electrode, which does not melt, is manually moved along the weld toe at a constant rate causing a small volume of the weld and the parent metal to melt and, thus, fuse together. The melted metal transits local irregularities and removes non-metallic intrusions. This technique can be used in lieu of bolting over the connections. This process does not correct a fatigue-prone connection but does reset the fatigue cycles back to zero.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-4
Title: Drilled Holes

Description:

At the tip of the crack, the tensile stress exceeds the ultimate strength of the metal, causing rapid progression if the crack size attains a critical level. The concept of drilled holes is in removing the tip. The location of the tip should therefore be established by means of one of the crack detection methods provided in Section 72-2.03. Missing the tip renders this process useless. Drilling holes at crack tips may be a final solution for distortion-induced fatigue cracks, but it is not a final solution for load-induced fatigue cracks.

Sections must be checked to ensure that the reduced member capacity due to the crack and the drilled hole is still adequate, but this is typically not a critical concern. The mitigation of the stress concentration at the tip is much more critical than the loss of net section. As such, the hole should be as large as can be tolerated in terms of net section. Drill bits of 21- and 27-mm diameter are common due to their use for fabricating bolt holes. Larger diameter holes should be avoided to reduce loss of cross-sectional area.

If holes overlap, the sides of the slots should be ground smooth to remove any projecting surfaces. This will create one oblong hole.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-5
Title: Bolted Splices

Description:

Where rivets or bolts in a connection are replaced, or where a new connection is made as part of the rehabilitation effort, the strength of the connection should not be less than 75% of the capacity or the average of the resistance of and the factored force effect in the adjoining components. Almost exclusively, the connections are made with high-strength bolts in accordance with ASTM A325M or A490M. The connection should be designed by a structural engineer.

This method can also be used to span a cracked flange or web, provided that such connection is designed to replace the tension part of the element or component.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-6
Title: Welding

Description:

It is common practice to use welding for shop fabrication of steel members and for welding pieces in preparation for rehabilitation work. Field welding is often difficult to perform properly in high-stressed areas, and individuals with the necessary skill and physical ability are required. The proper inspection of field welds is equally difficult.

Field welding should only be permitted on secondary members, for temporary repairs, or in areas where analysis shows minimal fatigue stress potential.

See INDOT *Standard Specifications* Section 711.32 for additional specifications for welding of steel.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-7

Title: Addition of Cover Plates — Strengthening

Description:

If the deck is deteriorated and removed, adding cover plates to strengthen a beam becomes a viable alternative. The *LRFD Bridge Design Specifications* place fully welded cover plates into category EN at the ends of the cover plates, which is the lowest fatigue designation, and therefore, the process may be counterproductive from the design perspective. If bolts designed in accordance with *LRFD* Article 6.10.12.2.3 are used at the end of the cover plates, fatigue category B is applied. Because this requires the presence of drilling equipment and work platforms, consideration should be given to a fully bolted cover plate construction.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-8

Title: Introduction of Composite Action — Strengthening

Description:

Introducing composite action between the deck and the supporting beams is a cost-effective way to increase the strength of the superstructure. The *LRFD Bridge Design Specifications* mandate the use of composite action wherever current technology permits. Composite action can be achieved by welded studs or high-strength bolts. Shear connectors shall be designed in accordance with *LRFD* Article 6.10.10.

Composite action considerably improves the strength of the upper flange in positive moment areas, but its beneficial effect on the beam as a whole is only marginal. The combination of composite action in conjunction with selective cover plating of the lower flange is the most effective way of beam strengthening.

Introducing composite action near joints prevents the deck from separating from the beams, thus increasing the service life of the deck. This should be done on each bridge that will have its deck removed for other reasons.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-9

Title: Addition of New Stringers — Strengthening

Description:

If the deck is removed, a new set of stringers added to the existing bridge is one alternative to strengthen the superstructure. To ensure proper distribution of live load, rigidity of the new stringers should be close to that of the existing ones.

The old stringers may also need rehabilitation, in which case, their replacement may be considered as both a structurally and economically more proper alternative. Using modern deck designs and composite action, continuous stringers with a large spacing should be explored as an alternative.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-10

Title: Post-Tensioning — Strengthening

Description:

External post-tensioning can be applied to both steel and concrete beams to reduce tensile stresses, to strengthen beams or to make simply supported beams continuous. There is a variety of successful methods of post-tensioning in the literature.

The *LRFD Bridge Design Specifications* requires that resistance at ultimate limit states be established, at which the interaction between the parent and the post-tensioning systems should be investigated.

Because they are always close to the beam ends, post-tensioning anchorages are vulnerable to salt-laden water seeping through imperfectly sealed deck joints. The tendons should be protected by corrosion-resistant ducts, either grease filled or grouted, especially if being exposed to airborne salts such as at overpasses. The post-tensioning system is basically a put-on harness which is difficult to conceal or to make architecturally appealing. It should not be, therefore, the first choice in high-visibility areas.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES

Reference Number: SS-11

Title: Bearings

Description:

The existing bearings may often only need to be cleaned and/or repositioned. Extensive deterioration, or the recurrence of frozen bearings, may indicate that the design should be modified. A variety of commercially available elastomeric devices may be substituted for sliding and roller bearing assemblies. If the reason for deterioration is a leak in the deck joint, it should be sealed.

Rocker bearings and elastomeric bearings should not be mixed on the same pier/bent, due to differences in movement.

If the bearing is seriously dislocated, its anchor bolts badly bent or broken, or the concrete seat or pedestal is structurally cracked, the bridge may have a system-wide problem usually caused by temperature or settlement, and should be so investigated.

The bearing design may require alteration if so warranted by seismic effects.

See Section 67-4.0 for more information on bearings.

Bridge Rehabilitation Technique
STEEL SUPERSTRUCTURES
Reference Number: SS-12 Title: Heat Straightening
Description: This technique is restricted to hot-rolled steels. Steels deriving their strength from cold drawing or rolling tend to weaken when heated. The premise of heat straightening is that the steel, when heated to an appropriate temperature, usually cherry color, loses some of its elasticity and deforms in a plastic (inelastic) manner. This enables the steel to rid itself of built-up stresses and/or permits forcing the steel into a desirable shape or straightness. The steel should not be overheated. Accordingly, this technique should be implemented by those having experience with this technique. The heating temporarily reduces the resistance of the structure. Measures such as vehicular restriction, temporary support, temporary post-tensioning, etc., may be applied as appropriate.

72-3.03 Concrete Superstructures

72-3.03(01) *Manual* Reference

Chapters Sixty-two and Sixty-three provide a detailed discussion on the design of concrete superstructures for new bridges of reinforced concrete and prestressed concrete. Many of the design and detailing principles provided in these Chapters also apply to the rehabilitation of an existing concrete superstructure. Therefore, these Chapters should be reviewed to determine their potential application to a bridge rehabilitation project.

72-3.03(02) Rehabilitation Techniques

Brief descriptions of concrete superstructure rehabilitation techniques which may be considered are shown below. These include the following:

- CS-1 Remove/Replace Deteriorated Concrete
- CS-2 Pneumatically Placed Mortar
- CS-3 Epoxy Injection
- CS-4 Low Viscosity Sealant
- CS-5 Grouting
- CS-6 Concrete Bridge Seat Extension
- CS-7 Post-Tensioning Tendons — Strengthening

Bridge Rehabilitation Technique
CONCRETE SUPERSTRUCTURES

Reference Number: CS-1
Title: Remove/Replace Deteriorated Concrete

Description:

A clean, sound surface is required for any repair operation; therefore, all physically unsound concrete, including all delaminations and previous patches, should be removed. The construction engineer will mark these areas in the field. If additional sections, such as those known to have high chloride counts, are to be removed, they shall be detailed on the plans.

If large contiguous areas of the substructure should be replaced, consideration should be given to providing details including replacement of reinforcing steel. The remaining concrete should be capable of resisting its own weight, any superimposed dead load, live load (if the bridge will be repaired under traffic), formwork, equipment, and the plastic concrete.

Areas of the substructure requiring patching shall be by means of repointing masonry in structure. Patching should be in accordance with INDOT *Standard Specifications* Section 710. This method of patching has historically had some bonding problems, but it is adequate for small areas. For larger areas of surface patching, pneumatically placed mortar should be used.

Bridge Rehabilitation Technique
CONCRETE SUPERSTRUCTURES

Reference Number: CS-2
Title: Pneumatically Placed Mortar

Description:

Instead of placing the new concrete in forms, it may be applied at high velocity by means of a pump through a hose and nozzle. For this application, the concrete should have a high cement content, low water-cement ratio, and the coarse aggregates replaced with fine aggregates.

Forming thin patches on vertical and overhead surfaces is often difficult as is placing and consolidating thick layers. This method is not economical for a small piece of work because of the high mobilization costs.

Troweling or other finishing should be discouraged because they tend to disturb bonding. Scraping and cutting may be used to remove high points or material that has exceeded the limits of the repair after the concrete has become sufficiently stiff to withstand the pull of the cutting device.

Dimensions are difficult to control with this method, and the finish is often rough. It should not be used on exposed surfaces in urban areas.

See INDOT *Standard Specifications* Section 708 for construction and material requirements and proper pay item descriptions for pneumatically placed mortar.

For additional information, see the *Guide Specifications for Shotcrete Repair of Highway Bridges*, 1998, AASHTO Task Force 37.

Bridge Rehabilitation Technique
CONCRETE SUPERSTRUCTURES
Reference Number: CS-3 Title: Epoxy Injection
Description: See the discussion for Technique BD-2, Epoxy Resin Injection.

Bridge Rehabilitation Technique
CONCRETE SUPERSTRUCTURES
Reference Number: CS-4 Title: Low Viscosity Sealant
Description: See the discussion for Technique BD-3, Low Viscosity Sealants for Crack Repairs. This techique cannot be used on vertical surfaces.

Bridge Rehabilitation Technique
CONCRETE SUPERSTRUCTURES
Reference Number: CS-5 Title: Grouting
Description: Because of the availability of epoxy injection, grouting is no longer used in crack repair unless the crack width is greater than 10 mm. Its application is limited to filling post-tensioning ducts and to provide mortar-beds for precast concrete deck components, barriers, and bearings.

Bridge Rehabilitation Technique
CONCRETE SUPERSTRUCTURES

Reference Number: CS-6

Title: Concrete Bridge Seat Extension

Definition: Concrete bridge seat extension refers to widening the bridge seat to increase the bearing area for the longitudinal concrete beams.

Application: Where a concrete beam has deteriorated from scaling and spalling induced by water, salt, and corrosion, or has been damaged by breakout or cracking in the bearing area, a repair of the beam is often inadequate. In such cases, this procedure is effective.

Procedure: At a minimum, the steps that apply are as follows:

1. Determine the cause of beam damage and include corrective measures to ensure that damage will not progress to the new bearing area.

2. Complete a structural evaluation of the suggested details to ensure that the extension will support the beams.

3. Perform a structural evaluation of the existing seat or cap to ensure that it is capable of supporting the extension and the nonsymmetrical loading that will result from the extension.

Bridge Rehabilitation Technique
CONCRETE SUPERSTRUCTURES

Reference Number: CS-7
Title: Post-Tensioning Tendons — Strengthening

Definition: The addition of post-tensioned tendons is used to restore the strength of a prestressed concrete beam where original strands or tendons have been damaged. Strengthening by means of post-tensioning is also applied to unprestressed concrete beams and steel girders and not only as a result of collision.

Application: Collision of over-height vehicles or equipment with a bridge constructed with prestressed concrete beams may result in breaking off the concrete cover and subsequent damage to or severing of the beam tendons. Exposure to water and salt may also cause damage, particularly when the concrete cover is damaged or cracked. Because the steel tendons determine the load-carrying capacity of the beam, any damage impairs resistance and must be repaired.

Procedure. At a minimum, the steps that apply are as follows:

1. Conduct a structural evaluation to determine the extent of the damage.

2. Evaluate the existing diaphragms to ensure their adequacy to support the end anchorage of the tendons.

3. Determine the placement of the temporary load to be applied to existing beams prior to removal and placement of concrete in prestressed concrete beams, if any.

The post-tensioning system should be designed and constructed in accordance with the manufacturer's recommendations. All wedge-type anchorages are susceptible to seating losses; therefore, for short lengths, the rolled steel bars are preferred.

A special provision should be developed for setting forth the work to be accomplished for completion of this technique.

72-3.04 Substructures/Foundations

72-3.04(01) *Manual* Reference

Chapters Sixty-six and Sixty-seven provide a detailed discussion on the structural design of substructures and foundations for a new bridge. Many of the design and detailing principles provided in these chapters also apply to the rehabilitation of the substructures and/or foundations of an existing bridge. Therefore, these chapters should be reviewed to determine their potential application to a bridge rehabilitation project.

72-3.04(02) Integral End Bents

Section 67-1.0 discusses those geometric conditions, e.g., skew angle and continuous deck length, where integral end bents may be considered for a new bridge. For an existing bridge, the design criteria in Section 67-1.0 should be used when converting an existing structure to an integral end bent structure. As an example, if the mudwalls of existing end bents will be removed as part of the project, it may be cost effective to convert the structure to an integral or semi-integral end bent structure. For additional information, see Technique BD-9.

72-3.04(03) Rehabilitation Techniques

Brief descriptions of substructure and foundation rehabilitation techniques which may be considered are shown below. These include the following:

- SF-1 Remove/Replace Deteriorated Concrete
- SF-2 Enlarge Footings
- SF-3 Riprap
- SF-4 Wing Wall Repair
- SF-5 Deadman Anchorages
- SF-6 Drainage Improvements
- SF-7 Grout Bag Underpinning
- SF-8 Pile Section Loss Repair
- SF-9 Jacketing Piers and Piles

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-1
Title: Remove/Replace Deteriorated Concrete

Description:

A clean, sound surface is required for any repair operation; therefore, all physically unsound concrete, including all delaminations and previous patches, should be removed. The construction engineer will mark these areas in the field. If additional sections, such as those known to have high chloride counts, are to be removed, they should be detailed on the plans.

Patching quantities are estimated during the field check and any subsequent testing. The estimated area to be patched should be shown in the plans. Traditionally, more patching is needed during construction than is determined visually on a field check.

If large contiguous areas of the substructure should be replaced, consideration should be given to providing details including replacement of reinforcing steel. The remaining concrete should be capable of resisting its own weight, any superimposed dead load, live load (if the bridge will be repaired under traffic), formwork, equipment, and the plastic concrete.

Areas of the substructure requiring patching shall be by means of repointing masonry in structure. Patching should be in accordance with INDOT *Standard Specifications* Section 710. This method of patching has historically had some bonding problems, but is adequate for small areas. For larger areas of surface patching, pneumatically placed mortar should be used.

Bridge Rehabilitation Technique

SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-2

Title: Enlarge Footings

Description:

The most common reasons for enlarging the footings are to widen the structure, inadequate strength, excessive settlement, andscour.

The method of rehabilitation is usually enlargement of the spread footing, enlargement of the spread footing with piles, or enlargement of the pile cap with additional piles.

Enlarging an Existing Spread Footing:

1. The preferred alternative is to design the spread footing extensions using the original soil or rock bearing pressure. For wide extensions, the designer should contact the Materials and Tests Division's Geotechnical Engineering Section for additional geotechnical information.

2. Where a scour condition exists at a spread footing in a stream, the footing should be extended by means of piles. The designer should contact the Materials and Tests Division's Geotechnical Engineering Section for additional geotechnical information. Piles should be designed to carry all loads.

Enlarging an Existing Pile-Supported Footing:

1. The footing should be extended with additional piles of similar capacity to the original piles; e.g., if original 305-mm diameter piles were designed with a 310-kN bearing capacity, 355-mm diameter piles should be used with a bearing capacity of 355 kN. Pile driving records for the existing structure should be checked.

2. For a large extension, the Geotechnical Engineering Section should be requested to investigate.

Overhead clearances from beams, decks, and cantilever caps should be checked when locating new piles.

Reference Number: SF-2 (Continued)
Title: Enlarge Footings

Description:

The use of a chemical anchorage system is the preferred method for tying the new footing to the existing footing. These anchorage systems are adequate for transferring shear and pull-out forces, but are not long enough to transfer moment to the existing reinforcement. The entire height of the footing, stem and cap connections should be considered when transmitting moments. See Section 72-5.0 for more detailed information.

For forming, placement of steel, pouring and curing concrete, the same criteria apply as for new construction.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-3
Title: Riprap

Description:

The stability of streambeds and banks is largely a function of water velocity and the size of the material constituting such beds and banks. If the size exceeds critical dimensions, scour will not likely occur.

Artificially placed protective material can be of natural stone, specially made concrete or recycled (crushed) concrete. The weight of the riprap material should be considered in the design of footings and foundations. For steeper embankments, the riprap may be enclosed in galvanized, wire mesh envelopes called gabions.

For more information, see Chapter Thirty-eight.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-4
Title: Wingwall Repair

Description:

In many old concrete abutments, the wingwalls tend to break-off and to separate from the main body due to earth-pressure and differential settlement. If the opening has been stable, the do-nothing option may be the best policy. If not stable, the wings should be removed and completely rebuilt. Footings for the new walls should be at the same level as that of the main body, and the entire new concrete structure should be attached to the old one by means of anchors as described in Section 72-5.0.

If the wingwall is deteriorated, the impaired concrete should be removed and the structure jacketed. The application of jacketing is a variation of enlargement as discussed for Technique SF-2, Enlarge Footings. Stabilization of existing wingwalls can also be attained by the application of gabions or, alternatively, replaced by gabions or by installing sheet piling.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-5

Title: Deadman Anchorages

Description:

The lateral force exerted by retained earth or stone, and superimposed gravitational loads thereon, tends to push forward and rotate abutments and retaining walls. One solution for this problem is the application of a deadman.

A deadman are heavy solid masses, usually concrete blocks that are connected to the retaining structure by long steel rods. A deadman is located in a stable earth mass well behind the structure. For wingwalls, or walls located on both sides of the roadway, they can simply be connected together by steel rods.

The rods should be protected against corrosion, and the effects of differential settlement should be considered.

Since this stabilization technique modifies the wall support from a cantilever to simple span pinned, the wall reinforcement should be checked for the revised moments.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-6
Title: Drainage Improvements

Description:

Water is the primary cause of instability of fills and embankments. As the water content of a fill behind a retaining structure increases, lateral pressure on the structure is amplified.

If the fill contains excessive amounts of silt or clay, it should be internally drained. This can be achieved either by means of perforated plastic pipes or french drains. The latter is a deep trough, the bottom of which is filled with crushed stone or riverbed gravel of equal size. The gravel is covered with a plastic sheet to prevent intrusion of the fill above. Both systems should have exits to ditches permitting unimpaired gravity flow.

Water retention behind retaining structures, such as abutments and walls, is caused either by non-existing or undersized drainage pipes or by clogging thereof. New weep holes of adequate size can be drilled into the concrete if so required. Clogged holes should be thoroughly cleaned.

To prevent future clogging, the entry side of the holes should be provided with a filter and/or a lump of crushed stone or gravel, covered with a plastic sheet.

Drainage improvement measures that should be considered for preventing erosion of the embankment surfaces at the corners of a structure caused by surface runoff include erosion control mats, riprap drainage turnouts, and curb inlets with piping. Only the resodding of these areas has limited short-term benefits.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-7
Title: Grout Bag Underpinning

Description:

Scour may cause excessive settlement or tilting of spread footings. Grout-filled bags offer a reasonably simple and economical method of rehabilitation. The construction procedure is as follows:

1. Install a concrete leveling sill to ensure pier stability during excavation. The sill consists of an appropriately positioned, concrete-filled grout bag extending the entire width of the pier.

2. Remove protruding boulders under footing.

3. Using high-pressure water jets, excavate to level footing. This will lower the pier.

4. Install preformed grout bags and fill with pressurized concrete to mold to and completely fill cavity under the pier.

5. Place grout bags around the periphery of the pier to increase footing size and depth, thereby reducing further potential for undermining.

6. Install horizontal and vertical reinforcement through the grout bags.

7. Drill and grout dowels on 1.0-m centers into the existing stem and footing to anchor new work to old.

8. After jacking and blocking superstructure, build new seats or pedestals and install bearings.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS

Reference Number: SF-8
Title: Pile Section Loss Repair

Description:

For section losses in steel piles, the following will apply.

1. Small Loss. Remove all oxidized material, sandblast the area to be repaired, then build up the section by layers of welding and grind the new surface to reasonable smoothness.

2. Medium Loss. The missing cross section is rebuilt by adding plates to the flanges and/or web as appropriate by either welding or bolting.

3. Extensive Loss. Install the new pile while the damaged pile may or may not be removed. This method can only be used where the clearance for pile driving can be obtained.

For wood piles, section losses may be repaired by means of partial replacement, epoxy injection, and/or jacketing.

More information on wood piles can be found in *Timber Bridges - Design, Construction, Inspection and Maintenance*, Chapter 14, by M. A. Ritter, United States Department of Agriculture, Forest Service, EM 7700-8, or *Evaluation, Maintenance and Upgrading of Wood Structures – A Guide and Commentary*, by American Society of Civil Engineers.

Bridge Rehabilitation Technique
SUBSTRUCTURES/FOUNDATIONS
Reference Number: SF-9 Title: Jacketing Piers and Piles
Description: This technique is applied in the surface rehabilitation of a steel, concrete, or wood substructure. It includes removing all deteriorated material, constructing a formwork for the jacket, placing a reinforcing steel cage of appropriate size in the formwork and filling it with compacted concrete. The technique has extensive literature on its application. A treatment similar to the details shown on INDOT *Standard Drawing* 701-BPIL-02 may be used.

72-3.05 Seismic Retrofit

72-3.05(01) Seismic Evaluation

Earthquakes cause what is best described as a shaking of the entire bridge structure. The ability to predict the forces developed by this motion is limited by the complexity of predicting the acceleration and displacements of the underlying earth material and the response of the structure. The motion can generally be described as independent rotation, in any direction, of each bridge abutment or pier, in or out of phase with each other, combined with sudden vertical displacements. Ground between piers can distort elastically and in some cases rupture or liquify. The bridge failures induced by the motions of the abutments and piers stem from two major inadequacies of many bridge designs: the lack of adequate connections between segments of a bridge, and inadequately reinforced columns or hinge points. Other deficiencies include inadequately reinforced footing and bent cap concrete; insufficiently reinforced, or too few, shear keys; and inadequate design force levels considering the likelihood of earthquakes at the location.

Fortunately, tying the segments of an existing bridge together is an effective means of preventing a prevalent failure, such as the spans falling off the bearings, abutments or piers. It is also the least expensive of the inadequacies to correct. A bridge with single-column bents is particularly vulnerable if segments are not connected.

Columns inadequately reinforced, because of too few and improperly detailed ties and spirals or short-lapped splices, generally do not sufficiently confine the concrete. This is particularly critical in single-column bents. Low flexural strength is an inadequacy of some columns.

Determining the retrofit technique to use involves the considerations as follows:

1. mode of failure anticipated;
2. influence on other parts of the bridge under seismic and normal loadings;
3. interference with traffic flow; and
4. cost of fabrication and installation.

Some retrofit procedures are designed to correct inadequacies of bridges related to earthquake resistance. The procedures may be categorized by the function the retrofit serves, including the following:

1. restraining uplift;
2. restraining longitudinal motion;
3. restraining hinges;
4. widening bearings;
5. strengthening columns; and
6. restraining transverse motion.

For more information, see *Seismic Design and Retrofit Manual for Highway Bridges,* FHWA-IP-87-6, and *Seismic Retrofitting Manual for Highway Bridges*, FHWA-RD-94-052.

72-3.05(02) Application

The policy for seismic evaluation of an existing bridge is as follows:

1. Seismic Zone 2. Zone 2 includes the counties of Gibson, Posey, and Vanderburgh. For the rehabilitation of an existing bridge within Zone 2, a seismic evaluation of the structure should be performed if major rehabilitation, i.e., deck replacement or superstructure widening, is anticipated.

2. Seismic Zone 1 All other counties are in Zone 1. The performance of a seismic evaluation on these existing bridges will be made on a case-by-case basis considering, for example, the following:

    a. the scope of the rehabilitation work, i.e., for more extensive rehabilitation work, a seismic evaluation may be appropriate; and

    b. the importance of the structure, i.e., for a major structure, a seismic evaluation may be appropriate even if the proposed scope of work is limited.

72-3.05(03) Typical Practices

The following summarizes the typical practices for the seismic evaluation of an existing bridge.

A bridge that is selected for seismic retrofitting should be investigated for the same basic criteria as that required for a new bridge, including minimum support length and minimum bearing force demands. Bridge failures have occurred at relatively low levels of ground motion.

For a Zone 2 bridge, the retrofitting measures should include modification or elimination of existing steel rollers. A major reconstruction project in Zone 1 may also be a good candidate for the elimination of existing steel rollers. Decisions concerning the elimination of steel rollers on a Zone 1 bridge will be made on a case-by-case basis.

See Section 67-4.0 when considering the use of seismic isolation bearings.

72-3.05(04) Seismic Retrofit Techniques

Brief descriptions of seismic retrofit techniques which may be considered are shown below. These include the following:

- SR-1 Jacketing of Columns
- SR-2 Other Techniques for Increasing Seismic Resistance of Columns
- SR-3 Seat Width Extension
- SR-4 Structural Continuity
- SR-5 Restrainers and Ties
- SR-6 Bearing Replacement
- SR-7 Seismic Isolation Bearings
- SR-8 Integral End Bents

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-1
Title: Jacketing of Columns

Description:

Jacketing consists of adding confinement steel to round columns and covering it with concrete or the use of a fiber wrap. The steel may be either individual reinforcing hoops tensioned with special turnbuckles or prestressing wire spirally wound by special equipment. Anchorage of the wire should be made to the original concrete core, because the first distress is normally the separation of cover. Additional information and specifications on fiber wrap systems may be obtained from the Bridge Rehabilitation Unit.

Jacketing should be located only at the points of potential column hinge formations. It increases column rigidity, which amplifies global seismic forces, and attracts more of it to the column. Consequently, it should be limited to a height which is the greater of the following:

1. maximum cross-sectional dimensions of the column;
2. one-sixth of the clear height of the column; or
3. 450 mm.

The spacing of steel should not exceed 90 mm, and the steel wire should be at least 6 mm in diameter.

Bridge Rehabilitation Technique

SEISMIC RETROFIT

Reference Number: SR-2

Title: Other Techniques for Increasing Seismic Resistance of Columns

Description:

The following techniques may be used to increase the seismic resistance of columns.

1. Steel Jacket. Non-circular columns cannot be retrofitted by the method provided in Technique SR-1, Jacketing of Columns, or its use may not be advisable due to increased rigidity. Instead, a solid-steel shell may be placed around the column with a small space which is pressure grouted for a perfect fit.

2. Flexural Reinforcement. Because of conservative provisions, concrete columns have often been both over-designed and over-reinforced in the past. Over-reinforcement means that the steel does not yield at ultimate, resulting in both higher compressive and shear forces on the concrete. If other design criteria permit, some of the flexural steel may be cut to induce yield therein.

   If circumstances warrant, the flexural reinforcement may be increased. The vertical bars are located in a concrete jacket, which is shear-connected to the column by means of drilled and grouted dowels. This also increases the rigidity of the column, potentially rendering it counterproductive.

3. Infill Shear Wall. A concrete shear wall can be added between the individual columns of a frame bent. If the existing footing is not continuous, it should be made so. The wall should be connected to the columns by means of drilled and grouted dowels. This method substantially changes the seismic-response characteristics of the structure, requiring a complete reanalysis.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-3
Title: Seat Width Extension

Description:

Seat width extensions allow larger relative displacements to occur between the superstructure and substructure before support is lost and the span collapses. Provisions in the *LRFD Bridge Design Specifications*, relative to the design of seat widths, should be followed as practical.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-4
Title: Structural Continuity

Description:

Some older bridges have been constructed without longitudinal continuity. Structurally unconnected units of the superstructure tend to respond to seismic excitation differently, resulting in the dropping of the bearings or, more severely, sliding of the substructure.

In older structures, shrinkage, creep and settlement have already occurred, and only the effects of temperature need be considered. Normally, there are no major structural reasons not to make the structure continuous. Seismic continuity is no different from continuity for gravitational loads. The structural behavior of a bridge made continuous, however, is fundamentally different from a non-continuous one and, therefore, it should be re-analyzed from every relevant perspective as if it were a new structure.

Bridge Rehabilitation Technique

SEISMIC RETROFIT

Reference Number: SR-5
Title: Restrainers and Ties

Description:

In general, restrainers are add-on structural devices which do not participate in resisting other than seismic force effects. These components are made mostly of steel. They should be designed to remain elastic during seismic action, and they should be protected against corrosion.

There are three types of restrainers: longitudinal, transverse, and vertical. The purpose of the first two is to prevent unseating the superstructure. The objective of the third is to preclude secondary dynamic (impact) forces that may result from the vertical separation of the superstructure.

The restraint devices should be compatible with the geometry, strength, and detailing of the existing structure.

Ties are restrainers which connect only components of the superstructure together. They are activated only by seismic excitation.

Bridge Rehabilitation Technique
SEISMIC RETROFIT
Reference Number: SR-6 Title: Bearing Replacement
Description: Damaged or malfunctioning bearings can fail during an earthquake. In addition, steel rocker and roller bearings perform poorly for obvious reasons. One option is to replace these bearings with steel reinforced elastomeric bearing pads. To maintain the existing beam elevation, either a steel assembly is inserted between the beam and the elastomeric pad, or the elastomeric pad is seated on a new concrete pedestal. Existing anchor bolts may assist in resisting shear between the pedestal and the pier.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-7

Title: Seismic Isolation Bearings

Description:

There is a broad variety of patented seismic isolation bearings which are commercially available. They permit either rotation or translation or both. They have special characteristics by which the dynamic response of the bridge is altered, and some of the seismic energy is dissipated. The primary change in structural response is a substantial increase in the period of the structure's fundamental mode of vibration. The *LRFD Bridge Design Specifications* determine the equivalent lateral static design force as a function of this period. The devices are designed to perform elastically in response to normal service conditions and loads.

Seismic isolation bearings sometimes contain an elastomeric element. The inelastic element is usually either a lead core, viscous liquid, or other mechanical damper whose resistance is a function of the velocity of load application. They are effective for seismic loads due to their high velocity. The liquid dampers are prone to leakage, thus requiring back-up safety devices.

The application of seismic isolation bearings substantially changes the response characteristics of the bridge. Because of the inelastic behavior of the bearings, non-linear time-history analysis should be performed, and at least three ground motion time histories should be used to account for the different frequency content and duration of excitation that may actually occur.

When considering these bearings, the designer should check with suppliers for available performance data and prepare a performance specification. An example specification may be obtained from the Bridge Rehabilitation Unit. The bearing supplier will provide the final design calculations and shop drawings for its proprietary system.

See Section 67-4.0 for more information on seismic isolation bearings.

Bridge Rehabilitation Technique
SEISMIC RETROFIT

Reference Number: SR-8
Title: Integral End Bents

Description:

One method to provide continuity between the superstructure and substructure is the integral end bent. Minimum design requirements for integral end bents are provided in Section 67-1.0. Integral end bents are only feasible if pile supported and if the arrangement of piles permits the longitudinal temperature movement of the bridge. Existing piling that is battered should be cut off below grade.

A more common rehabilitation situation is the construction of semi-integral end bents. This allows the reuse of the lower cap and existing piles. The new, upper portion of the cap is allowed limited movement, but is positively connected to the lower component, thereby providing seismic restraint.

72-3.06 Miscellaneous Approach Items

The following describes typical practices for bridge approach work as part of a bridge rehabilitation project.

1. Asphalt Wedge. Where an asphalt wedge is used at the end of a project, the wedge should be designed as illustrated in Figure 72-3B. Payment will be designated as follows:

   a. transition milling, in square meters;
   b. tack coat, in square meters; and
   c. asphalt wedges, in megagrams.

2. Other Asphalt Materials. Asphalt materials are used for wedges, minor shoulder widening, relief joints, etc. If a Typical Cross Sections sheet is not required, the asphalt materials will be shown on the General Plan or the Traffic Maintenance Details, as appropriate. The sheet will include Materials Notes, which will be placed below the General Notes or near the title block. As an alternate, the Materials Notes may be placed on the bridge approach details sheet.

   Asphalt materials used for widening shoulders, as asphalt wedges, etc., will be paid for by the megagram. They are not be included as part of the traffic maintenance pay item.

72-4.0 BRIDGE WIDENING

72-4.01 Introduction

It may be necessary to widen an existing bridge for the reasons as follows:

1. The existing bridge may provide an inadequate roadway width, especially substandard shoulder width.

2. The project may include adding travel lanes to a highway segment to increase the traffic-carrying capacity of the facility.

3. A bridge may be widened to add an auxiliary lane across the structure, e.g., increasing the length of an acceleration lane for a freeway entrance, adding a truck-climbing lane, adding a weaving segment at the interior of a cloverleaf interchange.

A bridge widening can present a multitude of problems during the planning and design stages, during construction, and throughout its service life. The overall design and detailing of the widening should consider minimizing construction and maintenance problems.

The widening of a structure should be designed to coordinate with the appearance of the original bridge. If possible, the bridge's appearance should be enhanced by the work.

The following briefly summarizes the basic objectives in bridge widening:

1. Match the components of the existing structure.
2. Match the bearing types under the existing beams.
3. Do not perpetuate fatigue-prone details.

It is not normally warranted to modify the existing structure solely because of revisions in the *LRFD Bridge Design Specifications* which are not reflected in the existing structure.

72-4.02 Existing Structures with Substandard Capacity

A bridge to be rehabilitated should be designed for HL93 or HS-20 loading, whichever was used in the original design. The Program Development Division's Bridge Inspection/Bridge Inventory Unit should be consulted on the condition and the load resistance of the structure. Based on this information, the designer will determine whether the existing structure should be strengthened to the same load-carrying capacity as the widened portion. The criteria for structural capacity of existing bridges to remain in place are provided in Chapters Fifty-three, Fifty-four, and Fifty-five. The information is segregated by functional classification, urban/rural location, and project scope of work. For the evaluation, the criteria to be considered, if appropriate, are as follows:

1. cost of strengthening the structure;
2. physical condition, operating characteristics and remaining service life;
3. seismic resistance;
4. other site-specific conditions;
5. structure is the only one that restricts permit loading on the route;
6. width of widening; and
7. traffic accommodation during construction.

72-4.03 Girder Type Selection

In selecting the type of girder for a structure widening, the widened portion of the structure should be of a construction type and material type consistent with that of the existing structure.

For conventionally-reinforced-concrete girder structure it is preferable to use prestressed concrete I-beams or box beams for the widened portion.

72-4.04 Bridge Deck Longitudinal Joints

Past performance indicates that longitudinal expansion joints in a bridge deck between a widened portion and the existing portion have been a continuous source of bridge maintenance problems. Therefore, no longitudinal expansion joints should be used, except for locations where concrete barrier railing is to be placed on both sides of the joint.

Experience has shown that a positive attachment of the widened and original decks by means of lapping reinforcing steel provides a better riding deck, usually presents a better appearance, and reduces maintenance problems. A positive attachment of the old and the new decks should be made for the entire length of the structure.

In some situations, it may be desirable to use a type of anchorage system other than lapping reinforcing steel. Lapped reinforcing steel may be more expensive than other options because of the need to provide adequate bond length.

The following recommendations should be considered when widening an existing beam/girder and deck-type structure.

1. A structure with large overhangs should be widened by removing the concrete from the overhang to a width sufficient to develop adequate length for lapping the original transverse deck reinforcing to that of the widening.

2. A structure with small overhangs, where removal of the overhang will not provide sufficient bond length, should be either doweled to the widening or have transverse reinforcing exposed and extended by means of a mechanical lap splice.

3. A structure with no overhangs should be attached by doweling the existing structure to the widening. Double row patterns for the dowels are preferred over a single row. Benching into the existing exterior girder as a means of support has proven to be unsatisfactory and should be avoided.

4. Longitudinal construction joints should not be located over the beam flanges.

5. Removal of the deck past the outside beam line will result in a cantilever slab condition. The design must ensure that the deck can resist the loadings anticipated during construction.

6. Longitudinal construction joints shall preferably be aligned with the permanent lane lines. These joints tend to be more visible than the pavement markings during adverse weather conditions.

See Section 72-5.0 for detailed information on anchoring reinforcing bars into existing concrete.

72-4.05 Effects of Dead Load Deflection

Unless the widened structure is completely prefabricated, deflection of the beams or girders will occur due to superimposed dead loads, such as the deck slab, diaphragms, barriers, etc. To prevent the undesirable effects of this deflection, the widening should initially be built above the grade of the existing structure to allow for dead load deflection, and the deflected widening should approximate the grade of the existing structure. If proper provisions are not made to accommodate the dead load deflection, construction and maintenance problems will ensue. Where the dead load deflection exceeds 50 mm, a closure pour should be considered to complete the attachment to the existing structure. A closure pour serves two useful purposes: it defers final connection to the existing structure until after the deflection from the deck slab weight has occurred, and it provides the width needed to make a smooth transition between differences in final grades that result from design or construction imperfections.

In terms of the effects of dead load deflection, two groups of superstructure types can be distinguished: precast-concrete-beam or steel-beam construction. The largest percentage of deflection occurs when the deck concrete is placed. For cast-in-place construction, e.g., a reinforced concrete slab bridge, the deflection occurs after the falsework is released.

In precast-concrete-beam construction, dead load deflection after placement of the deck is usually insignificant, but in cast-in-place structures, the dead load deflection continues for a lengthy time after the falsework is released. In a conventionally-reinforced-concrete structure, approximately one half to three quarters of the total deflection occurs over a four-year period after the falsework is released due to shrinkage and creep. A theoretical analysis of differential deflection that occurs between the new and existing structures after closure will usually demonstrate that it is difficult to design for this condition. Past performance indicates, however, that theoretical overstress in the connection reinforcing has not resulted in maintenance problems, and it is generally assumed that some of the additional load is distributed to the original structure with no difficulty or its effects are dissipated by inelastic relaxation. The closure width should relate to the amount of dead load deflection that is expected to occur after the closure is placed. A minimum closure width of 500 mm is recommended.

At the present time, INDOT is satisfied with the performance of its bridge decks that are widened without the use of deck closure pours. This satisfactory performance also applies to a deck replacement that is poured in two phases while maintaining traffic and without the use of deck closure pours. Consequently, deck widening and phased deck replacement normally do not require deck closure pours unless the designer or district representative recommends otherwise. An example of where a closure pour may be warranted is for a steel beam/girder structure where uplift could occur.

72-4.06 Vehicular Vibration During Construction

All structures deflect when subjected to live loading, and many bridge widenings are constructed with traffic on the existing structure. Fresh concrete in the deck is subjected to deflections and vibrations caused by traffic. Studies such as NCHRP 86 *Effects of Traffic-Induced Vibrations on Bridge-Deck Repairs* have shown the following:

1. good-quality reinforced concrete is not adversely affected by jarring and vibrations of low frequency and amplitude during the period of setting and early strength development;

2. traffic-induced vibrations do not cause relative movement between fresh concrete and embedded reinforcement; and

3. investigations of the condition of widened bridges have shown the performance of attached widenings, with and without the use of a closure pour, to be satisfactory.

Therefore, no additional measures must be taken to prevent movement and vibration during concrete pouring or curing.

72-4.07 Substructure

An existing structure will ordinarily not be subjected to any settlement of its footings by the time the widening is completed. Pile capacities of an existing structure should be investigated if additional loads will be imposed on it by the widening. It is possible for newly constructed spread footings under a widened portion of a structure to settle. The new substructure should be tied to the existing substructure to prevent differential foundation settlements. If the new substructure is not tied to the existing substructure, suitable provisions should be made to prevent possible damage where such movements are anticipated.

72-4.08 Details

Figures 72-4A and 72-4B illustrate details which should provide satisfactory results. Because each widening project is unique, these details present candidate ideas rather than solutions for bridge widening.

New diaphragms for widenings should line up with the existing diaphragms.

<u>**72-4.09 Design Criteria (Historical Background)**</u>

When preparing plans to modify an existing structure, it is often necessary to know the live load and stress criteria used in the original design. Since approximately 1927, with few exceptions, structures have been designed for loads and stresses specified by AASHTO.

The designer should be aware of the historical perspective of design criteria, such as live loads, allowable stresses, etc., when analyzing a rehabilitated structure. For accurate and complete information on a specific structure, see the General Notes of as-built plans, old standard drawings and special provisions, and the appropriate editions of the AASHTO *Specifications*.

Throughout the years, modifications to steel-beam sections have occurred. The designer should refer to the construction-year American Institute of Steel Construction's *Steel Construction Manual* for beam properties and other data.

72-5.0 CHEMICAL ANCHOR SYSTEMS

It may not always be possible or cost effective to expose sufficient existing reinforcing steel to lap with new reinforcement. If so, an anchor system may be used to attach the new reinforcement. The allowable materials that can be used to anchor the reinforcement are found on the Approved Materials List of Steel Reinforcement Anchors. The pay item for this work is field-drilled holes in concrete, which includes creating the hole and applying the grout.

Grout material for field drilled holes shall be either a high-strength, non-shrink, non-metallic, cementatious grout in accordance with U.S. Army Corps of Engineers *Specification CRD-C 621* or an approved 100% solids chemical anchor system. Chemical, or epoxy systems, may be either sealed capsules that contain premeasured amounts of resin, small aggregate, and catalyst, or a two-part epoxy resin injected into the hole through a mixing nozzle.

The embedment requirement to obtain a given tensile pullout value will vary somewhat between products. To maintain consistency, the plans should show the minimum required pullout value, and the reinforcing steel sized to project 150 mm into the hole. Any adjustment necessary for the hole depth or diameter or reinforcement length is the responsibility of the contractor.

Where vertical holes are to be drilled into the top of a concrete bridge deck, a minimum clearance of 50 mm should be maintained between the bottoms of the holes and the bottom of the slab. Where vertical holes are to be drilled over a concrete or steel beam flange, the holes may be extended to the top of the flange. Where grouted holes are specified, the diameter and length of the holes shall be in accordance with the grout manufacturer's recommendations.

Figure 72-5A lists the tensile and shear design strengths required for 420 MPa reinforcing steel. These values are for the embedment of reinforcing bars. Threaded or smooth dowels and headed studs can obtain significantly different values. The designer should review the manufacturers' literature before specifying these types of connectors.

If an anchorage is to be required, a note should be placed on the plans identifying the connection as "Field drilled hole in concrete. Embed bar 150 mm with an approved anchor system. Minimum pullout = _______ kN." The value should be obtained from Figure 72-5A, Design Data for Anchor Systems. The values shown are for ultimate loads. If the full strength of the reinforcing steel is required, the values for 125% F_y should be used. For all other connections, 100% F_y may be used.

If the anchorage design spacing of the holes or edge distance is not provided, a reduction in capacity occurs. See Figure 72-5B, Edge Distance and Spacing Requirements.

72-6.0 OTHER BRIDGE REHABILITATION PROJECT ISSUES

A bridge rehabilitation project requires the consideration of issues other than structural design. These include the following:

1. plan preparation conventions;
2. geometric design issues;
3. roadside safety issues;
4. maintenance and protection of traffic through construction zones;
5. project development;
6. environmental procedures;
7. permits; and
8. circular crown cross slope.

These topics are discussed elsewhere in the *Indiana Design Manual*. Section 72-6.0 identifies these references and, where necessary, provides additional information.

72-6.01 Plan Preparation

Chapter Fourteen discusses the preparation of plans, e.g., content of individual sheets, scales, symbols. These apply to each bridge rehabilitation project. See Section 14-2.04 for detailed information on the submittal of construction plan sheets, and other appropriate information, at the various design stages for a bridge rehabilitation project.

72-6.02 Geometric Design

Part V describes geometric design criteria. The geometrics which apply to a bridge rehabilitation project are based on urban/rural location, functional classification, and project scope of work.

Section 40-6.0 describes the project scope of work. Bridge rehabilitation is most often considered a 3R project on either a freeway or non-freeway. See Chapter Fifty-four or Chapter Fifty-five to determine the applicable geometric design criteria.

72-6.03 Roadside Safety

The primary roadside safety issues are the operational characteristics of the bridge railing, the guardrail-to-bridge-railing transition, and guardrail end treatments. All bridge railings, guardrail-to-bridge-railing transitions, and guardrail end treatments must be upgraded to meet current criteria. Section 61-6.01, and Section 72-3.01, Bridge Rehabilitation Techniques BD-7 and BD-8, discuss current criteria for bridge railing and guardrail-to-bridge-railing transitions. Other roadside safety issues, e.g., clear zones, obstructions, roadside barriers, impact attenuators, collision walls, bridge railing ends, are described in Chapter Forty-nine.

72-6.04 Maintenance and Protection of Traffic During Construction

The proposed strategy for maintaining traffic during construction could include alternating one-way traffic with signals, lane restrictions, median crossovers, or diverting the traffic to a detour route. See Part VIII for detailed information on policies and procedures.

72-6.05 Project Development Procedures

Chapter Two discusses the project development process for a bridge rehabilitation project, and it presents a project development flowchart.

72-6.06 Environmental Procedures and Permits

The Environment Planning and Engineering Division will evaluate the environmental impacts of the proposed project and determine the environmental class of action. A bridge rehabilitation project will most often be a Categorical Exclusion. The designer should prepare all permit applications. The Design Division's permits coordinator will secure all necessary environmental permits or certifications related to waterways. See Chapters Seven and Nine for more information on environmental considerations and permits.

72-6.07 Circular Crown Cross Slope

The cross slope may sometimes be that of a circular crown or other irregular form. The options to be considered are as follows:

1. overlay the deck and retain the existing circular crown;
2. overlay the deck and change the crown to a 1.5% cross slope; or
3. replace the deck.

Factors to consider include the following:

1. condition of the existing deck;
2. cost to overlay the existing deck versus cost of a new deck;
3. overlay thickness required to achieve a 1.5% cross slope;
4. crash frequency;
5. average annual daily traffic;
6. existing approach pavement condition;
7. future plans to upgrade the approach pavement; and
8. need to minimize traffic disruption by coordinating road and bridge work.

If it is decided to overlay the deck and retain the existing circular crown, a design exception is required. Each of the factors listed above should be addressed in the design exception request. See Section 40-8.0 for additional information.