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CHAPTER 1 GENERAL BRIDGE INFORMATION

This chapter describes the mechanics, components, construction materials, and classifications of bridges. This part of the manual addresses subjects common to fixed and movable bridges. Refer to Part 3 of this manual for a discussion of components unique to movable bridges.

SECTION 1.1 INTRODUCTION

Fixed bridges are the most common structures which carry the traveling public over roadways, railways, waterways, and valleys. Movable bridges are common over navigable waterways where the height of a fixed bridge would otherwise restrict marine traffic. It is the responsibility of the agencies that own both fixed and movable structures to uphold the public’s confidence in the infrastructure by knowing the condition of their structures and by maintaining them in a safe and cost-effective manner.

It is critical to know when a structure or component thereof has deteriorated to such an extent that it is unable to support the loads it is designed to carry. One of the responsibilities of a bridge inspector is to recognize this condition. To make this judgment, as well as to write a meaningful inspection report, an inspector must be knowledgeable about structural mechanics, be able to identify the components of a bridge and know their functions, and understand the behavior of different materials.

SECTION 1.2 OVERVIEW OF BRIDGE MECHANICS

A bridge inspector must know how a bridge functions to recognize and judge how a defect affects the load-carrying ability of a member and, eventually, the entire bridge. This section briefly describes bridge loads and bridge geometric classifications with the associated behavior of each. A more complete discussion may be found in the Bridge Inspector’s Reference Manual (BIRM).

Subsection 1.2.1 Design Loads

Bridge loads can be divided into three general categories: dead, primary live, and secondary.

Dead loads are the permanent self-weight loads of the bridge. Dead loads include the weight of items such as girders, deck, railings, diaphragms, and overlays. Utilities mounted on a bridge are also considered dead loads. Dead loads are gravity loads and exert downward forces on the bridge.

Primary live loads are the temporary gravity loads that act on the structure. These include all moving vehicles (trucks, cars, trains), with their associated impact loads, and pedestrians. Current American Association of State Highway and Transportation Officials (AASHTO) specifications for bridges establish the design live loads for highway bridges. Depending on a bridge’s use, different design trucks are specified. Differences include the design truck’s weight (15 tons up to 36 tons), number of axles (two or three), and axle spacing (14 feet to 30 feet). Major highways designed prior to the current Load and Resistance Factor Design (LRFD) specifications were designed for an alternate
military loading vehicle as well. The LRFD specification uses a design tandem with a pair of 25-kip axles in place of the alternate military vehicle which had a pair of 24-kip axles. It should be noted that the design vehicles do not represent actual trucks found on highways, but were developed to represent an approximate live load for consistent design. The maximum pedestrian load on sidewalks or pedestrian bridges is 85 pounds per square foot. Primary live loads are gravity loads and exert downward forces on the bridge. Load rating of bridges is discussed further in Part 1, Chapter 9 of this manual.

Secondary loads are all remaining loads which act on the bridge, many of which act in a lateral direction. These loads include the following:

**Buoyancy** – Upward forces on substructures when submerged in water

**Centrifugal forces** – Forces transverse to curved bridges due to vehicles traveling around a curve

**Curb loads** – Lateral forces due to vehicle wheels

**Earth pressure** – Lateral soil pressure on abutments and retaining walls

**Earthquake** – Lateral and vertical forces caused by seismic events

**Friction forces** – Transferred from bearings

**Ice pressure** – Lateral forces caused by river or stream ice flow hitting bridge components

**Longitudinal forces** – Forces parallel to the bridge span due to vehicles braking and accelerating

**Railing loads** – Lateral forces due to errant vehicles or pedestrians

**Rib shortening** – Forces in arches and frames caused by dead load deformations

**Shrinkage** – Forces within concrete members caused by member dimensional changes due to curing

**Stream flow pressures** – Lateral forces caused by river or stream flow acting on bridge members

**Temperature** – Forces within members caused by member dimensional changes due to temperature fluctuations

**Wind load on the primary live loads** – Lateral pressures transferred to the bridge due to wind blowing on the sides of vehicles traveling across the bridge

**Wind load on the structure** – Pressures due to wind blowing on the sides of bridge members

**Subsection 1.2.2 Simply Supported Spans**

A simply supported span is the most basic type of bridge and the easiest for an engineer to analyze and design. It forms a stand-alone, single span, with its beams or trusses commonly supported with one fixed end and one movable end. The movable end bearing devices allow the bridge to rotate and expand under load and temperature changes. On some bridges, the beam ends are encased within a concrete diaphragm
over the abutments, hiding the bearing devices. Simply supported bridges can be very forgiving structures should one of the supports settle. The bearings act like hinges to allow for unrestrained, free movement. Simply supported bridges can also be very unforgiving structures should the beams ever fail between the supports. A failed beam section may act as a third hinge, causing structural instability.

![Figure 4:1-1: Simply Supported Span with Prestressed Concrete Beams](image)

The most common simply supported bridges are single span structures with the beam ends bearing on abutments. Alternatively, a bridge may consist of a series of simply supported spans, with the beam ends supported on abutments or piers. Each pier will therefore support two lines of bearings. To allow for unrestrained rotation of the bridge ends, joints are normally provided in the deck above all abutments and piers with simply supported spans.

When a simply supported span is loaded, it deflects downward between its supports and rotates at its bearings. For a uniformly loaded beam, shear forces (vertical forces within the beam) are maximum at the supports, and zero at midspan. Point loads produce uniform shears of varying magnitudes along the beam. For a simply supported beam with any type of loading, the amount of bending is zero at the supports. Bending is a maximum at midspan for uniform loading or directly under the load for point loading.
An important mechanical concept to understand is beam bending. Bending is measured in units of length, multiplied by force (defined as a moment). Most commonly in the U.S., moment is measured in foot-kips or foot-pounds. For example, suppose a person wanted to hold, horizontally, a 5-pound hammer with a 1-foot-long handle in one hand. The person’s wrist would need to resist a 5-pound x 1-foot = 5 foot-pound bending moment. If the hammer weighed 10 pounds, a 10-pound x 1-foot = 10 foot-pound bending moment would need to be resisted. Similarly, a 5-pound-hammer with a 2-foot-long handle would produce a 5-pound x 2-foot = 10 foot-pound bending moment.

As it relates to a beam, bending is classified as either a positive or negative. A deflected beam having a concave curve (producing a “smiling face”) will be resisting positive bending moments. A deflected beam having a convex curve (producing a “frowning face”) will be resisting negative bending moments. When a beam is resisting positive bending moments, the fibers at the top surface of the beam are shortened and experience compressive stresses, while the fibers at the bottom surface are stretched and experience tensile stresses. Conversely, when a beam is resisting negative bending moments, the fibers at the bottom surface of the beam are experiencing compressive stresses, while the fibers at the top surface are experiencing tensile stresses. In both situations, there is a point somewhere between the beam’s top and
bottom that does not change length. Since there is no length change, there are no stresses generated. This point on the beam’s cross-section is known as the neutral axis. Simply supported bridge spans will always deflect in a concave shaped curve and will, therefore, only experience positive bending moments. As a result, the top fibers, or flanges, of the beams will always be in compression, and the bottom fibers, or bottom flanges, will always be in tension.

**Subsection 1.2.3 Continuous Spans**

Continuous spans are more complex in their behavior, design, and analysis. Continuous spans are beams or trusses with supports at their ends with one or more intermediate supports. As with simply supported spans, the supports are most commonly pins, rockers, rollers, or bearing pads which allow the bridge to rock, rotate, and expand under load. Continuous bridges can be very forgiving structures should the beams ever fail between the supports. To illustrate this, if the middle span of a three-span bridge fails and creates a hinge, the end spans can act as anchor spans. In doing so, the end spans can prevent a collapse by acting as levers with pivots at the piers to hold up the failed middle span. Conversely, continuous bridges can be unforgiving structures should one of the supports settle. Since continuous spans have no internal hinges, support settlements act like additional loads to the bridge. Depending on which support settles, the settlement load may overstress and possibly fail the beams.

In continuous spans, the beam depths will be smaller, deflections will be less, and spans can be made longer in comparison with multiple simple spans. Also, each pier under a continuous span will have only one line of bearings, saving costs in multi-span structures. Because the beams are continuous over the intermediate supports, deck joints are not required, which is another economic advantage. This also provides a smoother riding surface. Continuous bridges can cost more to design, fabricate, and erect than simple span bridges and are subject to developing transverse deck cracks over the piers.

![Continuous Span Bridge with Steel Girders](image-url)
When a continuous span bridge is uniformly loaded, it deflects downward between the supports and rotates at its supports. Shear forces are at a maximum at the supports and zero at or near midspan. Positive bending moments are at a maximum between supports, while negative bending moments are at a maximum directly over the interior supports. The deflected shape of the bridge will therefore have a concave curve between supports and convex curvature over the supports. Point loads produce more complex patterns of shears and bending moments. Point loads will deflect the beam downward in the loaded span producing uniform shears of varying magnitudes and a maximum bending moment at the point of the load. For any loading type, the bending moment is zero at locations where the curvature changes from concave to convex and at the end supports.

Subsection 1.2.4  Cantilever Spans

A cantilever span has one end that is free to deflect and rotate and one end that is fixed against deflection. The fixed end is idealized as fully fixed against rotation; but, in reality, a small amount of rotation will occur. The deflected shape of a cantilever span
will always be convex. Therefore, bending moments are always negative and vary from zero at the free end to a maximum at the fixed end. At the free end, shear forces may be zero, but are usually relatively high since tips of the cantilevers are commonly used to support the end of another span. Shear forces are a maximum at the fixed end. The free ends of cantilever spans are always locations for expansion joints.

Figure 4:1-5: Steel Cantilever Span

Cantilever spans will rarely form an entire bridge, but are typically portions of a structure. Usually, fixed cantilevers are simply extensions of continuous spans, with the continuous spans providing anchorage for the cantilever. Long span bridges frequently employ cantilevers to form part of the main crossing. The tips of two cantilevers sometimes meet in the middle; but, more commonly, an independent simply supported structure is suspended between the tips of each cantilever. On some large girder bridges, short cantilever spans may be used to join a series of independent continuous bridges to form a single, long structure. The cantilever span free end is sometimes called a ship lap joint, since the supported span of one structure laps over the cantilever supporting span. Cantilever spans reduce the positive bending moment in adjacent spans and can eliminate the use of expensive shoring for the main span construction of truss cantilevers.
Subsection 1.2.5  Span Definition Overview

Figure 4:1-7 summarizes the span types discussed above.
SECTION 1.3 FIXED BRIDGE COMPONENTS

There are three basic components common to most fixed bridges. These components are the deck, superstructure, and substructure.

Subsection 1.3.1 Deck

A deck provides a place to drive or walk and transfers the live loads and dead loads to superstructure. Sometimes, the deck acts compositely to become part of the beam’s top compression flange. On concrete slab bridges, the deck itself is the main load-carrying member, delivering all live and dead loads directly to the substructure units.

Subsection 1.3.2 Superstructure

The superstructure supports the deck and all of the live and dead loads applied to it, delivering these loads to the substructure units. There are three main types of bridge superstructures: beam bridges such as slab, beam, girder, and truss bridges; arch bridges; and cable-supported bridges such as cable-stayed and suspension bridges. The difference is in how each type delivers loads to the bridge supports. Beam type superstructures act primarily in bending, arches in compression, and cable-supported in tension.
Subsection 1.3.3 Substructure

Substructure units of a bridge support the superstructure and deliver all of the bridge live and dead loads to the foundation soil or rock. Substructure units include the abutments, wing walls, piers/bents, and, in the case of suspension bridges, the cable anchorages. Abutments provide superstructure support at the ends of the bridge, while piers and bents provide intermediate support. In addition to providing support for vertical loads, other loads must be resisted by the substructure, such as horizontal loads due to lateral pressures (soil, wind, current, and impact) and temperature expansion effects. Substructure components must, therefore, function as both compression and bending elements.

SECTION 1.4 BRIDGE MATERIALS

Several materials can be used to construct the various components of a bridge. Each has its own advantages and disadvantages with respect to material properties, weight, durability, cost, and appearance. It is of primary importance for a bridge inspector to understand the material properties, to understand the durability of each material, to recognize the seriousness of the material’s deterioration and its causes, and to know the best remedial actions for each material.

Subsection 1.4.1 Concrete

(a) PHYSICAL PROPERTIES

Concrete is a building material used since the ancient Roman Empire. It is a mixture of cement, water, and aggregate (sand and stone). When cement is mixed with water, a chemical reaction takes place that produces a strong, durable construction bonding material. Aggregates, which typically comprise approximately 75 percent of a concrete mix by volume, are used as an inexpensive filler material. In addition, aggregate improves a concrete’s abrasion and weather resistance. Entrained air increases workability while the concrete is being placed and improves its durability against freeze/thaw once the concrete has cured.

Plain concrete weighs about 145 pounds per cubic foot, and concrete reinforced with steel bars weighs approximately 150 pounds per cubic foot. Entrained air within the cement paste allows the absorption and passage of water, making concrete a somewhat porous material. It expands and contracts with increasing and decreasing temperatures, respectively.

(b) MECHANICAL PROPERTIES

Concrete is a material used for its compressive strength, which generally ranges from 2,500 pounds per square inch to 6,000 pounds per square inch. High-performance concrete may develop compression strengths in the 10,000 psi range. Its tensile and shear strengths are poor, being only about 10 percent and 12 percent, respectively, of its compressive strength.

To make concrete ductile and usable, reinforcing steel bars, often referred to as rebar, are cast within the concrete mass to create a heterogeneous material known as
reinforced concrete. The reinforcing steel is able to resist the tensile forces that the concrete is unable to withstand. The concrete and reinforcing steel also work together in carrying a member’s shear forces. Reinforcing steel bars that transfer shear forces are placed as vertical stirrups in beams and as horizontal ties in columns. Reinforcing steel resists the tensile forces generated as a member undergoes bending. As an example, a simply supported reinforced concrete beam experiences only positive bending moments, generating compressive stresses near the top of the beam and tensile stresses near the bottom. As the beam is loaded to its ultimate capacity, the concrete’s tensile capacity near the bottom surface will be exceeded, and the concrete will crack. A simply supported reinforced concrete beam will therefore have its reinforcing steel placed near the bottom surface to resist the tensile load. Concrete near the top surface resists the compressive loads.

Reinforcing steel is “deformed,” or has transverse ribs, to provide a mechanical interlock with the concrete. In prestressed or post-tensioned concrete, high-strength steel strands or bars replace deformed reinforcing steel. For prestressed concrete beams, the strands are pulled into tension and concrete is cast around them. The strands are released (cut) after the concrete is cured. The tensile force of the released strands introduces compressive stresses into the concrete. For post-tensioned concrete beams (usually made in the field), concrete is cast around ducts placed near the beam’s tension surfaces. After curing, post-tensioning strands or rods are placed into the ducts, anchored at one end, and stretched into tension by jacking at the other end of the beam. Locking or anchoring the jacked ends keeps the strands/bars in tension, introducing compression into the concrete. The ducts are grouted after the strands or bars are stressed. Prestressing and post-tensioning minimize or eliminate net tensile stresses in the concrete. With the concrete and steel working together, a strong, ductile, and durable construction material is created.

(c) **CONCRETE DETERIORATION**

Concrete can experience many types of deterioration and the causes of each can vary. It is important for the inspector to understand these causes so that a proper evaluation and recommendation can be made.

Delamination is the separation of concrete at or near the level of the reinforcing steel, and is mainly caused by reinforcing steel corrosion. Delamination can also be caused by overstress in the member. Corroded steel has a volume approximately seven to 10 times that of the original steel. Since concrete has only limited tensile strength to counteract this expansive force, it cracks internally in a plane along the layer of reinforcing steel. The presence of delamination may indicate that chlorides, salts, or other corrosive chemicals have reached the reinforcing steel.
Detection of Delamination is often performed by sounding the surface with a hammer. Chain dragging, a technique similar to hammer sounding, can be used to detect Delamination on the top of a bridge deck. For each method, a popping or hollow sound is generated when the hammer hits or the chain drags over a delaminated area. Thin delaminations are more readily detected than thicker ones since thicker delaminations will begin to sound more like undamaged concrete. Sometimes slight surface discolorations, surface cracks, moisture, or rust stains indicate the presence of delamination. Delaminated areas should be outlined with a lumber crayon or spray paint to allow for monitoring of the deterioration rate or to mark the area for removal.

One high-tech method for delamination detection is infrared thermography. It is mostly used for large area deck investigations or high-traffic situations. It is discussed further in Part 4, Chapter 4.

If it can be performed safely, removal of small delaminated areas may be done during an inspection. Removing the delaminated concrete allows the base concrete to dry out, slowing down the reinforcing steel corrosion process. Additionally, removing concrete in a controlled manner eliminates the possibility of the delaminated area suddenly falling and causing damage below. Large areas of delaminated concrete should be removed as a maintenance action if there is any possibility that its falling could result in damage.

When delaminated concrete is removed or falls off of the base concrete, the resulting depression is called a spall. Spalls are typically circular or oval in shape, often exposing the surface of the corroded reinforcing steel. Causes of spall formation include freeze/thaw action from trapped water, friction from thermal movement, expansive effects from reinforcing steel corrosion, and impact fractures.
The high alkaline environment of concrete temporarily protects the underlying reinforcing steel from corrosion. As the structure ages, however, chlorides from deicing salts and potentially corrosive atmospheres may reach the steel reinforcement by diffusion through the concrete or cracks in the concrete cover. These chemicals, along with moisture and oxygen, form an electrolytic cell that corrodes the steel. As the corrosion advances, it expands, delaminating and spalling the concrete.

Heavy reinforcement corrosion can lead to a structural capacity loss in a member. As corrosion advances, the cross-sectional area of the reinforcing steel is reduced. Since the reinforcing steel must resist the same load, its stresses increase. Excessive section loss may lead to yielding or fracture during an overload. Fortunately, however, there are usually several reinforcing steel bars carrying the tensile loads in any one member. This results in redundancy and a lesser likelihood that a total member failure will occur.
Cracks are linear fractures in the concrete that may extend partially or completely through a member. Due to the nature of reinforced concrete, it is not possible to prevent crack development. Prestressed concrete should not develop any cracks, other than shrinkage cracks, under normal use. Cracks in the flexural region of beams may indicate a serious structural overload. Cracks are described by their length, width, type, and orientation. Prestressed concrete members may have cracks as a result of fabrication at or near the beam ends. These should be noted in the initial inspection.

The BIRM classifies cracks as hairline, narrow, medium, or wide. On conventionally reinforced structures, hairline cracks less than 1/16 inch wide are visible, but difficult to measure and usually insignificant. Cracks larger than 1/16 inch could be structurally significant and should be monitored and recorded in the inspection notes. Narrow cracks have widths between 1/16 inch and 1/8 inch and may be measured with a finely divided ruler or crack comparator card. Medium cracks are 1/8 inch to 3/16 inch wide. Cracks over 3/16 inch are considered wide. When cracks approach this width, aggregate interlock can be lost, resulting in the loss of shear capacity at the ends of slabs and beams.

On prestressed structures, all cracks are significant and an optical crack gauge is needed to measure the cracks. Hairline cracks have widths less than 0.004 inch. Narrow cracks are 0.004 to 0.009 inch. Medium cracks are 0.01 to 0.03 inch. Wide cracks are over 0.03 inch.

Figure 4:1-12: Map Cracks in a Wingwall
Cracks are grouped into two categories: structural and nonstructural.

Structural cracks are caused by dead and live loads and include flexural and shear cracks. Flexural cracks always develop on the tension surface near the point of...
maximum moment of reinforced concrete members. Flexural cracks are most commonly seen on undersides of beams near midspan, between the piers, but are also found on continuous beam tops and decks above the piers due to negative bending moments. Columns under fixed supports may develop flexural cracks when expansion/shrinkage of the superstructure bends the pier. Flexural cracks are oriented perpendicular to the length of the member. The longest cracks are located in areas of the highest bending moment, sometimes extending up to about 75 percent of the member’s depth. Flexural crack lengths shorten as bending moments are reduced. Shear cracks, if present, will always develop near piers and abutments and are always oriented diagonally. These cracks begin near the bearing and extend up towards midspan at an approximate 45-degree angle. Cracks in prestressed members originating at the prestressing strands and inclined diagonally down towards the center of the beam are related to fabrication and the release of tensioning. These are generally nonstructural cracks.

Structural cracks develop when tensile stresses acting on the member exceed the tensile strength of concrete. Reinforcing steel embedded within the concrete picks up all tensile forces immediately upon cracking. Normal loading generally causes uniformly spaced hairline cracks in reinforced concrete. These are not generally viewed as a problem. Narrow to wide cracks accompanied by excessive deflections, or any flexural cracks found in prestressed beams, suggest that the bridge has been overloaded. Foundation movement or settlement can induce stresses in the superstructure or substructure members which can also cause flexural cracks.

Nonstructural cracks do not generally affect the load-carrying capacity of the member. All concrete develops small, generally shallow, nonstructural cracks due to drying and shrinkage during the curing process. Concrete creep (the increased deflections or shortening under sustained loads) and seasonal temperature changes expand and contract the concrete after it has cured. This causes further random cracks. These long-term effects can have serious consequences if the movable bearings become locked up, restraining concrete movement and increasing the crack widths. A nominal amount of reinforcing steel placed transverse and longitudinal to the member controls widths and lengths of shrinkage and temperature cracks.

Depending on the cause of cracking, cracks can travel in several directions within a structural member. Cracks are generally oriented perpendicular to the stress that caused the crack. Their patterns may be described as follows:

**Map cracking** – Nonstructural temperature/shrinkage cracks which travel randomly within the member. Several usually occur within any given area, giving the surface an appearance of a road map.

**Random cracks** – Individual meandering cracks.

**Transverse cracks** – Cracks oriented perpendicular to the bridge centerline. May be structural flexural cracks on slab bridges or nonstructural temperature/shrinkage cracks on bridge decks. These are commonly found in the deck over floor beams in truss structures.

**Longitudinal cracks** – Cracks oriented parallel to the bridge centerline or horizontal members such as beams, girders, slabs, decks, or parapets.
Horizontal cracks – Cracks oriented transversely to vertical members such as structural flexural cracks in pier shafts, pier columns, walls, and abutments.

Vertical cracks – Cracks oriented vertically on vertical members such as pier shafts, columns, walls, and abutments.

Diagonal cracks – Cracks angled with respect to the member centerline; commonly structural shear cracks.

D-cracks – Letter “D”-shaped cracks found at the edge of deck or slab joints, especially on skewed decks.

Radial cracks – Cracks oriented in a circular pattern; may indicate a punching shear type of failure in a bridge deck.

Efflorescence, informally referred to as leaching, is a white deposit on the concrete surface caused by the crystallization of soluble salts (calcium chloride, calcium hydroxide) contained within the cement paste. Water traveling through the concrete dissolves these salts and usually deposits them along cracks where the water exits. Efflorescence indicates that water and dissolved chemicals are able to pass through and contaminate the concrete.

Light efflorescence does not affect the compressive strength of the concrete paste. Heavy efflorescence, which is sometimes accompanied with rust stains from reinforcing steel corrosion, indicates a reduction in the compressive strength of the concrete and reduction in the structural member’s overall strength. A corresponding wet look to the concrete on the underside of a concrete deck, slab, or concrete member indicates the concrete may be unsound and debond from the lower layer of steel reinforcing and fall off the deck, slab, or concrete member.

![Figure 4:1-15: Heavy Efflorescence on an Abutment and Slab](image)

Scaling is the gradual loss of cement paste and surface aggregates caused by freeze/thaw activity or chemical degradation. It is classified by the BIRM as light, medium, heavy, or severe. Light scaling indicates mortar loss of up to 1/4 inch with surface exposure of coarse aggregates. Medium scaling indicates mortar loss from 1/4
inch to 1/2 inch, exposing coarse aggregates. Heavy scaling indicates mortar loss of from 1/2 inch to 1 inch with clear exposure of the coarse aggregates. Severe scaling indicates a loss of coarse aggregate, as well as surface mortar, with depths greater than 1 inch; reinforcing steel may be exposed.

![Figure 4:1-16: Medium Scaling on Bridge Pier](image)

Scaling is typically located along the gutter lines of the deck and is caused by deicing chemicals. Ponded salt water along the gutter, caused by clogged drains or scuppers, is the usual culprit for the chemical attacks. Other bridge components, especially substructure units located in a waterway, can be subjected to scaling by way of sulfate compounds found in soil and water and the freeze/thaw action of the waterway.

**Pop-outs** are small conical shaped depressions in the concrete surface caused by coarse aggregates which expand during moisture absorption. Shale and chert are common expansive aggregate types.
Pop-outs may also be caused by reactive aggregates and high alkali cement. Pop-outs can normally be discerned by seeing the aggregate particle’s fractured surface in the bottom of the depression. Pop-outs themselves are not a structural concern, although the pop-outs may eventually cause a rougher ride or help to speed the rate at which water can reach the underlying reinforcing steel.

![Figure 4:1-18: Pop-Out on Concrete Deck](image1)

**Honeycombs** are voids within the concrete mass caused by congested reinforcing steel or improper concrete vibration during construction. Small honeycombs are not detrimental to the strength of the member, whereas large honeycombs may be structurally significant. Severe honeycombing may leave some of the reinforcing steel within the member uncovered. Only voids adjacent to the concrete surface are detectable by visual inspection techniques.

![Figure 4:1-19: Honeycombing on Concrete Pier](image2)
Trucks, over-height vehicles, derailed trains, floating debris, and marine traffic may strike and damage concrete piers, abutments, or girders. Stream debris or ice floes may also impact bridge piers or abutments located in the channel. Large sections of concrete may be cracked or chipped off a structural member, exposing reinforcing steel or prestressing strands. If damaged sections are similar to spalls, patching may be used as a repair method. Damaged prestressed beams with exposed or broken strands generally need to be replaced. Serious impacts can result in the failure of pier columns or girders. A bridge may need to be closed until the severity of the damage is assessed. Damage inspections are discussed in Part 1, Section 3.8.

Abrasion causes section loss of concrete members over time. Surface abrasion is often caused by the erosive action of silt or sand found in fast-flowing rivers, streams, or surf zones. It affects piers, pilings, and abutments. Decks, curbs, and parapets are subject to abrasion from snow plows, street sweepers, tire chains, and studded tires.

Though concrete is considered a fire-resistant material, fire can cause deterioration. Surface effects of fire may include deposition of combustible materials and discoloration on the concrete surface. Concrete pop-outs, scaling, delaminations, and spalls may be caused by the intense heat expanding the aggregate and reinforcing steel and the expansion of moisture present in the concrete. Prolonged exposure to fire may cause the deterioration of the concrete matrix. When this is suspected, concrete samples should be obtained for laboratory examination.
Subsection 1.4.2 Structural Steel

Carbon steel is often referred to simply as steel and has been a widely used building material since the latter part of the 19th century. Steel is differentiated from iron by the inclusion of carbon and other alloying elements. Many standard cross-sectional steel shapes such as angles, channels, and wide flange sections are produced by rolling mills. Nonstandard shapes may be created by welding, bolting, or riveting together combinations of flat plates and/or smaller rolled sections. In Indiana, all rolled I-shaped members are called rolled beams and all built up I-shaped members are called girders.

(a) PHYSICAL PROPERTIES

Steel weighs approximately 490 pounds per cubic foot. The chemical composition of steel varies widely depending on the type of steel. Steels used for bridge construction are normally classified as low carbon steels, containing less than 0.30 percent carbon. Various alloying elements such as copper, chrome, manganese, silicone, vanadium, and nickel are added for improved mechanical properties, weldability, and corrosion resistance. Steel also contains deleterious elements such as sulphur and phosphorus. Higher-strength steels are produced using higher percentages of alloying elements coupled with heat-treatment. These are known as quenched and tempered alloy steels, and they are not commonly used for bridge structures.

Unprotected structural steel will readily corrode or rust. Painting and galvanizing (the application of a sacrificial coating of zinc) are the most common methods used to protect steel against atmospheric corrosion. Some steels, known as weathering steels, oxidize to produce a dense protective coating of rust which inhibits further corrosion. When used in the proper environment, these steels require no painting and develop an even-textured, dark red-brown appearance.

(b) MECHANICAL PROPERTIES

Steel is a material used for its high tensile and compressive strengths. The yield strength of steel, the greatest stress a material can withstand without being permanently deformed, ranges from approximately 28,000 pounds per square inch to 70,000 pounds per square inch. Tensile and compressive yield strengths are the same. Shear strength is about 60 percent of the steel’s yield strength.

When stressed below its yield point, steel is elastic and a loaded beam will return to its unloaded position once the load is removed. Should high loads or impacts be applied which produce stresses beyond yield, the member will be permanently deformed. Because steel is ductile, it can usually withstand these deformations without failure. However, steel may have reduced ductility or become brittle due to the effects of welding, heat treatment, fatigue, or very low temperatures.

Fatigue is material fracture under cyclic loading at stresses below its yield strength. It affects the part of a member’s cross-section subject to varying tensile stresses or stress reversals. Steel strength is reduced if it is subject to a large number of stress fluctuations or reversals. This strength reduction depends on the number of load cycles, the magnitude of the stress fluctuation, and the type of detail involved. Reductions in allowable stresses may be required when discontinuities such as changes in the cross-
section, cuts, tack welds, and rough edges exist. Small discontinuities may be removed or improved by grinding to a smooth profile.

Sudden fracture of a steel member may occur under unique circumstances when a member is being stressed in multiple directions.

(c) STEEL DETERIORATION

Steel can have many types of defects and is subject to many types of damage, including corrosion, fatigue, overload, impact, and fire. Steel’s susceptibility to corrosion and fatigue damage makes reporting these defects all the more critical.

The following information is a brief overview of causes of fatigue cracking in steel. An excellent resource for a more complete discussion of fatigue, as well as for example photographs and diagrams, is the *Manual for Inspecting Bridges for Fatigue Damage Conditions* by Yen, Huang, Lai, and Fisher.

Corrosion, or rust, is the most visible type of steel deterioration. It is a chemical reaction in which the iron in the steel combines with oxygen in the air to form ferric oxide and ferric hydroxide. More specifically, it is an electrochemical process between an area having a tendency to corrode (the anode) and an area with a lower tendency to corrode (the cathode). The anode and cathode may be located on the same piece of steel. A liquid electrolyte (water) must be present to allow for the flow of metal ions, and a conductor (the steel itself) must be present to allow electron flow from the anode to the cathode. Iron in the steel dissolves in the water to form iron ions. These ions react with oxygen in the air to form rust at the anode. Electrons that flow from the anode to the cathode combine with other ions in the water, typically hydrogen ions, to form hydrogen gas. As a result, the cathode is left undamaged.

![Figure 4:1-21: Steel Corrosion at Girder Splice](image-url)
The corrosion process can be stopped by preventing the electrolyte (water) from coming in contact with the base metal. In most steel bridge structures, this is done by the application of a protective paint coating. In lieu of painting, a galvanized coating may be applied. The galvanized zinc provides both a barrier coating and a galvanic protection layer. Since zinc has a greater tendency to corrode than iron, it becomes the anode and the steel becomes the cathode.

Once the base steel is exposed to the atmosphere, there are several causes for corrosion. The most common cause is the environment, and this primarily affects steel in contact with water or soil. Impurities in water, such as deicing chemicals, bird waste, atmospheric pollutants, and acids in the soil, produce ionic solutions which create more efficient electrolytes, increasing the rate of corrosion.

Other less common causes for corrosion include fretting, stress corrosion, bacterial-induced corrosion, and direct currents. Fretting is the rubbing of two closely fitted steel parts. Pitting and a red deposit occur at the interface. Stress corrosion occurs when a metal is loaded in tension. The tensile stress exposes an increased amount of surface area at the metal’s grain boundaries, leading to corrosion and cracking. Waterborne bacteria, heavy clay, and contaminated waters can destroy the steel’s protective coating and sometimes corrode the steel itself. Stray currents from sources such as welding equipment, substations, and railway power or signal systems can also create or speed the rate of the electrochemical process.

The three commonly recognized stages of corrosion are light, moderate, and heavy. Light or surface rust is a loose form of corrosion usually appearing as a dark orange or light brown color. It can also be observed as light pitting or spotting on the paint surface. Its effect is not serious, as it does not oxidize away a measurable amount of the steel. Moderate corrosion has a medium to dark brown color and a scaly appearance. Shallow pits may have formed in the steel surface. There is no paint left to protect the steel, and small amounts of section loss may have occurred. Heavy corrosion is easily recognized by its dark brown to almost black color, flaking, and laminations. These rust laminations may be removed with a chipping hammer, exposing large deep pits in the steel surface. Heavy corrosion causes reductions in plate thickness that can easily be seen with the naked eye or can even cause through-thickness section loss.

Corrosion can occur between two plates that are riveted, bolted, or pinned together, such as field splices, bracing connections, cover plates, hanger bars, or bearings. If the plates are not clamped tightly together or paint does not properly seal the edge of the faying surface, moisture is able to penetrate between the plies. This moisture can remain for extended periods, since it is difficult for this area to dry out. When corrosion begins, it expands to separate the plates, providing increased moisture penetration and creating prying forces on the fasteners. Advanced corrosion will exhibit layered rust, plate bending, and failed rivets or bolts.
If left unchecked, corrosion will remove a significant quantity of a member’s cross-sectional area. Member stresses increase significantly when the area is reduced.

For example, suppose a member has an uncorroded area of three square inches and carries a load of 60,000 pounds. Stress in the original member is 60,000 pounds ÷ 3 square inches, or 20,000 pounds per square inch. If corrosion removes one-third of the original cross-sectional area, leaving only two square inches of steel, the remaining stress is increased by 50 percent to 60,000 pounds ÷ 2 square inches, or 30,000 pounds per square inch.

For a given load, stress is inversely proportional to the cross-sectional area. Continuing with the procedure above, a 50 percent reduction in area will lead to a stress of 40,000
pounds per square inch. If steel with a yield strength of 36,000 pounds per square inch were used for the member, an overstress and possible failure may occur.

Corrosion causes surface discontinuities in the form of rough edges and surface pits. Discontinuities act as notches. When stress “flow” is forced to bend around a notch, local stresses in the immediate vicinity are greatly amplified. Under repeated loading, the notch may act as a crack initiation point, and the high-stress concentrations, coupled with repeated loading, will eventually tear the steel apart. As a result, a corroded member is more prone to fatigue damage than members with smooth, uncorroded surfaces.

Corrosion that forms at expansion devices such as pins and hangers, sliding plate bearings, and pinned bearings can become so excessive that these devices stop allowing movement. When this occurs, unintended loads are introduced into the structure which could cause overstresses and possible component failure.

Fatigue is material failure or fracture at stress levels below the yield point under cyclic loading. Stress fluctuations are caused by repeated member loading, such as trucks driving over a bridge. Each load cycle causes member stresses to increase and then decrease. The fatigue stress range is the algebraic sum of the minimum and maximum stress at the location. Bending a paper clip back and forth until it breaks is an example of a fatigue failure.

Fatigue cracks are of primary concern since their growth can lead to sudden catastrophic failures. It is extremely important for an inspector to understand where fatigue cracks are likely to occur and be able to identify a fatigue crack. Fatigue crack development depends on several factors. These factors include load frequency, stress type, stress range, and type of detail. Fatigue is discussed in detail in Part 4, Chapter 11.
Steel is more likely to develop fatigue cracks under a high number of load applications. Bridges that experience multiple truck loadings on a daily basis are more prone to fatigue damage than rural or local bridges that carry minimal truck traffic. Older bridges have probably seen a greater number of truckload applications than recently built structures.

Load frequency is generally a concern for highway and railroad bridges where heavy vehicles commonly use the structure. It is generally not a concern for pedestrian bridges, or where the frequency of design loads is relatively low.

Fatigue is most often a concern when the stress during each load cycle is from repeated tension or compression-tension load reversals. Susceptible components include the tension chords, diagonals, and verticals of truss bridges; the tension flanges of beam/girder bridges; and the hangers of suspended girders or trusses. Beam webs can also be subject to fatigue cracking when cross-frames or diaphragms create out-of-plane distortion in the web. Fatigue-prone details are shown in Part 4, Appendix B.

Cyclic compression stresses can also produce fatigue cracks, but any cracking in locations subject to cyclic compression stress is usually due to residual tensile stresses in the steel from welding or uneven cooling after rolling. Cyclic compressive stress is rarely a concern for bridges.

Another factor for steel's susceptibility to fatigue is the stress range. Steel is more likely to crack when the stress range during each load cycle is high.

Resistance to fatigue cracking is not dependant on the yield strength of the steel. Steel toughness, the ability of steel to resist fracture, has an impact on resistance to fatigue, especially at colder temperatures.

Secondary member attachments such as welded cover plate ends, bolt holes, or tack welds create a material discontinuity and introduce an interruption in the stress flow. Each discontinuity acts as a notch in the steel member, creating a sudden rise in the stress level. Smooth transitions are less susceptible to cracking; whereas sharp transitions, such as transverse welds at the end of a cover plate or gouges in the flange, are very susceptible.
Notches force the stress flow to suddenly "bend" around a corner. This sudden direction change produces a rise in the stress which may, on the microscopic level, reach yield. Repeated loading to yield will eventually fracture the steel, creating a crack (similar to the repeated bending of a paper clip mentioned above). Once a crack forms, the cross-sectional area of the member is reduced, and the crack tip acts as a stress riser, leading to higher stresses and further crack growth. If the crack is left unarrested and occurs within a tension or stress reversal zone, the member could eventually tear itself apart.
The AASHTO bridge specifications have categorized several steel bridge details with respect to their susceptibility to fatigue cracking. All were categorized with respect to beam or girder in-plane bending and axial loading of members or member components. See Part 4, Appendix C for these details.

Several inspection techniques are used to detect fatigue cracks. The most common and most important method is visual examination, as this is usually how cracks are found. While it would be ideal to examine every square inch of every element experiencing tensile stress variations or stress reversals, this is unnecessary and expensive. Since fatigue cracks develop at discontinuities, it is reasonable to inspect local suspect details only. Telltale, visual signs suggesting a crack include rust drips (bleeding), rust powder (due to rubbing along the crack), and small, usually rusty cracks. Some cracks can be very large, and in extreme situations they may even open and close under traffic loading. Another sign is a fine line of discoloration in the paint at the toe of a connecting weld or on the surface of a weld. The Manual for Inspecting Bridges for Fatigue Damage Conditions contains several photos and diagrams illustrating these signs. Suspected cracks may be more easily confirmed by using a magnifying glass. All suspect cracks should be reported, and their location marked directly on the member with a permanent felt tipped marker or paint stick.

After visual detection, some small cracks may require confirmation through the use of nondestructive testing techniques. Most commonly, magnetic particle or liquid (dye) penetrant testing is used because these methods are easy to administer, inexpensive, quick, and require fairly low-tech equipment. Since magnetic particle and dye penetrant testing will only reveal the size of the crack at the metal’s surface, more advanced nondestructive techniques may need to be used to establish the extent of a crack within the base metal. The most common advanced method of examination is ultrasonic testing. Generally, more expensive methods include acoustics, eddy current, and radiography (x-ray).
Confirmed cracks should be re-examined during subsequent inspections until the cracks are eliminated or repaired. Shallow cracks may be ground or drilled out. Holes (sometimes referred to as “mouse holes”) may be drilled at the tips of long cracks to eliminate the sharp rise in stress in this area. Longer cracks typically require the drilling of mouse holes plus bolting splice plates to the member. These holes must be properly sized in relation to the length of the crack, the stress range, and the fatigue detail in order to ensure that the crack does not continue past the drilled hole. The plug from the drilled hole and the edges of the hole must be examined to ensure that the end of the crack was correctly identified.

Although the base metal away from component details is generally not a fatigue concern (such as tension flange areas located between diaphragm connections), crack initiation points may still exist in the form of tack welds, welded flange splices not ground smooth, and notches resulting from traffic impact or fabrication carelessness. These flaws should be examined closely and reported. The flaws should also be re-examined during subsequent inspections until they are eliminated or repaired. Tack welds or butt welds with the reinforcement left in place can generally be ground smooth, eliminating the defect. Notches are typically ground smooth to form a smooth, tapering transition in the plate.

A detail contributing to the cracking of many fabricated girders is the web-gap. A web-gap is created when a horizontal gusset plate is notched to fit around a transverse, vertical connection plate. The horizontal gusset plate, used to connect lateral bracing, is then welded directly to the girder web. The small space created between the transverse connection plate and horizontal gusset plate notch is called the web-gap. Web cracking is not related to the in-plane bending details indicated in the AASHTO stress categories. Web-gap cracking is produced by out-of-plane, or sideways, web bending. Forces in the lateral bracing/horizontal gusset plate push and pull on the girder web, causing it to bend sideways (out-of-plane). This bending is restrained due to the stiffness created by the transverse connection plate. As a result, the web is forced to deflect and bend over the very short gap distance, generating extremely high, local stresses. After numerous load cycles, a vertical web crack within the web-gap region will develop, creating a material discontinuity and notch with respect to in-plane bending. This effect is shown in Figure 4:1-28. Left unarrested, this crack can grow into the tension flange to create a critical situation.
Figure 4:1-28: Girder Web Gap Fatigue Crack

(Note the drilled crack arrest holes at crack tips and the outline of the lower lateral shelf plate located on the opposite side of the web in Figure 4:1-28.)

An overload occurs when live loads crossing the bridge are so great that the structural members are stressed beyond their design strength, causing permanent deformation. In tension components, a permanently elongated member, a reduced cross-section, or fracture are all signs that an overload has occurred. Compression members or components may become unstable when overloaded. Symptoms of compression overloading include buckled members that form either a single, curved bow, or a double, curved “S” shape. Bucking or waviness in plates or outstanding beam flanges or the legs of angles also indicates compression stress overloads. Separations or wrinkling in paint coatings in the absence of corrosion may also indicate member overloads.

Impact damage, most often caused by vehicular collisions, normally occurs above the roadway or waterway on the fascia girder. Stream debris or ice floes may also impact bridge piers or abutments located in the channel. Indications include dislocated and distorted members and scrape marks on the flange undersides. Distorted portions of members or components may act as stress risers, making a normally sound component a fatigue-prone detail. A bridge may need to be closed until the severity of the damage is assessed. Damage inspections are discussed in Part 1, Section 3.8.
Unprotected steel has poor resistance to extended heat exposure. Although it is incombustible, both the yield strength and the modulus of elasticity are reduced at elevated temperatures. Yield strengths of steels normally used in bridge construction are reduced by about 23 percent at 800 degrees Fahrenheit, 37 percent at 1,000 degrees Fahrenheit, and 63 percent at 1,200 degrees Fahrenheit. Melting points of different steel alloys vary, but the melting temperature of pure iron, about 2,800 degrees Fahrenheit, is a good approximation. Thermal expansion can produce high axial forces and steel properties may be adversely affected by rapid quenching in efforts to extinguish a fire.

**Subsection 1.4.3 Timber**

Timber has been a widely used building material for all of recorded history. Timber has many advantages as a bridge material, including excellent resistance to fatigue and impact loading, resistance to deicing chemicals and freeze/thaw effects, a favorable strength to weight ratio, and ease of construction. Timber bridges can be aesthetically pleasing. Timber is a readily available, renewable resource. Traditionally, solid sawn lumber was used for all bridge components due to the abundance of large, old growth trees. Current manufacturing processes allow very large timber members to be created by glue-laminating several smaller pieces together. These members can be assembled into many types of structures including slabs, beams, trusses, arches, trestles, and even suspension bridges. Timber bridges are generally inefficient for long spans and are subject to insect and biological attack.

(a) **PHYSICAL PROPERTIES**

Wood used for bridge construction weighs about 50 pounds per cubic foot, although this value can vary widely, depending upon the wood species and moisture content. It is a hygroscopic material that absorbs and loses moisture as the humidity of the air
changes. These moisture content fluctuations cause the wood to expand and shrink. Wood is an orthotropic material, meaning that its physical properties parallel to the grain are different than those perpendicular to the grain. It is resistant to many chemicals. Heavy wood members resist continued fire damage by the forming of a char layer that acts to insulate the underlying sound wood.

Features related to tree growth, such as knots, splits, checks, and shakes, can adversely affect a member’s strength. High moisture content can also negatively affect the wood’s strength, and wood without a preservative treatment has limited resistance to decay or insect attack. Fungi, termites, carpenter ants, powder-post beetles, marine borers, and caddis flies are the most common sources for timber deterioration.

(b) MECHANICAL PROPERTIES

Wood is a material used for its tension, compression, and bending capabilities. Its mechanical properties vary greatly from species to species. Because wood is an orthotropic material, the mechanical properties also vary depending on its principal axes of anatomical symmetry. Ultimate strengths for the most common properties used in design range from 6,600 to 17,500 pounds per square inch for tension parallel to the grain, 1,700 to 10,100 pounds per square inch for compression parallel to the grain, 3,900 to 20,200 pounds per square inch for bending, and 500 to 2,600 pounds per square inch for shear parallel to the grain. Similar properties in wood’s other two orthogonal directions (perpendicular to the grain in the radial and tangential directions) will have different ultimate strength values.

For most engineering applications, wood behaves elastically, and a beam stressed below its ultimate strength will return to its unstressed shape once the load is removed. Recovery from its deformed loaded shape may not be immediate. If the load had been in place long-term, recovery will take a longer period of time. Wood is susceptible to creep. Creep is a gradual deformation under a sustained load. Over a period of years, the initial deflection of a wood beam can eventually double under high, permanent loading.

Should high-dynamic impact loads be applied, wood is a very resilient material. It can sustain dynamic loads up to approximately twice the amount that would produce failures if applied statically.

(c) TIMBER DETERIORATION

Timber is susceptible to deterioration and damage. Untreated wood can suffer structural deterioration due to insect or biological attack. Treated or untreated wood is susceptible to structural damage from mechanical or atmospheric sources such as fire, vehicle impact, overloads, and drying.

Biological damage to wood is caused by living organisms. The main defense against such attacks is to treat the wood with chemical preservatives. Decay caused by fungi is the primary reason for timber bridge replacement. Brown rot and white rot are the two fungi most responsible for structural damage. They feed on the cellulose and lignin that make up the wood’s cell wall configuration and give it its strength. Brown rot makes the wood dark brown and crumbly. Because its enzymes can diffuse into the wood far from
their source, brown rot can weaken the wood substantially in the early stages of its attack. White rot makes the wood white and stringy. Though the enzymes do not migrate into the wood as with brown rot, white rot uses more of the wood cell wall as a food source, causing more severe, localized decay. Other fungi may be present on a timber member, but do not cause any serious structural damage. However, their presence indicates that conditions are right for the growth of brown or white rot. These indicator fungi include molds, which have cottony or powdery appearances and vary from white to black in color. Stains may appear as specks, spots, streaks, or patches of varying color on the wood surface. Soft rot attacks the wood, but only to just below the surface. It makes the wood soft and spongy.

For fungi to survive, there must be sufficient oxygen and over 26 percent moisture present in the wood. Fungi must have a food source, and this is the wood itself. Temperatures must range between 32 degrees and 90 degrees Fahrenheit, with the rate of biological activity higher at warmer temperatures. Areas that trap moisture promote fungi growth. These commonly exist at connections, supports, splices, and the ground line. The natural decay due to fungi can be stopped using wood preservatives, which poison the fungi food source, or by reducing the moisture content.

Wood parasites include insects, mollusks, or crustaceans that live within or feed upon the timber member. Termites feed on damp wood, usually in contact with the ground. Their tunnels contain no exit holes, so a termite-damaged timber may look sound. A sharp tap on a timber's surface, however, will easily punch a hole into a termite-damaged interior. Mud tubes that run from the ground to the wood member are a sign of termite activity. Timber damage due to termites on frequently used bridges is rare. It is suspected that they may be intolerant of the frequent vibrations.

Carpenter ants tunnel through a timber’s interior for shelter. As with termites, they damage the interior of a timber so that infestation is not readily apparent. They will, however, leave a pile of sawdust at the entrance tunnel, signaling their presence.

The larvae of powder-post beetles feed on the interior of timbers, creating tunnels and many exit holes. A powdery residue is often packed into these exit holes, indicating their presence.

Caddis flies are insects found in fresh or brackish water. Caddis fly larvae use timber piles for protection by boring holes into the sides of the timber. They are attracted to timber with fungal decay. Since they do not eat the wood, they can also be found in piles treated with creosote.

Mechanical damage is usually caused by the live loads acting on the bridge. Overload damage occurs when live loads acting on the bridge are so great that the structural members are stressed beyond their ultimate strength. Compression members may buckle into a single, curved bow; double, curved “S” shape; crack; or even break. Tension and bending members will crack or fracture. Cracks due to overloads will generally be perpendicular to the grain, splintering the wood. Overloads may be caused by traffic or by foundation settlements.

Impact damage, most commonly caused by vehicular collisions, normally occurs above the roadway or navigable channel on the fascia girder. It can also occur on the main
load-carrying members of through trusses and arches. Stream debris or ice floes may also impact bridge piers or abutments located in the channel. Indications of impacts include damaged timbers and scrape marks.

Abrasion is most often seen on timber bridge decks and is caused by vehicle tires and snow plows. These forces can cause ruts in the deck that hold water, further weakening the wood. Mechanical wear occurs from fasteners rubbing against their holes at loose connections.

The weathering effects of moisture, light, and heat can adversely affect the physical properties of wood. Moisture loss in wood can cause dimensional instabilities of a timber, resulting in warps, cracks, and shrinkage. Warping of a wood member is caused by uneven drying, allowing one side of the timber to shrink at a different rate than the other. As a result, the member may bow, twist, or cup.

Moisture loss in a timber will often cause the member to shrink, causing cracks. Cracks create openings into a timber’s untreated interior, allowing biological agents to enter and begin the decay process. Cracks may also reduce the timber’s strength. Checks are cracks oriented parallel to the grain and perpendicular to the annual growth rings. Splits are similar to checks, but these extend completely through the member. Some cracks, called shakes, may form before a tree has been felled. Shakes are oriented parallel to both the grain and annual growth rings.

Improperly dried wood may shrink during service, resulting in loose connections. Loose connections may allow biological agents to enter the untreated timber interior. Mechanical wear due to the fastener rubbing against the wood may also take place under live load.

Though fire can completely consume a small timber member, large timber members offer some resistance to fire. Fire consumes wood at a rate of about 0.05 inch of thickness per minute for the first 30 minutes, and about 0.021 inch per minute thereafter. As wood burns, a black char layer is formed. This char helps to insulate the underlying unburned wood, slowing the consumption rate. Large timbers have enough volume to develop this protective char layer, leaving a core of undamaged wood. Though the remaining wood core does not have the strength of the original undamaged timber, it is often enough to prevent a total collapse.

**Subsection 1.4.4 Other Materials**

(a) **STONE MASONRY**

Stone masonry is rarely used in modern construction as a structural material for bridges. However, it was used extensively for abutments and piers in the 1800s and early 1900s. It was also used during this time to build arch superstructures and culvert structures. Different types of stone were used, depending on local availability. These are most commonly limestone, sandstone, and granite.

Stone masonry is classified as rubble masonry, square-stone masonry, or ashlar. Rubble masonry is rough-cut stones used for random-coursed or roughly coursed construction. Square-stone masonry is roughly squared and dressed and may be laid in
random or coursed construction. Ashlar masonry is precisely squared and finely dressed and may be laid in random or coursed construction.

Stone masonry weighs between 135 pounds per cubic foot (sandstones) to 165 pounds per cubic foot (granites). It expands and contracts with increasing and decreasing temperatures, respectively. It may be porous and, therefore, absorbs moisture. Limestone, common in Indiana, tends to be more absorptive than most other stones. Stone is a durable material, and different stone types will have different durability.

Stone masonry is a material used for its compressive strength. Depending on the material type and where it had been quarried, compressive strengths generally range from 6,000 pounds per square inch (limestone and sandstones) up to 36,000 pounds per square inch (granites). Its tensile strengths are poor, ranging from about two to 13 percent of its compressive strength. Mortar is used to form a bedding material for each masonry unit, bond individual stone units together, seal joints against moisture penetration, and seal irregularities on the masonry unit’s surface.

![Figure 4:1-30: Masonry Deterioration/Spalls at an Arch Bearing](image)

The three main causes of stone masonry deterioration are splitting, spalling, and weathering.

Splitting refers to the seams or cracks that may form in rocks. This common type of deterioration may occur due to freezing water within small seams and pores, due to volume changes from seasonal temperature fluctuations, and due to the wedging force of plant roots growing into crevices and joints. Structural overloads may also cause the stone masonry units to split. Small pieces of rock which break out or chip off of the stone masonry unit are called spalls. Sources of spalling are the same as those that produce splits. Vehicle impacts may also produce spalls. Weathering is the degeneration of the rock surface into small granules. Causes that chemically attack the stone include lichens and ivy, acid rain, and gasses and solids dissolved in water. Windborne or waterborne particles can cause abrasion. Freeze/thaw cycles may also produce weathering.
(b) CAST IRON

Cast iron is a material not used in modern construction as a structural material for bridges. However, it was used for the compression members and bearing castings of bridges built in the 1800’s and early 1900's. Cast iron is produced by pouring molten iron into a mold and letting the metal solidify.
Cast iron has a gray color due to the presence of graphite particles distributed throughout the metal. It weighs approximately 450 pounds per cubic foot. The chemical composition of cast iron varies widely depending on the type. However, the most common gray cast iron is composed mainly of iron, carbon (2.0 percent to 4.0 percent of carbon by weight), and silicone (up to 2.8 percent). Other elements include sulphur, phosphorus, and manganese. Unprotected cast iron will corrode, but tends to be more corrosion-resistant than steel. It is usually painted to protect against atmospheric corrosion.

Cast iron is a material used for its high compressive strength. The tensile yield strength of gray cast iron is about the same as its ultimate tensile strength of 20,000 to 30,000 pounds per square inch. Its compressive yield strength varies from approximately 80,000 to 100,000 pounds per square inch.

The free carbon, slag, and other impurities in cast iron make it a brittle material and difficult to weld. These impurities act as discontinuities in the crystal structure, restricting the movement of dislocations and acting as nucleation points for cracks. This ultimately results in decreased ductility. It has poor resistance to shock, impacts, and fatigue loading, but has good damping properties and is easy to machine. Types of cast iron deterioration are similar to those found on steel (see Subsection 1.4.2[c]).

(c) WROUGHT IRON

Wrought iron is a material that is not used in modern construction as a structural material for bridges. It is, however, still found on many old bridges as tension members. Wrought iron is produced by mechanically rolling or working relatively pure iron into a desired shape, producing a fibrous material with properties in the worked direction similar to steel.

Wrought iron weighs about 480 pounds per cubic foot. The chemical composition of wrought iron is mainly of iron, slag (iron silicate, up to 3.0 percent by weight), and phosphorous (approximately 1.2 percent). Other elements include sulphur, manganese, and carbon.

Unprotected wrought iron will corrode, but tends to be more corrosion-resistant than steel. Its fibrous nature produces a tight rust that is less likely to flake and scale than structural steels.

Wrought iron is a material used for its high tensile strength. Its yield strength is about 30,000 pounds per square inch. When wrought iron is worked or rolled, the slag distributed throughout the metal is elongated into fibers. Because of this, it is an anisotropic material, having different mechanical properties with respect to the direction of the slag fibers.

The slag fibers give wrought iron many desirable properties. It surpasses steel in its ductility, fatigue strength, and corrosion resistance. It has good machinability properties and good impact and shock resistance. Wrought iron is also weldable.

Types of wrought iron deterioration are similar to those found on steel (see Subsection 1.4.2[c]).
(d) CAST STEEL

Cast steel is a material not normally used in fixed bridge construction, but it has been used for tracks in movable bridges. Cast steel is produced by pouring molten metal into a casting mold directly from the steel-making furnace.

Several types of cast steel exist, including carbon steel, low-alloy steel, alloy steel, and stainless steel. Cast steel weighs about 490 pounds per cubic foot. The chemical composition of cast steel varies widely depending on the type. However, carbon steel castings are composed of iron and carbon (0.2 percent to over 0.5 percent of carbon by weight). Unprotected cast steel will corrode.

Cast steel is a material used for its machinability qualities. The yield strengths of carbon steel castings commonly used for bridges range from 35,000 to 95,000 pounds per square inch, and tensile strengths range from 60,000 to 120,000 pounds per square inch. Low-alloy and alloy bridge castings are stronger, and can have yield and tensile strengths up to 135,000 pounds per square inch and 140,000 pounds per square inch, respectively.

Types of cast steel deterioration are similar to those found on steel (see Subsection 1.4.2[c]).

(e) ALUMINUM

Aluminum is not normally a material used as a structural material for vehicular bridges except for some underfill structures. However, it may be found as part of the deck, superstructure, or substructure on pedestrian bridges where fatigue is not a concern.

Aluminum weighs about 175 pounds per cubic foot. The chemical composition of aluminum varies widely depending on the type. However, the most common aluminum used for structural applications is composed mainly of aluminum, magnesium, silicon,
copper, and chromium. Aluminum is more corrosion-resistant than steel. Because of this, painting is usually unnecessary to protect it from the atmosphere.

Aluminum is a material used for its high tensile and compressive strengths. Depending on the aluminum type, yield strengths range from 40,000 to 48,000 pounds per square inch, giving it a high strength-to-weight ratio. Tensile and compressive yield strengths are the same. Shear strength is about 60 percent of its yield strength. The modulus of elasticity values of aluminum are approximately one-third that of steel. Modulus of elasticity is a material property relating material stress to elongation. Since modulus of elasticity values are inversely proportional to elongations, an aluminum beam will deflect three times as much as a similarly shaped steel beam carrying the same load. In addition, aluminum’s fatigue strength is approximately one-third that of steel, making it less desirable when fatigue is a concern.

When stressed below its yield point, aluminum is elastic, and a loaded beam will readily spring back into shape once the load is removed. Should high loads or impacts be applied which produce stresses beyond yield, aluminum is ductile and can withstand excessive deformations without failure. Although weldable, aluminum experiences significant base metal strength reductions of up to one-half the yield strength in the vicinity of welds.

With the exception of atmospheric corrosion, types of aluminum deterioration are similar to those found on steel (see Subsection 1.4.2[c]).

(f) COMPOSITES

Composites are plastics/resins reinforced with carbon, glass, or other fibers. Their use as main load-carrying members for bridges is limited. Although composites can have a high strength-to-weight ratio, can attain strengths similar to steel, and have excellent corrosion and impact resistance, there are several reasons why structural engineers do not generally specify composites. The main reason is that design standards do not currently exist. There are numerous types of plastics available, but their properties lack consistency from producer to producer. Also, costs are generally high.

Composites often exhibit viscoelastic (nonlinear) behavior. This means that at any given strain magnitude, temperature changes can produce marked changes in strength and deflection. Similarly, load duration and magnitude affect a composite’s strength and deflection. Viscoelastic behavior is less pronounced in composites than in plain, unreinforced plastics/resins. Though fatigue data does exist for some of the composites, no method is currently available to characterize the fatigue strengths of composites.
SECTION 1.5   CLASSIFICATION OF FIXED BRIDGES

Bridges are classified according to their superstructure type. The use of each type generally depends on the distance the bridge must span, although more than one type can be used for the same span length. Other factors include the depth of the channel or ravine to be crossed, required underpass clearance, horizontal curvature, economics, and aesthetics.

Subsection 1.5.1   Slab

Slab bridges are the simplest bridge structures, constructed using reinforced concrete or timber for short spans. Typically concrete slab bridges are cast-in-place; however, some slabs are pre-cast. Long spans are usually continuous, often constructed with a thickened slab over the piers. These are called variable depth slabs. Longer span concrete slab bridges often utilize prestressed or post-tensioned slabs. Slab superstructures act like a very wide beam spanning between substructure elements. For slab bridges, including flat slabs, haunched slabs, and rigid frames, the superstructure is also the deck.

Figure 4:1-34: Deteriorated Single Span Concrete Slab
Subsection 1.5.2  Beam/Girder

Beam/girder bridges rely on the use of two or more primary elements acting in bending to support the deck and traffic. Beam/girder bridges are usually constructed of steel or concrete, although timber is also sometimes used.

The shortest steel bridges are typically constructed using standard hot-rolled “I” shapes, referred to as beams. Longer steel spans require deeper sections that are not produced by rolling mills. For these situations, welded, bolted, or riveted “I” shapes fabricated from plates are used. In Indiana, a shape built-up by welding, bolting, or riveting together plates and structural shape is called a girder. Longer spans also utilize steel plates built-up into a four-sided rectangular or trapezoidal closed shape, known as a box girder. Due to the box girder’s inherent resistance to the effects of torsion, box girders are commonly used for horizontally curved spans.
Many types of concrete beam bridges exist since concrete can be cast into many different shapes. The earliest examples are cast-in-place structures, usually of single spans. The rectangular beams and deck were typically cast simultaneously, forming “T” beams with the deck acting as the top flange. In Indiana, these cast-in-place “T” beams are called “Reinforced Concrete Girders.” On some older bridges, the fascia beams protruded above the deck and acted as bridge parapets, as well as superstructure elements. In Indiana, these are classified as “Concrete through Girder” bridges if there are no girders except the two fascia girders.
In Indiana, most prestressed, pre-cast members are called beams. Prestressed concrete beams, cast at an off-site plant and delivered to the site, gained acceptance in the 1950s. By pre-compressing the beam with steel tendons, internal tensile stresses in the concrete are greatly reduced or eliminated. Prestressed beams/girders come in a variety of geometric cross-sections, including I, C, T, Bulb-T, modified or hybrid Bulb T, U, and closed-box shapes.

For longer spans or horizontally curved structures, post-tensioned concrete box girders may be used. Rather than being prestressed at a plant, the girders are either cast-in-place, or segments are precast at a plant and joined on-site to form a girder. Both contain ducts through which post-tensioning rods or tendons are passed. The rods or tendons are then pulled into tension, compressing the girder.

Rectangular timber beams may be either sawn or glue-laminated and are used for fairly short span bridges. Solid sawn beams are most often associated with older structures built when large timber members were plentiful. Currently, multiple strips of wood are glued together to build up large, laminated, or glulam, members.

**Subsection 1.5.3  Truss**

A truss is a structure whose members are arranged to form triangles. Each member is classified as either a top chord, bottom chord, vertical, or diagonal. Most trusses have vertical members. The mechanics of this arrangement is such that each member is acting as either a pure tension or pure compression member. Generally, two parallel trusses form the main load-carrying system of a bridge superstructure. Each may be thought of as a very deep beam with holes cut into the web. The top chord acts as the top flange, and the bottom chord acts as the bottom flange. Thus, under positive bending, the top chord is in compression, and the bottom chord is in tension. The reverse is true if the truss undergoes negative bending. Truss diagonal members deliver the shear loads of the imaginary deep beam to the supports by means of tension or compression, depending on their orientation within the truss.

Most truss bridges are constructed using steel members, while very old trusses used timber and wrought iron. Loads are delivered to trusses by way of the deck, supported on stringers (longitudinal beams), which in turn bear on floor beams (transverse beams). The floor beams frame into the sides of the trusses, usually at the panel points. Timber trusses are used only for fairly short spans. Simply supported steel trusses are used for spans up to approximately 800 feet long. Cantilevered and continuous spans often range from 500 to 1,500 feet long.
Figure 4:1-38: Parker Truss Bridge

Figure 4:1-39: King Post Truss Bridge
Subsection 1.5.4 Arch

Arch bridges generally transmit their loads to the ground by diagonally pushing on their supports rather than bearing vertically as with slabs, beams, or trusses. To resist this push, or thrust, buttresses are built at the arch ends, or the ends are tied together with a tension member in a manner similar to an archer’s bow. Arches resist a combination of compression, bending, and shear. The relative magnitude of each depends upon the shape of the arch. True arches are parabolic in shape and are subjected only to compressive forces. For practical reasons, most arches are not designed or built as true parabolas and, therefore, must transmit bending and shear in addition to compression.

Arches have been used for a wide range of bridge spans. Almost all types of construction materials have been used to build arches, including stone masonry, wood, cast iron, steel, and concrete. They may be comprised of two or more parallel ribs, or of a single curved member called a barrel. Arch ribs can be constructed with steel, concrete, or wood. Usually, only stone masonry and concrete are used to form barrel arches.

The space between the flat deck and curved arch is called the spandrel. Open spandrel arches use columns placed within the spandrel to transfer the live loads and deck dead loads to the arch ribs. Closed spandrel arches usually use earth fill retained by spandrel walls to transfer the live loads and deck dead loads to barrels. Other closed spandrels do not use earth fill, but leave the spandrel unfilled or vaulted. Deck live and dead loads are delivered to the barrel by way of the spandrel and interior walls.
Subsection 1.5.5  Rigid Frame

Rigid frames are similar to arches in that they transmit their loads to the ground by diagonally pushing on their supports. However, since they consist of horizontal members rigidly connected to the tops of inclined or vertical members, they have the advantage of reducing span length while allowing more head clearance for traffic traveling underneath. Rigid frames primarily resist bending and shear forces, with compression loads occurring mostly in the vertical or slanted legs.

Only steel and concrete are used for rigid frame bridge construction. Steel rigid frames
are usually multi-span structures, known as K-frames, with main spans ranging from 50 feet to 200 feet. They are built of welded plate girder construction and require a minimum of two frames placed parallel to the roadway to carry the deck and live loads. Concrete rigid frames can be built as single or multi-span structures with a main span of each typically in the range of 50 feet in length. Single-span concrete rigid frames are commonly slab-type structures, similar to barrel arches. Multi-span bridges are usually built of multiple frames similar to steel rigid frames.

![Steel Rigid Frame](image)

Figure 4:1-43: Steel Rigid Frame

**Subsection 1.5.6  Cable-Stayed**

Cable-stayed bridges have superstructures supported by diagonal cable tension members. Each cable stay is connected to a pylon (tower) located at the main pier. Superstructures may be built of steel or concrete.
The cable stays act as spring supports, causing the superstructure to act as a multi-span bending member. Since the cables are sloped relative to the roadway, the cable stays also introduce compressive forces into the superstructure. Compression forces are also introduced into the pylon at each cable stay connection point. Because of the possible unequal live loading from span to span, variable cable stay forces also cause the pylon to bend. Back-stay cables, either anchored to the approach spans or to an anchorage block on land, help to balance the forces of the main span cables, thereby minimizing pylon bending. When used for highway bridges, they can be used for spans from 200 to 2,000 feet.

**Subsection 1.5.7 Suspension**

Suspension bridges can span distances in excess of 1,800 feet when used for highway bridges. They use vertical cable hangers to suspend the superstructure from two or more main cables. The main cables are draped over towers and terminate at heavy anchor blocks. The main suspension cables often have diameters exceeding 3 feet for long roadway spans. The main cables exert large compressive loads on the tops of the towers and may introduce some bending due to unequal live loading from span to span.

The horizontal distance between adjacent hanger cables is relatively small and, therefore, only a relatively shallow superstructure is required for strength. However, this results in a very flexible structure, giving rise to large deflections. Because of this, deep stiffening trusses, girders, or box girders are normally used to more evenly distribute the live loads among the hangers, thereby reducing deflections. Stiffening trusses and girders for highway suspension bridges are normally built of steel.
Figure 4:1-45: Pedestrian Suspension Bridge
CHAPTER 2 CONDITION EVALUATION

SECTION 2.1 INTRODUCTION

The biggest challenge in any bridge inspection program is to relate the material distress found on a bridge to its effect on the structure's strength and safety. Another challenge is to create uniformity between all bridge inspectors for evaluating and rating the structural condition of a bridge.

All qualified bridge inspectors must have a basic understanding of bridge mechanics and of how deterioration of a certain bridge component will affect the bridge's performance and public safety.

Indiana uses the National Bridge Inspection Standards (NBIS), as outlined in the Federal Highway Administration's (FHWA's) Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges (FHWA Coding Guide) as the basis for all inspections. The information gathered is supplemented with data on the condition of various elements in each bridge.

Figure 4:2-1: Damaged Girder
SECTION 2.2  NBI INSPECTION

The FHWA Coding Guide is the basis for the NBI condition ratings. It has been used as the basis for bridge inspections since 1971 and its primary objective is to monitor the safety of the nation’s bridges. The FHWA Coding Guide provides guidance for rating the condition of a bridge’s deck, superstructure, substructure, and channel, if it exists. It also provides condition rating guidance for underfill structures.

In addition to establishing a component’s physical condition, rating data is used in a variety of analyses and decisions performed by the bridge owners and FHWA. The data helps to determine the sufficiency of a bridge to remain in service and its eligibility for rehabilitation or replacement.

NBI inspection results rate the major bridge components without being specific as to where, how much, or what type of deterioration exists. Each bridge component is assigned a numeric rating code ranging from 9 to 0, with 9 being excellent condition and 0 being failed condition. The ratings represent the overall physical condition of the component as compared to the day it was built. It provides an evaluation of the bridge component’s material and its state of deterioration, and not an evaluation of its ability to carry current legal loads.
Indiana collects information about various bridge elements in addition to the data required in the Coding Guide. This helps to identify problems and actions that need to be taken to ensure the safety and longevity of a bridge. The supplemental information required for each bridge owner is identified in the Bridge Reporting for Appraisal and Greater Inventory (BRAGI) Coding Guide.

An estimate of the remaining life of the wearing surface, deck, joints, superstructure, substructure, approach features, channel features, and culvert or underfill features is required for all bridges.

For state-owned bridges, this supplemental inspection data breaks out various bridge components, such as the railings, girders, diaphragms, abutments, and pier columns. Each component is inspected and assigned a numeric rating code, based upon its state of deterioration. Rating codes generally follow rating guidelines in the FHWA Coding Guide.
CHAPTER 3 DECKS

SECTION 3.1 INTRODUCTION

Decks are structural components of a bridge, and serve several functions. The wearing surface of a deck provides a smooth riding surface for traffic. The deck distributes the bridge live loads such as vehicle wheel loads to the girders, stringers, and floor beams. Reinforced concrete decks also serve as the top flange of reinforced concrete T-beam bridges, and reinforced concrete decks may function as part of the top flange of steel open girder, steel box girder, prestressed concrete, and concrete box girder bridges. For concrete slab bridges, the deck is also the superstructure.

Decks receive a considerable amount of abuse from truck overloads; corrosive deicing chemicals; freeze/thaw weathering; and parasites/fungi and other sources that cause wear and abrasion, such as wheels, snow plow blades, and road debris. Decks can deteriorate rapidly and must be monitored diligently.

SECTION 3.2 CONCRETE DECKS

Concrete decks are the most common type of deck an inspector will encounter. The inspector should review the bridge history to confirm the construction details for each deck. The history should include information about any overlays, the year each overlay was constructed, the design load, if the steel is coated with epoxy, and whether or not the deck is composite with the superstructure. There are several types of concrete decks:

Concrete decks that are cast on the superstructure on-site are referred to as cast-in-place. Forms are used to contain reinforcing bars and wet concrete so that after curing, the deck components will be in the correct position and shape. Bar chairs are used to support reinforcement in the proper location during casting. Removable forms are usually wood planking or plywood, but can also be fiberglass reinforced plastic. These forms are removed from the deck after the concrete has cured. Corrugated metal sheets, fiber reinforced precast concrete, and polymers are common materials used for stay-in-place forms.

Precast deck panels are cast and cured off-site. Precast deck panels are typically reinforced with conventional mild reinforcement. The panels are transported to the bridge site, placed on the superstructure, leveled, and attached to the superstructure/floor system. The panels are either bolted to the stringers with mechanical clips, or attached using grout or concrete filled block-out holes as shear connectors.

Pre-cast, prestressed deck slabs are cured off-site. They are reinforced with prestressing steel in addition to some mild reinforcement. The prestressing tendons or bars are tensioned prior to placing the slab (pretensioned) or after the slab is cured (post-tensioned). This creates compressive forces in the slab, which reduce the amount of tension cracking in the cured concrete.
Concrete deterioration normally starts in the wearing surface and along the copings, joints, or curb lines and progresses downward and inward until the entire slab is involved. Therefore, when deterioration is observed on the bottom of a slab, there is a good chance that the deterioration is worse above this point and the deck should be rated accordingly.

A bituminous overlay can accelerate the deterioration of the deck, as well as hide patches, spalls, delaminations, and repairs in the original deck or debonding of an overlay from the deck. Repaired and distressed areas which are known to exist through historical documentation or previous inspection reports need to be taken into account when assigning a rating to the deck. Inspectors should state the source of any information beyond visual inspection of the wearing surface. Chain dragging or other soundings may provide knowledge about distress under an overlay and should be used when deterioration is suspected.

Technically advanced means of evaluating a wearing surface or concrete deck include ground-penetrating radar and infrared thermography. These are seldom used due to cost and effort limitations, but it may be appropriate to utilize these tools for large bridges with high average daily traffic (ADT).

The inspection of concrete decks should include a thorough evaluation of the wearing surface, copings, curb lines, and the underside of the deck for the following items:

1) Check for cracks, note their location, orientation, length, maximum width, and type. The extent of cracking gives an indication of how much water is able to penetrate the deck. Cracks to note include:
   a) Longitudinal flexural cracks caused by deck positive bending between the girders or stringers. Wide cracks may indicate a serious structural overload.
b) Longitudinal flexural cracks in areas of negative moment bending over the girders or stringers in the deck.

c) Transverse flexural cracks adjacent to and over piers, where reinforcement bars end, and over floor beams.

d) Diagonal or transverse temperature/shrinkage cracks. These will be found on most concrete decks and can provide a means for chlorides to reach steel reinforcement.

2) Check for pop-outs, scaling, abrasion, and rutting. This may be most evident in the gutters and around the drains.

3) Look for spalls and note any large individual spalls.

4) Look for signs of corroding reinforcing steel, such as rust stains.

5) Note exposed reinforcing steel, corrosion, or loss of section.

6) Check for efflorescence. Note if it is stained with rust, since this condition suggests reinforcing steel corrosion.

7) Check for areas of delaminations. Loose concrete can fall and cause serious damage or injury.

8) Note all collision damage.

9) Check for sagging.

10) Note distressed repair areas.

11) Check for water leakage. Frequently, water leakage appears on support structures, under drains, or under expansion joints.

12) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

13) Check stay-in-place forms for corrosion and other signs of leakage through the deck. Stay in place forms may trap moisture and hide the condition of a deck.

14) Check the deck at the railing and/or light standard connections.

SECTION 3.3 STEEL DECKS

Steel decks are sometimes used on bridges because they weigh less than concrete decks. They are often used on movable bridges to reduce the required counterweight needed to balance the span. Steel decks have been used to replace concrete decks on older bridges when an increased live load capacity is desired, or when existing superstructure or substructure elements do not have enough strength to support the heavier dead load of a concrete deck.

Subsection 3.3.1 Steel Grid Deck

Steel grid decks are the most common type of steel deck. Steel grid decks contain several components that are either welded or riveted together, including bearing bars,
cross bars, and supplementary bars. Openings between these bars may be filled with concrete to improve the durability of a steel grid deck. Exodermic decks are a type of steel grid system utilizing a reinforced concrete slab placed on top of the steel grid. The concrete acts compositely with the grid.

Steel open grid decks are strong and lightweight. Open grids are prefabricated using rectangular bars and delivered to the bridge site in several panels, which are then connected to the superstructure. The tops of the bars may be serrated to provide a skid-resistant riding surface.

Steel open grid decks are constantly exposed to the elements. Even though they are often galvanized or painted, traffic wear quickly exposes the deck top surface, leaving the deck vulnerable to corrosion. Open grids also leave the superstructure exposed to roadway debris, rain, and deicing chemicals.

On concrete and bituminous concrete-filled steel grid decks, the steel grid serves as the deck’s structural component. The material between the bar openings offers better corrosion protection and a more durable riding surface than an open deck. The deck system provides some protection for the superstructure below from rain, deicing chemicals, and roadway debris. Filled steel grid decks are heavier than open grid decks, but lighter than traditional concrete decks. The fill of these elements may be placed flush with the top layer of bars or preferably overfilled 1 to 2 inches. The bottom of the fill may be flush with the bottom of the grid or at mid-depth of the main bars.
The inspection of steel grid decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

1) Examine the bearing bars in the bearing areas at stringers/girders for cracked welds or broken fasteners. Special attention should be paid to the tension areas of the bars.

2) Examine welds attaching the deck to the stringers or girders to ensure cracks are not developing.

3) Look for twisted, cracked, broken, or missing bars, particularly at bearing bars.

4) Check for corrosion and related section loss.

5) Look for worn serrations or excessive wear causing section loss or broken welds between the bars.

6) Listen for any rattling as traffic passes over the deck. Rattling suggests loose, broken, or missing fasteners.

7) Look for broken fasteners on bolted or riveted steel grid decks.

8) Check any repair plates placed over the grid to make sure they are still securely fastened.

9) Check for grid expansion at the joints and bridge ends. This is often caused by corrosion.

10) Check for bowing of the deck panels.

11) Look for filler that is cracked, broken, leaking, or missing altogether.

12) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

**Subsection 3.3.2 Steel Orthotropic Decks**

Steel orthotropic decks are often used on long span bridges for their light weight. An orthotropic deck consists of a flat steel plate with longitudinal stiffeners welded to the underside of the plate. The floor beams of the bridge act to stiffen the deck perpendicular to the length of the bridge. Orthotropic decks may act as the top flange of the superstructure primary members, reducing the total bridge dead load. The deck surface usually includes a manufacturer-applied coating.

The inspection of steel orthotropic decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

1) Check for corrosion of the steel plate or stiffeners.

2) Check for leakage.

3) Check for proper support.

4) Look for cracked or broken stiffeners, welds, and connectors.

5) Listen for rattling as traffic passes over the deck. Rattling suggests loose, broken, or missing fasteners.
6) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

7) Check for failure of the wearing surface coating.

Subsection 3.3.3 Steel Railroad Car Decks

When reclaimed railroad cars are used as bridges, the bridge deck is the floor of the original rail car. They may be overlaid with an asphaltic wearing surface or timber decking. These reclaimed structures were likely exposed to many load cycles before being re-used as bridges and should be carefully inspected.

The inspection of steel railroad car decks should include a thorough evaluation of all visible portions of the top, bottom, and sides of the deck for the following items:

1) Check for corrosion of the steel flooring or stiffeners.
2) Check for leakage.
3) Check for proper support.
4) Look for cracked or broken stiffeners, welds, and connectors.
5) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

Subsection 3.3.4 Steel Corrugated Flooring

This deck type uses corrugated steel plates spanning transversely between the girders or stringers. After the flooring is fastened to the superstructure, the corrugations are filled with asphalt. This deck system can trap and hold water that passes through the topping, making it very susceptible to corrosion. The corrosion often cannot be seen until the corrosion extends through the thickness of the corrugated plate.

The inspection of steel corrugated decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

1) Check for corrosion of the steel plate.
2) Check for cracked or broken-up areas of asphalt that would allow water penetration.
3) Check for areas of asphalt that look “settled.” This may indicate that the steel plates below are deforming or sagging.
4) Check for leakage.
5) Check for proper support.
6) Look for cracked or broken welds and connectors.
7) Examine the welds attaching the deck to the stringers or girders to ensure cracks are not developing.
8) Listen for rattling as traffic passes over the deck. Rattling suggests loose, broken, or missing fasteners.
9) Check the wearing surface for rutting or spalls and note any large individual spalls.
10) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

SECTION 3.4 TIMBER DECKS

Timber decks are normally used for timber superstructures, although they are occasionally found on other steel superstructures. Timber decks may also be referred to as decking or timber flooring. There are several types of timber decks.

**Plank decks** – These are the most common type of timber deck. Deck planks are sawn timber planks laid flat across the tops of the timber beams or steel stringers. They span transversely between the beams/stringers and are fastened to the superstructure with nails or bolt clamps. Common planks are three-to-six inches thick and 10-to-12 inches wide.

**Nail laminated decks** – This deck type uses sawn planks laid on edge across the tops of the timber beams or steel stringers, creating a very stiff deck. Each plank is placed tight against and nailed to the adjacent one. When used in conjunction with timber superstructures, each plank is toe-nailed to the beam. When used in conjunction with steel superstructures, the deck is attached with clamps at regular intervals.

**Glued laminated decks** – These decks are similar to nail laminated decks, but the planks are glued together in a factory and shipped to the job site in three-to-five-foot wide planks. After setting the planks on top of the superstructure, the planks are clamped together for the full length of the bridge by way of tie rods. The deck is then fastened to the beams/stringers using nails, bolts, clip angles, or nailers. Glued laminated decks are generally stronger, stiffer, and more water-resistant than plank or nail-laminated timber decks.

**Prestressed laminated deck** – These decks use laminated timbers similar to nail and glued laminated decks. They are different in that external prestressing is used to clamp the laminations together. The individual laminations work together as a unit due to the large frictional forces generated by the prestressing. Normally, steel rods passing through the laminations are used to deliver the prestressing forces at approximately two-foot centers.

Because of timber’s low resistance to abrasion, wearing surfaces are often used. These may be timber or steel running boards or a bituminous overlay. Running boards are placed longitudinal to traffic, usually along the wheel paths. They are easily replaced when worn. Bituminous wearing surfaces may be placed on any type of timber deck, although this can trap water against the timber. Bituminous surfaces tend to crack and deteriorate quickly on plank decks due to plank flexibility and differential deflection.
Figure 4:3-3: Timber Plank Deck

Figure 4:3-4: Steel Running Boards on a Timber Deck
The inspection of timber decks should include a thorough evaluation of the top, bottom, and sides of the deck for the following items:

1) Look for signs of wear and abrasion, weathering, splitting, crushing, and decay.

2) Look for loose, missing, or damp members.

3) Check all bearing areas for decay and crushing. Crushing can be caused by decay or by overloads.

4) Check for corroded, loose, or missing fasteners.

5) Check tension areas for excessive deflections, fractures, and transverse cracks. These are typically signs of excessive flexural stresses and overloads.

6) Hammer tap random and suspect areas to evaluate the wood’s soundness.

7) Perform probe tests where decay is suspected. Using an awl, ice pick, or pocketknife, lift a small sliver of wood from the surface. Wood that lifts up and splinters is sound, while wood that breaks up upon lifting the tool is decaying.

8) Drill or bore suspect planks to estimate the extent of decay.

9) Examine any overlay for signs of wear and abrasion, cracks, potholes, or impending potholes.

10) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

11) Check for fire damage.

12) Note the presence and condition of any insecticides, preservatives, or protective flashings or coverings.
SECTION 3.5 NBI DECK RATING

Deck condition ratings assess the current structural condition of the deck as compared to its original, as-built condition. Postings or original design capacities less than current legal loads will not influence the rating. Because only a single number is used to rate the deck, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, but widespread deterioration would influence the rating. The rating must consider the extent and severity of the deterioration.

Temporary deck supports, bituminous overlays, partial concrete overlays, patching, and temporary strengthening methods do not improve the condition of the deck material or influence the deck rating.

On slab bridges, the deck is also the superstructure, so the ratings of the deck and superstructure must be the same.

Decks integral with the superstructure (rigid frame, box girder, etc.) will be rated as a deck only, and not how they may influence the superstructure rating. Similarly, the superstructure of an integral deck-type bridge will not influence the deck rating.

For some decks integral with the superstructure, such as adjacent box beams, you cannot see the underside of the deck and must rate the deck based on the top surface alone. If the bridge has an overlay, the deck rating will be based on an assessment of the condition of the overlay and any documented history of the concrete below the overlay.

Ratings of 9 to 7 apply to decks in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests critical condition, and 1 to 0 suggest a condition where the bridge must be closed to traffic. It is important to note that there is a significant change from a deck in condition rating 5 to condition rating 4. If the load-carrying capacity is reduced, the deck rating must be less than 5.

The condition of the wearing surface, protective systems, joints, expansion devices, curbs, sidewalks, parapets, fascias, bridge rail, and scuppers shall not be considered in the overall deck evaluation of NBIS Item 58, Decks. However, these items should be evaluated and reported as described in Subsection 3.5.2

The general condition ratings and Indiana supplemental rating guidelines for decks are as follows.
<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong> Used for structures without decks such as underfill structures or filled arch bridges.</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong> Generally used on properly constructed new bridges.</td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Deck</strong> – There are no spalls, delaminations, cracks, or scaling present.</td>
</tr>
<tr>
<td></td>
<td><strong>Steel Deck</strong> – There are no deficiencies which affect the deck condition.</td>
</tr>
<tr>
<td></td>
<td><strong>Timber Deck</strong> – There are no deficiencies which affect the deck condition.</td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – No problems noted.</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong> Generally used on properly rehabilitated bridges or bridges in nearly new condition.</td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Deck</strong> – There are no spalls, delaminations, cracks, or scaling present. Minor transverse cracks may be present in the deck surface or the underside of the deck.</td>
</tr>
<tr>
<td></td>
<td><strong>Steel Deck</strong> – There is no damage to the primary or secondary bars other than surface corrosion on uncoated decks. Any deck coating system is sound. The grid deck is securely fastened to the floor system and any filler present is sound.</td>
</tr>
<tr>
<td></td>
<td><strong>Timber Deck</strong> – There is no crushing, rotting, or splitting. The deck is tightly secured to the floor system.</td>
</tr>
<tr>
<td>7</td>
<td>GOOD CONDITION – Some minor problems.</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Deck</strong> – Insignificant cracks which can be sealed with tar or epoxy are present. There are few transverse cracks and only light scaling of the deck surface. No exposed reinforcing steel is present. There is no leaking or corrosion of stay-in-place forms.</td>
</tr>
<tr>
<td></td>
<td><strong>Steel Deck</strong> – There may be minor damage to the primary or secondary bars, such as small twists or bends. There may be surface corrosion on uncoated decks, or minor isolated areas of corrosion of coated decks. Any filler present is sound.</td>
</tr>
<tr>
<td></td>
<td><strong>Timber Deck</strong> – There is minor checking or splitting with a few loose planks.</td>
</tr>
<tr>
<td>6</td>
<td>SATISFACTORY CONDITION – Structural elements show some minor deterioration.</td>
</tr>
<tr>
<td></td>
<td><strong>Supplemental Rating Guidelines:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Deck</strong> – Spalls and delaminations may be present on up to five percent of the deck surface or soffit area. Up to 10 percent of the deck surface or soffit area may have map cracking. Transverse cracking at greater than five-foot spacing may be present. Moderate scaling of the deck surface may also be present.</td>
</tr>
<tr>
<td></td>
<td><strong>Steel Deck</strong> – There may be some twisted, bent, or cracked bars. There may be some isolated broken welds or loose/broken fasteners. Filler may have broken out at a few localized areas. There is surface corrosion on uncoated decks, and surface or freckle corrosion of coated decks.</td>
</tr>
<tr>
<td></td>
<td><strong>Timber Deck</strong> – Less than 10 percent of the planks are checked or split, but they are sound. There may be some loose or moderately worn planks. Some areas of wetness are present.</td>
</tr>
</tbody>
</table>
5 FAIR CONDITION – All primary structural elements are sound, but some may have minor section loss, cracking, or spalling.

Supplemental Rating Guidelines:

Concrete Deck – Up to 10 percent of the deck surface or soffit area is spalled or delaminated. Up to 25 percent of the deck surface or soffit area may have map cracking. Transverse cracking on the underside at less than five-foot intervals in the majority of the deck, with or without efflorescence, may be present. The underside of the deck has spalls with exposed reinforcing bars with up to 10 percent section loss in isolated areas. Heavy scaling of the deck surface may also be present.

Steel Deck – There are some twisted, bent, or cracked bars and possibly a few broken or missing bars. There are some broken welds or loose/broken fasteners. Filler may have broken out at a few scattered locations. Some section loss may be occurring due to corrosion, but the section loss is not measurable. Section loss due to wear may be noticed in the wheel lines.

Timber Deck – Ten percent to 40 percent of the planks are checked, split, rotted, or crushed. Many planks are loose. Fire damage is limited to surface charring with minor, measurable section loss. Less than 10 percent of the planks are in need of replacement.

4 POOR CONDITION – Advanced section loss, deterioration, or spalling is present.

Supplemental Rating Guidelines:

Concrete Deck – Longitudinal cracks exist over the majority of the deck. Up to 25 percent of the deck surface or soffit area is spalled or delaminated. Up to 50 percent of the deck surface or soffit area may have map cracking. The underside of the deck has wet-looking areas. Stay-in-place forms are corroded in numerous areas. Full-depth failures are imminent. Significant efflorescence is present. The underside of the deck has spalls with exposed reinforcing bars with up to 30 percent section loss in isolated areas. Loose delaminations are in danger of falling on traffic or pedestrians below.

Steel Deck – There are numerous cracked, broken, or missing bars. There are numerous broken welds or loose/broken fasteners. Filler has broken out at many locations. Measurable surface pitting and/or section loss is occurring due to corrosion. The coating system has failed. Measurable section loss due to wear has occurred in the wheel lines.

Timber Deck – Over 40 percent of the planks are rotted, crushed, or split. Fire damage with significant section loss, possibly reducing the load-carrying capacity, may be present. Over 10 percent of the planks are in need of replacement.

3 SERIOUS CONDITION – Loss of section, deterioration, or spalling has seriously affected the components. Local failures are possible. Flexure and shear cracks in concrete may be present.

Supplemental Rating Guidelines:

Concrete Deck – Full-depth failures are present or imminent. Greater than 25 percent of the deck surface or soffit area is spalled or delaminated. Excessive efflorescence is present. Large areas on the underside of the deck look wet. Large areas of stay-in-place forms are corroded. Significant exposed reinforcing bars, with greater than 30 percent section loss, are present.

Steel Deck – There are numerous broken or missing bars. There are widespread broken welds or broken fasteners. Much of the filler is missing. Serious section loss and measurable section loss in the wheel lines is present.
**Timber Deck** – Severe signs of distress are visible. Extensive plank damage is evident with reduced deck load-carrying capacity.

**2 CRITICAL CONDITION** – Advanced deterioration of primary components is present. Fatigue cracks in steel or shear cracks in concrete may be present. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

**Supplemental Rating Guidelines:**

**All Decks** – There are deficiencies in the deck that would likely cause a driver to lose control of his/her vehicle. Local deflections exist.

**Concrete Deck** – Full-depth failures exist over much of the deck. The deck is grossly compromised.

**Steel Deck** – There are widespread broken or missing bars accompanied with partial deck failures. There are widespread broken welds or broken fasteners. Most of the filler is missing. Excessive section loss is evident.

**Timber Deck** – There is advanced deterioration with partial deck failure. There are broken or missing planks.

**1 “IMMINENT” FAILURE CONDITION** – Major deterioration or section loss is present. The bridge is closed to traffic, but corrective action may put it back in light service.

**0 FAILED CONDITION** – The bridge is out of service, beyond corrective action.
SECTION 3.6 ADDITIONAL DECK RATINGS

Indiana requires the deck wearing surface to be rated for all bridges. Additional items to be rated for state-owned bridges are shown in Figure 4:3-5. Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 58, the NBIS deck condition rating. Each item shall be rated as follows unless noted:

N Not Applicable
9 Excellent Condition – new
8 Very Good Condition – no problems noted
7 Good Condition – some minor problems
6 Satisfactory Condition – structural elements show some minor deterioration
5 Fair Condition – minor section loss, cracking, or spalling
4 Poor Condition – advanced section loss, deterioration, or spalling
3 Serious Condition – loss of section, deterioration, or spalling has seriously affected components
2 Critical Condition – advanced deterioration of primary elements
1 Imminent Failure Condition – bridge closed to traffic, but corrective action may put bridge back in light service
0 Failed Condition – beyond corrective action

Figure 4:3-5: Additional Deck Items
ITEM 58.01 – WEARING SURFACE

The wearing surface is the portion of the top of the deck used for vehicle traffic. This rating is used for all decks, whether they are monolithic, or have an added wearing surface. The rating of wearing surface can be significantly different than the rating of the deck. The rating should be determined using the following guidelines:

**N** NOT APPLICABLE:

Supplemental Rating Guidelines: Used for structures without decks such as underfill structures or filled arch bridges.

**9** EXCELLENT CONDITION:

Supplemental Rating Guidelines: Generally used on properly constructed, new bridge wearing surfaces.

Concrete Wearing Surface – There are no noticeable deficiencies.

Steel Wearing Surface – There are no noticeable deficiencies.

Timber Wearing Surface – There are no noticeable deficiencies.

**8** VERY GOOD CONDITION:

Supplemental Rating Guidelines: Generally used on properly constructed, new bridge wearing surfaces.

Concrete Wearing Surface – There are no spalls, delaminations, or scaling present. Minor transverse cracks may be present in the wearing surface.

Steel Wearing Surface – There is no damage to the primary or secondary bars other than surface corrosion on uncoated decks. Any deck-coating system is sound. Any concrete filler present is sound.

Timber Wearing Surface – There is no crushing, rotting, or splitting.

Bituminous Wearing Surface – There are no spalls or delaminations present. Minor transverse cracks may be present in the wearing surface.

**7** GOOD CONDITION:

Concrete Wearing Surface – There are no spalls or delaminations. Cracks which can be sealed with tar or epoxy exist, or light scaling may be present.

Steel Wearing Surface – There may be minor damage to the primary or secondary bars, such as small twists or bends. There may be surface corrosion on uncoated decks, or minor isolated areas of corrosion of coated decks. Any filler present is sound.

Timber Wearing Surface – There is minor checking or splitting with a few loose planks.

Bituminous Wearing Surface – There are no spalls or delaminations. Sealed cracks are present.

**6** SATISFACTORY CONDITION:

Concrete Wearing Surface – Up to five percent of the wearing surface area is spalled or delaminated. Up to 15 percent is patched. The patching is in good condition. Minor open cracking in the wearing surface (five-foot maximum spacing) or moderate scaling may be present.
Steel Wearing Surface – There may be some twisted, bent, or cracked bars. There may be some isolated broken welds or loose/broken fasteners. Filler may have broken out at a few localized areas. There is surface corrosion on uncoated decks, and surface or freckle corrosion of coated decks.

Timber Wearing Surface – Less than 10 percent of the planks are checked or split, but they are sound. There may be some loose or moderately worn planks.

Bituminous Wearing Surface – Up to five percent of the surface area is unsound (potholes, spalls, etc.). Up to 15 percent is patched. The patching is in good condition. Minor open cracking in the wearing surface (five-foot maximum spacing) may be present.

5 FAIR CONDITION:

Concrete Wearing Surface – Up to 15 percent of the wearing surface area is spalled or delaminated. Fifteen percent to 30 percent is patched. The patching is in fair condition. Less than 20 percent of the wearing surface is delaminated with no spalls or patching. Excessive open cracks or heavy scaling may be present.

Steel Wearing Surface – There are some twisted, bent, or cracked bars, and possibly a few broken or missing bars. Filler may have broken out at a few scattered locations.

Timber Wearing Surface – Ten percent to 40 percent of the planks are checked, split, rotted, or crushed. Many planks are loose. Fire damage is limited to surface charring with minor, measurable section loss. Less than 10 percent of the planks are in need of replacement.

Bituminous Wearing Surface – Five percent to 15 percent of the wearing surface area is unsound (potholes, spalls, etc.). Fifteen percent to 30 percent is patched. The patching is in fair condition. Excessive open cracks may exist in the wearing surface. Minor raveling may be present.

4 POOR CONDITION:

Concrete Wearing Surface – Up to 25 percent of the wearing surface area is spalled or delaminated. Thirty percent to 50 percent is patched and the patching is in poor condition.

Steel Wearing Surface – There are numerous cracked, broken, or missing bars. There are numerous broken welds or loose/broken fasteners. Filler has broken out at scattered locations. Measurable surface pitting and/or section loss is occurring due to corrosion. The coating system has failed. Measurable section loss due to wear in the wheel lines may be present.

Timber Wearing Surface – Over 40 percent of the planks are rotted, crushed, or split. Fire damage exists that has significant section loss. Over 10 percent of the planks are in need of replacement.

Bituminous Wearing Surface – Fifteen percent to 25 percent of the wearing surface area is unsound (potholes, spalls, etc.). Thirty percent to 50 percent is patched and the patching is in poor condition. Visible rutting or raveling may be present.

3 SERIOUS CONDITION:

Concrete Wearing Surface – Full-depth failures are present or imminent. Greater than 25 percent of the wearing surface area is spalled or delaminated. Over 50 percent of the surface is patched.

Steel Wearing Surface – There are numerous broken or missing bars. There are widespread broken welds or broken fasteners. Several areas of filler are missing. Serious section loss and measurable section loss due to wear in the wheel lines may be present.
Timber Wearing Surface – Extensive plank damage is evident.

Bituminous Wearing Surface – Greater than 20 percent of the wearing surface area is unsound (potholes, spalls, etc.). Over 50 percent is patched. Serious rutting or raveling may be present.

2 CRITICAL CONDITION:

All Wearing Surfaces – There are deficiencies in the deck that would likely cause a driver to lose control of his/her vehicle. Local deflections exist.

Concrete Wearing Surface – Full-depth failures exist over much of the wearing surface.

Steel Wearing Surface – There are widespread broken or missing bars accompanied with partial deck failures. There are widespread broken welds or broken fasteners. Much of the filler is missing. Excessive section loss is present.

Timber Wearing Surface – There are broken or missing planks.

Bituminous Wearing Surface – Full-depth failures exist over much of the wearing surface.

1 FAILURE CONDITION – Major deterioration in the wearing surface exists. The bridge is closed to traffic, but corrective action may put it back in light service.

0 FAILED CONDITION – The bridge is out-of-service, beyond corrective action.

Figure 4:3-6: Concrete Wearing Surface with No Noticeable Deficiencies
Figure 4:3-7: Concrete Wearing Surface with Patches and Spalls

Figure 4:3-8: Timber Plank Wearing Surface
Figure 4:3-9: Concrete Wearing Surface with Spalls and Patching

Figure 4:3-10: Bituminous Wearing Surface with Spalls and Patching
ITEM 58.02 – DECK UNDERSIDE

This item rates the underside of the deck as described as NBI Item 58, above. The ratings follow those outlined above for Item 58 and, because the underside of the deck generally reflects the structural condition of the deck, Item 58.02 will usually match Item 58.
ITEM 58.03 – CURBS

Curbs are vertical concrete surfaces designed to keep traffic on the wearing surface and off of the bridge sidewalks or railings. Curbs keep water from draining over the bridge coping.

Inspection of concrete curbs should include the following items:

1) Check the curb for delaminations, spalls, and exposed reinforcing steel.
2) Inspect the curb for both vertical and transverse cracks.
3) Inspect the curb for scaling or efflorescence. Note if it is stained with rust, since this condition suggests reinforcing steel corrosion.
4) Check the curb for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
5) Check previously repaired areas for soundness by hammer tapping.
Rate the physical condition of the curb and its ability to function as designed according to the following criteria:

- **N** Not Applicable
- **9** Excellent Condition – new
- **8** Very Good Condition – no problems noted
- **7** Good Condition – some minor cracking or scaling
- **6** Satisfactory Condition – some cracking, scaling, or delaminations
- **5** Fair Condition – general cracking, scaling, or delaminations
### ITEM 58.04 – COPINGS

Copings are the outside, vertical faces of the bridge deck. Inspection of copings should include the following:

1) Check for delaminations, spalls, and exposed reinforcing steel.
2) Inspect for cracks, scaling, or efflorescence. Note if the efflorescence is stained with rust, since this condition suggests reinforcing steel corrosion.
3) Check for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
4) Check previously repaired areas for soundness by hammer tapping.

Rate the physical condition of the copings according to the following criteria:

<table>
<thead>
<tr>
<th>Condition Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>Not Applicable</td>
</tr>
<tr>
<td><strong>9</strong></td>
<td>Excellent Condition – new</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td>Very Good Condition – no problems noted</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>Good Condition – some minor cracking, or scaling.</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>Satisfactory Condition – some cracking, scaling, or delaminations</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Fair Condition – general cracking, scaling, or delaminations</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Poor Condition – up to 10 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Serious Condition – ten to 30 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Critical Condition – thirty to 50 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td>Failure Condition – greater than 50 percent of coping is spalled, patched, or delaminated</td>
</tr>
<tr>
<td><strong>0</strong></td>
<td>Failed Condition – crumbling</td>
</tr>
</tbody>
</table>
ITEM 58.05 – MEDIAN

Medians are areas of raised concrete or steel located between opposing travel lanes to keep traffic separated. Inspection of the median should include the following:

1) Check for delaminations, spalls, and exposed reinforcing steel.
2) Inspect for cracks, scaling, and efflorescence.
3) Check the curb for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.
4) Check previously repaired areas for soundness by hammer tapping.

Note the type of median and rate the physical condition of the median and its ability to function as designed according to the following criteria:

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor cracking or scaling
6  Satisfactory Condition – some cracking, scaling, or delaminations
5  Fair Condition – general cracking, scaling, or delaminations
4  Poor Condition – up to 10 percent of median is spalled, patched, or delaminated
3  Serious Condition – ten to 30 percent of median is spalled, patched, or delaminated
2 Critical Condition – thirty to 50 percent of median is spalled, patched, or delaminated

1 Failure Condition – greater than 50 percent of median is spalled, patched, or delaminated

0 Failed Condition – crumbling

ITEM 58.06 – SIDEWALKS

Sidewalks are areas designated for pedestrian traffic. They are generally raised to provide separation from vehicular traffic. Any hazard that could potentially result in harm to the public should be noted on the inspection form and reported to the structure owner. Inspection of concrete sidewalks should include the following:
1) Checking the sidewalk for delaminations, spalls, pop-outs, and exposed reinforcing steel. Large spalls or exposed rebar can pose tripping hazards to pedestrians.

2) Note any loose or misaligned expansion joint plates that pose a tripping hazard to pedestrians.

3) Inspect the sidewalk for cracks.

4) Check the sidewalk for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.

5) Check previously repaired areas for soundness by hammer tapping.

6) Notify the owners of any sidewalks that pose a tripping hazard.

Figure 4:3-19: Sidewalk with Minor Pop-Outs

Figure 4:3-20: Sidewalk with Rust Stains and Minor Spalling

Rate sidewalks for the walking surface quality and accessibility according to the following criteria:
<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition – new</td>
</tr>
<tr>
<td>8</td>
<td>Very Good Condition – no problems noted</td>
</tr>
<tr>
<td>7</td>
<td>Good Condition – some minor cracking or scaling</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition – some cracking, scaling, or delaminations; accessible; and no hazard to pedestrians or motorists</td>
</tr>
<tr>
<td>5</td>
<td>Fair Condition – general cracking, scaling, or delaminations and minor hazards or barriers to accessibility</td>
</tr>
<tr>
<td>4</td>
<td>Poor Condition – not accessible and hazards to pedestrians or motorists present; up to 10 percent of sidewalk is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition – not accessible and hazards to pedestrians or motorists present; 10 to 30 percent of sidewalk is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition – not accessible and hazards to pedestrians or motorists present; 30 to 50 percent of the sidewalk is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>1</td>
<td>Failure Condition – not accessible and hazards to pedestrians or motorists present; greater than 50 percent of the sidewalk is spalled, patched, or delaminated</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition – sidewalk is unusable</td>
</tr>
</tbody>
</table>

Figure 4:3-21: Sidewalk with Spalling and Delaminations
ITEM 58.07 – PARAPET

Parapets are concrete railings or concrete barriers. The primary function of a parapet is to keep errant vehicles on the bridge. Additionally, if there is foot traffic, the parapet should keep pedestrians and bicycles on the bridge and provide a minimum level of comfort while crossing. They can also protect the main load-carrying elements of certain superstructure types, such as through trusses and arches, from damage due to vehicular impacts. Inspection of parapets should include the following:

1) Look for signs of impact damage such as spalls and localized heavy cracking. The location, severity, and size of the damage should be documented.

2) Check for delaminations, spalls, exposed reinforcing steel, and scaling.

3) Inspect the parapet for both vertical and transverse cracks.

4) Check the entire member for signs of corroding reinforcing steel as indicated by rust stains or exposed reinforcement.

5) Look for efflorescence and note if it is stained with rust, since this condition suggests reinforcing steel corrosion.

6) Check previously repaired areas for soundness by hammer tapping.

7) Check that any anchorage is sound.

Rate the parapet according to the following criteria:

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor cracking or scaling
<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td><strong>Satisfactory Condition</strong> – some cracking, scaling, or delaminations</td>
</tr>
<tr>
<td>5</td>
<td><strong>Fair Condition</strong> – general cracking, scaling, or delaminations</td>
</tr>
<tr>
<td>4</td>
<td><strong>Poor Condition</strong> – up to 10 percent of parapet is cracked or spalled; hazards to pedestrians or motorists present</td>
</tr>
<tr>
<td>3</td>
<td><strong>Serious Condition</strong> – ten to 30 percent of parapet is cracked or spalled; hazards to pedestrians or motorists present; anchorage deficiencies present; and moderate efflorescence present</td>
</tr>
<tr>
<td>2</td>
<td><strong>Critical Condition</strong> – thirty to 50 percent of parapet is spalled, patched, or delaminated; hazards to pedestrians or motorists and significant efflorescence present</td>
</tr>
<tr>
<td>1</td>
<td><strong>Failure Condition</strong> – greater than 50 percent of parapet is spalled, patched, or delaminated; hazards to pedestrians or motorists and significant efflorescence present</td>
</tr>
<tr>
<td>0</td>
<td><strong>Failed Condition</strong> – crumbling</td>
</tr>
</tbody>
</table>

**ITEM 58.08 – RAILING/POST**

Railings/posts are the wood or metal components of bridge railings. Rate railings and posts for cracks and section loss in metal components, and for splitting, rot, and insect attack in timber components. Note any impact damage. Special attention must be given to the size, type, and spacing of fasteners and the anchorage. Inspection of railings and posts should include the following items:

1) Look for damage caused by vehicular collisions.

2) Report any loose connections or anchorage.

3) Check the horizontal and vertical alignments.
4) Examine timber members for splits, checks, and decay.

5) Check metal members for corrosion and section loss.

6) Notify owner of any damaged railing that would be unable to redirect an errant vehicle.

7) Check that railing meets current design criteria.

Rate the railing/post according to the following criteria:

N  Not Applicable

9  Excellent Condition – new; meets current design criteria

8  Very Good Condition – no problems noted; meets current design criteria

7  Good Condition – some minor problems; meets current design criteria

6  Satisfactory Condition – elements show some minor deterioration; no hazard to pedestrians or motorists; meets current design criteria

5  Fair Condition – structurally sound; does not meet current design criteria

4  Poor Condition – any hazard to pedestrians or motorists; does not meet current design criteria; up to five percent of sections are missing, corroded through, or broken; horizontal or vertical misalignment; up to five percent loose connections or anchorage

3  Serious Condition – any hazard to pedestrians or motorists; does not meet current design criteria; five percent to 10 percent of sections are missing, corroded through, or broken; less than five percent to 10 percent loose connections or anchorage

2  Critical Condition – any hazard to pedestrians or motorists; does not meet current design criteria; 10 percent to 20 percent of sections are missing, corroded through, or broken; 10 percent to 20 percent loose connections or anchorage

1  Failure Condition – any hazard to pedestrians or motorists; does not meet current design criteria; more than 20 percent of sections are missing, corroded through, or broken

0  Failed Condition – any hazard to pedestrians or motorists; does not meet current design criteria; not providing value as a railing or post
Figure 4:3-24: Guardrail with Collision Damage

Figure 4:3-25: Steel Railing/Post
Figure 4:3-26: Steel Railing/Post

Figure 4:3-27: Steel Railing/Post with Minor Corrosion

Figure 4:3-28: Timber Railing/Post with Minor Checks
Figure 4:3-29: Railing/Post Does Not Meet Design Criteria

Figure 4:3-30: Railing/Post with Missing Section
Figure 4:3-31: Steel Railing on Concrete Parapet

Figure 4:3-32: Metal Railing
ITEM 58.09 – PAINTED LINES

Rate the overall condition of lines painted on the wearing surface, considering visibility, reflectivity, and coverage.
ITEM 58.10 – DRAINS

A drainage system should remove water from the structure as quickly and completely as possible without causing erosion below the structure. Poor or insufficient drainage can cause a range of problems. Deck drains are receptacles to receive water. Deck drains include simple holes through the deck, slots at the base of a concrete parapet, and inlet boxes (scuppers).
Figure 4:3-37: Deck Drain

Figure 4:3-38: Deck Drain Inoperable

Inspection of deck drains should include the following items:

1) Check the deck drains for debris accumulation (plant growth, sand, gravel, and trash).

2) Note any inlets or inlet grates that are deteriorated, broken, or missing. Broken grates that are hazards to traffic or pedestrians should be reported immediately.

3) Look for evidence of ponding on the deck, such as debris accumulation in the gutters or low spots. Try to determine why roadway water is not getting to drains, and note these reasons on the inspection form. Notify the owner of any drains that allow ponding on the bridge deck.

4) Examine the embankments and slopes for evidence of erosion. Clogged drainage systems force more runoff water onto these areas, increasing the erosion potential.
Rate the condition of the deck drains, as seen from the deck, including alignment, using the following criteria:

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor problems
6  Satisfactory Condition – some minor deterioration or clogging; operating properly
5  Fair Condition – partially clogged; minor misalignment
4  Poor Condition – clogged; misalignment interferes with function; any hazard to pedestrians or motorists
3  Serious Condition – inoperable drainage
2  Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken
1  Failure Condition – bridge closed to traffic, but corrective action may put it back in light service
0  Failed Condition – bridge closed to traffic; beyond corrective action

ITEM 58.11 – DOWN SPOUTS/DRAIN PIPES

Down spouts and drainage pipes carry runoff away from the drain and off of the superstructure and substructure. Runoff water that drains directly onto the superstructure or substructure may corrode structural steel, deteriorate concrete piers, and contribute to erosion of earthen abutment slopes.
Inspection of down spouts and drain pipes should include the following:

1) Check for clogging and debris accumulation.

2) Examine down spouts and drain pipes and their fittings for splits, breaks, or disconnected pipes.

3) Check to see that clean outs are in place and operating.

4) Look for any missing or broken pipe brackets and check to see that all components are supported properly.

5) Check the condition of any rubber down spout boots. Rubber boots connect a fixed rigid pipe (such as a pipe attached to a pier) to a movable rigid pipe (such as an outlet pipe) at expansion joints. These flexible boots allow superstructure expansion and contraction without breaking the downspout.

6) Check that drains do not allow water to run onto superstructure or substructure elements.

Rate the overall condition of the down spouts or drain pipes, as seen from under the deck, according to the following criteria. Note any clogs.

- **N** Not Applicable
- **9** Excellent Condition – new
- **8** Very Good Condition – no problems noted
- **7** Good Condition – minor problems
- **6** Satisfactory Condition – some minor deterioration; operating properly
- **5** Fair Condition – partially clogged; minor misalignment; some erosion of embankment
- **4** Poor Condition – clogged; misalignment interferes with function; any hazard to pedestrians; channels water onto superstructure or substructure, causing damage; erosion of embankment
- **3** Severe Condition – severe erosion of embankment; channels water onto superstructure or substructure elements
- **2** Critical Condition – inoperable
- **1** Failure Condition – inoperable
- **0** Failed Condition – missing
Figure 4:3-40: Down Spout with Crushed Section

Figure 4:3-41: Down Spout
ITEM 58.12 – LIGHTS

Rate the overall condition of any lighting or lighting supports on the bridge. On concrete supports, look for spalls and cracks. On steel supports, check for corrosion and cracks. On aluminum supports, check for fatigue cracks, particularly on roadway lights. On timber supports, check for rotting, insect attack, and splitting. Check all supports for loose connections, vandalism, alignment, and collision damage.
Rate the overall condition of the lights according to the following criteria:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Condition Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition – new</td>
</tr>
<tr>
<td>8</td>
<td>Very Good Condition – no problems noted</td>
</tr>
<tr>
<td>7</td>
<td>Good Condition – some minor problems</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition – elements show some minor deterioration</td>
</tr>
<tr>
<td>5</td>
<td>Fair Condition – structurally sound, but some deterioration such as corrosion, rot, or splitting of lighting units; lights functioning properly; no hazard to pedestrians or motorists</td>
</tr>
<tr>
<td>4</td>
<td>Poor Condition – structural condition of the lighting units is deteriorated; lights not operating as designed; hazard to pedestrians or motorists</td>
</tr>
<tr>
<td>3</td>
<td>Serious Condition – possibility of structural failure; lights not operating as designed</td>
</tr>
<tr>
<td>2</td>
<td>Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken</td>
</tr>
<tr>
<td>1</td>
<td>Failure Condition – bridge closed to traffic, but corrective action may put it back in light service</td>
</tr>
<tr>
<td>0</td>
<td>Failed Condition – bridge closed to traffic; beyond corrective action</td>
</tr>
</tbody>
</table>

Figure 4:3-44: Lighting Support with Deteriorated Grout Pad
ITEM 58.13 – SIGNS

Signs are critical to the public safety. Signs must be posted at each bridge approach in a location that is near the bridge, but will also allow vehicles to change direction if the signs restrict the bridge.

Common signs found on bridges include the following:

**Object markers**: Used at most highway bridges to warn the traveling public of the approaching crossing. This is most often a Type 3 object marker, mounted at the ends of the bridge rail. These are rectangular, vertically oriented signs with diagonal black and yellow stripes.

**Narrow bridge**: Used when the bridge horizontal clearance of a two-way road is between 16 feet and 18 feet, or when the bridge roadway clearance is less than the width of the approach travel lanes.

**One-lane bridge**: Used when the bridge horizontal clearance of a two-way road is less than 16 feet. If commercial vehicles constitute a high proportion of the traffic, or if the approach sight distance is limited, the bridge would be considered one-lane if the horizontal clearance is less than 18 feet.

**Vertical clearance**: Used when the vertical clearance of the traveled way under the bridge is less than 14 feet, six inches. The clearance in feet and inches is always printed on this sign.

**Weight limit posting**: Used to indicate a weight restriction on the bridge. The allowable load is always printed on this sign. See Part 1, Chapter 9 for Load Posting Information.

**Other**: Posted signs related to the bridge, such as curve warning signs, high water signs, “Watch for Ice on Bridge” signs, or “Bridge Out” signs.
Rate the condition of the bridge’s signage. Items that must be considered include the following:

1) Look at visual items such as legibility, reflectivity, faded paint, and obstructing vegetation or dirt.

2) Look at message effectiveness and clarity.

3) Examine support structural condition and deterioration.

4) Evaluate the physical condition of the sign board and post, such as traffic impacts, loss of foundation material, or lateral support.

5) Watch for vandalism such as graffiti, damage, or a missing sign.

Rate the overall condition of any signs or sign supports on the bridge in accordance with the following criteria:

- **N  Not Applicable** – no signs
- **9  Excellent Condition** – new signs
- **8  Very Good Condition** – no problems noted
- **7  Good Condition** – some minor problems
- **6  Satisfactory Condition** – elements show some minor deterioration
- **5  Fair Condition** – deterioration such as corrosion, rot, or splitting on sign supports; signs’ messages applicable and readable; no hazard to pedestrians or motorists
- **4  Poor Condition** – structural condition of signs is deteriorated; signs are incorrect, inapplicable, or unreadable; any hazard to pedestrians or motorists
- **3  Serious Condition** – possibility of structural failure; signs are incorrect,
inapplicable, or unreadable; any hazard to pedestrians or motorists

2 Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken

1 Failure Condition – bridge closed to traffic, but corrective action may put it back in light service

0 Failed Condition – bridge closed to traffic; beyond corrective action

ITEM 58.14 – UTILITIES

Utility companies are often given permission to mount their services on a bridge. These could include gas lines, telephone lines, or sewer line. The utility owner is responsible for the adjustments, repairs, or restoration of their attachments to the bridge. Utilities are
mounted on bridges by permit. Utility owners must be notified of problems. Failure of the utility owner to act promptly to eliminate hazards or utilities in poor condition is reason to rescind the permit.

Inspection of utilities should include the following:

1) Note any utilities on the bridge, the location of the utilities, and any visible problems with their condition, supports, or hangers.

2) Report any hazards to motorists or pedestrians posed by the utility to the utility and to the bridge owner.

3) Look for leaks, breaks, corrosion, loose wires, or bad insulation.

4) Check that utilities are not reducing the vertical clearance or freeboard.

Rate the overall condition of any utilities or their supports on the bridge and note the type of utility. Utilities that are close to the bridge and that may affect the bridge function should be noted. Describe any unknown utilities in the notes.

ITEM 58.15 – LONGITUDINAL JOINTS

Longitudinal joints are joints parallel to the direction of travel. In addition to the condition rating of each joint, the joint type needs to be identified. Inspection of longitudinal joints should include the following:

1) Check for horizontal or vertical displacements or misalignments of the joint or its elements.
2) Check for debris in the joint and deterioration of the joint materials or anchorage of the joint.

3) Check for leaking or discoloration of the underside of the deck in the vicinity of the joint.

4) Record the approximate air temperature (Fahrenheit) and the width of the joint opening, in inches, on each end of each joint.

Rate the overall condition of longitudinal joints on the bridge in accordance with the following:

- **N** Not Applicable
- **9** Excellent Condition – new
- **8** Very Good Condition – no problems noted
- **7** Good Condition – some minor problems
- **6** Satisfactory Condition – some minor deterioration
- **5** Fair Condition – deterioration or misalignment, minor leaking, or minor debris
- **4** Poor Condition – damaged and/or misaligned; horizontal or vertical displacement, creating a hazard; significant debris; significant leaking
- **3** Serious Condition – advanced damage, misalignment, and/or displacement; hazardous
- **2** Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken
- **1** Failure Condition – bridge closed to traffic, but corrective action may put it back in light service
- **0** Failed Condition – bridge closed to traffic; beyond corrective action

**ITEM 58.16 – TRANSVERSE JOINTS**

Expansion joints provide for thermal expansion and contraction of the deck and superstructure. The clear opening of the joint should provide adequate space for movement of the adjacent superstructure elements. Joints also fill the gap between deck and abutment backwall to provide a smooth ride for vehicles transitioning onto and off the bridge. They must also be durable enough to withstand the abuse from traffic wheel loads, snow plow blades, road debris, sunlight, freezing, and deicing chemicals.

Transverse joints are joints perpendicular to the direction of travel. In addition to the condition rating of each joint, the location of each joint and the joint type needs to be identified.

Inspection of transverse joints should include the following:

1) Check that there are no horizontal or vertical displacements or misalignments of the joint or its elements.
2) Check for debris in the joint.

3) Check for deterioration of the joint materials and anchorage of the joint.

4) Check for leaking or discoloration of the underside of the deck in the vicinity of the joint.

5) Note any overlays placed over the joint.

6) Listen for any rattles or indications of component looseness as traffic drives over the joint.

7) Check the support condition from below the deck. Look for broken welds and corrosion.

8) Record the approximate air temperature (Fahrenheit) and the width of the joint opening, in inches, on each end of each joint.

Rate the overall condition of any transverse joints on the bridge according to the criteria below. Record the type of joint. Estimate the length of the joints using NBI Item 51 or 52. If more than one type of transverse joint is used on the bridge, enter the data for the most critical type. List other joint types in the notes.

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor problems
6  Satisfactory Condition – some minor deterioration
5  Fair Condition – deterioration and/or misalignment; minor leaking; minor debris
4  Poor Condition – damaged and/or misaligned; horizontal or vertical displacement, creating a hazard; significant debris; significant leaking
3  Serious Condition – advanced damage, misalignment, or displacement; hazardous
2  Critical Condition – unless closely monitored, may be necessary to close the bridge until corrective action is taken
1  Failure Condition – bridge closed to traffic, but corrective action may put it back in light service
0  Failed Condition – bridge closed to traffic; beyond corrective action
Figure 4:3-50: Transverse Joint

Figure 4:3-51: Transverse Joint with Debris
Figure 4:3-52: Transverse Joint with Deck Cracks Suggesting a Failing Anchorage System

Figure 4:3-53: Transverse Finger Plate Expansion Joint
SECTION 4.1 INTRODUCTION

For bridge inspection purposes, superstructure refers to all structural members, other than the deck, that distribute loads to the substructure units. One exception to this definition is a reinforced concrete slab, where the deck and superstructure are one and the same. Figure 4:4-1 shows cross sections for many common superstructure types:

(A) Reinforced Concrete Slab
(B) Reinforced Concrete Voided Slab
(C) Timber Slab
(D) Steel Multi-Beam
(E) Steel Through Girder
(F) Steel Girder/Floor Beam/Stringer
(G) Reinforced Concrete Girder (T-Beam)
(H) Prestressed Concrete I-Beam
(I) Precast Concrete Channel Beam
(J) Prestressed Concrete Box Beam
(K) Steel Box Girder
(L) Post-Tensioned Concrete Box Girder
(M) Reinforced Concrete Through Girder
(N) Timber Multi-Beam
(O) Steel Truss
(P) Timber Truss

Figure 4:4-1: Common Superstructure Types

Superstructure members are categorized into two groups: primary and secondary. Primary superstructure members are those that directly carry the deck dead loads and
live loads to the substructure. Primary superstructure members include girders, beams, stringers, arches, trusses, cables, bearings, and bearing stiffeners. Primary superstructure members must carry repetitive live loads, as well as repeatedly applied impact loads.

Secondary superstructure members provide lateral stability for the primary members and help laterally distribute the live loads so that the primary members act together as a unit. Secondary members include diaphragms, cross-frames, sway bracing, lateral bracing, transverse web stiffeners, and longitudinal web stiffeners.

Depending on the type of superstructure, the members may need to deliver these loads to the substructure by way of bending, tension, compression, or a combination of these. To handle this type of demand, it is critical that the members be sound, as any failure of a member could be catastrophic. This chapter provides guidelines for the bridge inspector on which parts of the superstructure are critical to inspect and what defects may cause future problems.

Figure 4:4-2: Through Arch Truss Bridge
SECTION 4.2 STEEL SUPERSTRUCTURES

Since the late 1800s, steel has been one of the most commonly used materials for the construction of bridge superstructures. It can be designed to carry tension, compression, and bending loads. Steel can be configured in many different ways and can be used to create virtually any bridge type, including multi-beam bridges, two-girder bridges, arches, rigid frame bridges, trusses, and box girder bridges.

The most common defect found on steel superstructures is corrosion, and the worst corrosion is generally found where the steel is subjected to cycles of moisture. Corrosion reduces the section of a member, leading to an increase in stress. Corrosion can also affect how a structure operates. For example, unintended bending stresses may be introduced to a member when corroded pins restrict movement. In order to check for corrosion, inspectors must remove local areas of debris accumulation. Dirt and debris on members trap moisture and road salts and increase corrosion. Bird waste is acidic and traps moisture and road salts, accelerating corrosion. Figure 4:4-3 shows corrosion on a girder flange.

![Figure 4:4-3: Pitting Caused by Corrosion on Girder Bottom Flange](image)

Pack rust is corrosion occurring between two pieces of lapped steel, such as between the vertical leg of a flange angle and the girder web. These details trap moisture and do not allow for quick water evaporation; so, pack rust most often occurs under leaking drains or expansion joints, at fascia girders, and on trusses and arches. The expansive force of pack rust can be great enough to bend thick plates and to pry and fracture rivets and bolts. Details prone to pack rust include girder flange and web splices, gusset plates, riveted cover plates, and back-to-back angles. Figure 4:4-4 shows corrosion on a girder flange.
Bridges constructed with weathering steel are also susceptible to corrosion. The signs of corrosion on weathering steel include deep pitting, laminar rust, flaking, or a rough surface.

Steel structures are also susceptible to developing fatigue cracks. Fatigue failure is of special concern because fatigue failures can be brittle, giving no warning as to imminent collapse. When steel is welded, the stress from the weld can create a crack. Certain details, especially those where welds intersect or where the steel is constrained in more than one direction, are especially prone to cracking. Appendix A shows several illustrative examples of fatigue-prone details. All welds must be carefully examined because poor welding may have left flaws within the weld metal even where fatigue cracks are not normally expected to be found. Fatigue cracks usually show up as rust stains or rusty breaks in the paint, propagating perpendicular to the direction of stress. Detection of fatigue cracks will most often occur during arm's length inspections. See Part 4, Chapter 11 for more information on Fatigue and Fracture Critical Inspections.

Subsection 4.2.1  Beam and Girder Bridges

Beam and girder bridges are constructed using hot rolled steel beams or fabricated girders including fabricated box girders. These shapes can be used to construct multi-beam bridges, two-girder bridges, or single-girder bridges when using box beam construction.
Rolled Multi-Beam Bridges: Rolled multi-beam bridges are constructed using three or more hot-rolled steel beams as the primary members. Beam depths are usually no more than 36 inches, which limits spans to about 90 feet. Transverse diaphragm secondary members, using C-shaped channel sections or I-shaped members, may be bolted, riveted, or welded with intermittent welds to the beam webs. To increase a beam’s bending capacity, cover plates may be riveted, bolted, or welded to the tension and/or compression flanges.

Fabricated Multi-Girder Bridges: Fabricated multi-girder bridges are constructed using three or more built-up steel girders as the primary members. The girders are fabricated by either riveting or bolting steel plates and sections, or by welding steel plates. Greater economy is typically achieved by varying flange thickness/width or the number of plates in a flange to accommodate the bending moment. Web depths may also be deepened (haunched) over the piers to accommodate the bending moment. Girder depths are usually greater than 36 inches, allowing for spans up to about 500 feet. Due to their greater web depths, transverse cross-frames using angles or T-shapes are usually used as secondary members. In addition, vertical and longitudinal stiffeners may be welded or riveted to the web to prevent web buckling. Older structures may use lateral bracing placed at the level of the bottom or top girder flanges to connect adjacent girders. Larger spans may be built with a floor system consisting of stringers and floor beams as additional primary members. Floor beams are transverse members that frame into the girder webs. The stringers bear on or are framed into the floor beams. Stringers are usually rolled beams placed between, and running parallel to, the girders.
Fabricated Two-Girder Bridges: Two-girder system bridges are constructed using only two built-up steel girders as primary members. These bridges have floor systems that use floor beams and sometimes stringers. As in fabricated multi-girder bridges, the girders are fabricated by either riveting/bolting together steel plates and angles, or by welding steel plates together. Two-girder systems do not have load path redundancy and are classified as fracture critical bridges.
Steel Through Girder Bridges: Through girder bridges are fabricated two-girder bridges with the deck placed between the girders rather than on top of them. Many older short- to medium-span highway and railroad bridges use this configuration. Through girder bridges lack redundancy and are fracture critical.

Railroad Flatcar Bridges: Railroad flatcar bridges are steel girder bridges constructed from salvaged railroad flatcars. They are available in many configurations. The design
and installation of a railroad flatcar bridge should be overseen by an engineer registered in the state of Indiana. Special attention must be given to the selection of the flatcar, the design of the longitudinal connections between flatcars, and load transfer. Most railroad flatcars should be supported on the bolsters and the design engineer should ensure that the support is adequate. Welded connections should be visually inspected to ensure that fatigue cracks are not present when a flatcar is selected for use as a bridge. Box cars and gondola cars should not be used in the construction of bridges.

**Steel Box Girder Bridges:** Box girder bridges have one or more girders fabricated from plates welded into a rectangular or trapezoidal closed shape. Because closed shapes are more torsionally stiff than open I-shaped girders, box girders are commonly used for curved spans. Closed shapes also help protect the steel from corrosion since only half the plate area is exposed to the elements. The vertical plates form the webs and the bottom plate forms the bottom flange. The top flange is formed by the top plate, if present, or the concrete deck. Both the web and flange plates are normally strengthened with transverse and longitudinal stiffeners to prevent buckling. Box girders can usually be entered through access hatches to allow inspection of their interiors. Bridges using one box girder do not have load path redundancy and are classified as fracture critical bridges. Most two-box girder bridges are also classified as fracture critical. However, some two-box girder bridges have been designed with substantial bracing between the boxes so that one of them can support the entire bridge should the other fail. Steel box girder bridges are considered complex in Indiana. The steel box girders constructed in the 1960s and 1970s often developed cracks due to torsion from improper shipping and erection. These cracks were often found at the web gaps.

![Figure 4:4-10: Steel Box Girders](image)

The inspection of steel girder bridges should include the following:

1) View down the member’s length to check vertical and horizontal alignments and check for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.
2) Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to the areas below the deck expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This situation should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

3) Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note any deformation of plates.

4) Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

5) Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

6) Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

7) Look for overload damage in the form of compression flange buckling and tension flange elongation or fracture.

8) Look for web crippling, a permanent wrinkling or buckling of the web due to overloads.

9) Look for torsion-related damage on curved box girders at the diaphragms/cross-frames, webs, and flanges as evidenced by plate or member distortions.

10) Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel. Impact damage is usually most prominent on the fascia girders, although damage can occur across the entire cross section of the superstructure due to impact and recoil of all members after impact.

11) Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

12) Inspect cables and rods in accordance with Part 4, 4.2.7.2.

13) Inspect pins at eyebars, bearings, hangers (U-bolts), or other devices holding up the floor beams in older trusses.
14) Examine the connections between railroad flatcars.

15) Note where railroad flatcars are supported. If not supported at the bolsters, recommend that the members be checked for adequate strength and stability in the bearing area.

16) Note any pre-installation damage on railroad flatcars and check damaged areas for cracks.

17) For railroad flatcar bridges, note areas where original equipment such as mounting brackets and braking equipment have been removed and check for stress risers.

18) For railroad flatcar bridges, note if any primary structural components have been modified and check that the load rating reflects the modifications.

Figure 4.4-11: Damaged Steel Flatcar Bridge

Subsection 4.2.2 Steel Truss Bridges

Steel truss bridges are structures with two or more parallel trusses supporting the deck. The deck may be placed on top of the trusses (deck truss) or between the trusses (through truss when there is overhead lateral bracing, or pony truss when there is no overhead lateral bracing). Through or pony trusses are most often constructed using two trusses, and are considered fracture critical structures. Two-truss deck trusses are also fracture critical structures.

Truss chord, diagonal, and vertical members may be fabricated from eyebars, rolled shapes, or built-up members. Connections are made with rivets, bolts, welding, or pin connections in some older trusses. All truss bridges have floor systems similar to two-girder systems. To keep the two trusses in line longitudinally, secondary lateral bracing members diagonally connect the bottom chords. For deck and through trusses, the top chords are laterally braced in a similar way. Sway bracing keeps the two trusses in line laterally. On deck and through trusses, sway bracing transversely frames between the
truss verticals. On pony trusses, sway bracing is usually placed as a transverse diagonal on the outside of the trusses. It connects the top chord to transverse outrigger floor beam extensions and prevents buckling of the top chord. Typical components are labeled in Figure 4:4-12.

![Figure 4:4-12: Truss Components](image)

Truss members are theoretically loaded in either pure tension or compression and are considered to be axially loaded. Members carrying tensile loads are fracture critical members. Though each of these members may contain internal redundancy (multiple eyebars or built-up riveted shapes), each member is inspected as a fracture critical member. Steel through trusses and trusses with pin and eyebar connections are considered complex bridges in Indiana.

![Figure 4:4-13: Steel Through Truss Bridge](image)

Tension members must be identified prior to performing a Fracture Critical Inspection. It is also advantageous to identify tension members for a Routine Inspection. On simply supported trusses, the bottom chords will always be in tension and the vertical member closest to each support will always be in tension. On continuous trusses, the top chord
will be in tension over the piers, and the bottom chord will be in tension between supports; the bottom chord will be in compression over the piers, and the top chord will be in compression between supports. On simply supported trusses, diagonals that point upward and away from mid-span are tension members, as well as any counters which form an “X” pattern at or near mid-span. There is no easy method to determine which diagonals are in tension for continuously supported trusses and for vertical members of any truss.

Visual methods are not always capable of adequately evaluating the condition of gusset plates with section loss due to corrosion in tightly configured connections, or those where the members framing into the gusset plate are closely spaced. Trusses with these fracture critical connections may require special documentation and nondestructive testing (NDT) to quantify the gusset plate thickness. This is further discussed in detail in Part 4, Chapter 11, Section 11.3.

Figure 4:4-14: Multiple Eyebars Connected with a Pin
Inspection of steel truss bridges should include the following:

1) View down the member’s length to check vertical and horizontal alignments, and check for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.

2) Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas below expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

3) Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note any deformation of plates.

4) Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, or re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and/or photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

5) Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

6) Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

7) Closely examine eyebar heads for cracks, corrosion, and lack of movement. Check any forged areas on eyebars for cracks or separations.

8) Check to make sure all eyebars in a multiple eyebar member are parallel to one another.

9) Check for bowed or buckled tension members. Unintended bending and compressive stresses may be introduced into a tension member from substructure settlement or heavily rusted/frozen pinned joints. Look for overloads on other
members when this situation is encountered, since loads previously carried by the tension member must be redistributed somewhere else within the bridge.

10) Document the primary truss gusset plates where limited access prevents section loss from being adequately quantified.

11) Look for compression overload damage in the form of local member buckling or waviness. Global buckling will take the form of a bowed member or a member bowed into an “S” shape if support is provided between its ends.

12) Check all pins for excessive wear.

13) Check to see if pin spacers are keeping the eyebars or loop rods properly aligned and symmetric about the truss plane.

14) Examine the condition of threaded members such as truss rods at turnbuckles.

15) Check for heavily corroded pins that may have locked-up eyebar or loop rod movement. Transverse cracks may appear in the member body away from the forge zone or in the eyebar head.

16) Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on member edges or corners. Particularly strong collisions may tear the steel. Cracks can develop in the connections at each end of any member that has been hit.

17) Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

18) Inspect cables and rods in accordance with Part 4, 4.2.7.2.

Subsection 4.2.3 Steel Arch Bridges

Arches resist axial compressive loads and bending moments. Because they are not tension members, arches are not considered fracture critical even though most steel arches have only two main members. Tied arches are the exception and are considered fracture critical. Arch members are classified as solid-ribbed, braced-ribbed (trussed arch), spandrel-braced, or tied. The Bridge Inspector’s Reference Manual (BIRM) has several photographs in Chapter 8 illustrating some of these arch styles.

Solid-ribbed steel arches are fabricated into I-girders or box shapes. Braced-rib arches have two curves (usually fabricated boxes) defining the arch shape, braced with truss webbing between the curves. These are usually used for longer spans or where better control of live load deflections is required. Spandrel-braced arches are similar to solid-ribbed arches, but have diagonal bracing between the spandrel bents above the arch. Tied arches have their ends connected with a tension tie girder as a means to remove the arch’s horizontal thrust from its bearing. These tension ties are fracture critical components of the arch superstructure. The ties and arches are usually fabricated box members.

Arch ribs carry compressive loads and bending moments. Compressive forces are fairly constant throughout the arch. Bending moments will be variable and depend on the location of arch hinges. Moments are zero at the hinges. Arches may have three hinges (one at the crown and two at the bases), two hinges (at the bases), or no hinges (fixed).
Columns or shafts on arch bridges may carry a combination of compressive loads and bending moments (spandrel columns), tensile loads (hangers or longitudinal bracing members), or compressive loads (longitudinal bracing). Hangers, arch braces, and spandrel braces are tension members.

**Steel Deck Arch Bridges:** Steel deck arch bridges are structures with the deck placed on top of two or more riveted, bolted, or welded arches. The arches are the main load-carrying members and their ends bear on foundations at grade. Their bearing ends are usually pinned. The end reactions have a vertical component due to the dead and live gravity loads and a horizontal component due to the arch’s outward thrust. A pin may also be present at the arch crown, forming a three-hinged arch. The area between the deck and arch is known as the spandrel. Deck arches use vertical compression members, called spandrel columns, to deliver the deck loads to the arch ribs. The spandrel columns may be rolled or built-up shapes. Each arch rib may be fabricated into an “I” or box shape (solid-ribbed arch) or into a truss shape (braced-rib arch). When diagonal braces connect the spandrel columns above the rib, the bridge is classified as a spandrel-braced arch. The floor system will contain floor beams, spandrel girders, and sometimes stringers. Secondary members include the upper and lower lateral bracing which brace the floor system and arch ribs, respectively. Transverse sway bracing keeps the ribs and spandrels in line laterally. Although many deck arch bridges have only two arch ribs, the bridges are not considered fracture critical since arches resist a combination of compression loads and bending moments, not tension. Open spandrel deck arch bridges are considered complex in Indiana.

**Steel Through Arch Bridges:** Steel through arch bridges are structures with the deck placed below the crown of, and between, two riveted, bolted, or welded arches. As with deck arches, the arches are the main load-carrying members and are usually pinned, with the ends bearing on foundations at grade. A pin may also be present at the arch crown to form a three-hinged arch. Through arches use vertical tension members to suspend the deck under the arch ribs. The tension members may be steel cables, wire rope, or solid steel hangers. Each arch rib may be fabricated into a box shape (solid-
ribbed arch) or more commonly into a truss shape (braced-rib arch). The floor system will contain floor beams, girders, and sometimes stringers. Secondary members include lateral bracing for the arch ribs and floor system, and transverse sway bracing to keep the ribs in line laterally. As with deck arches, most through arches are not fracture critical bridges.

![Through Arch Bridge](image)

**Figure 4:4-17: Through Arch Bridge**

**Steel Tied Arch Bridges:** Steel tied arch bridges are special types of through arches. The ends of tied arches bear on piers and are tied together with a tie girder. The tie girder is in tension to resist the large horizontal thrusts of the arch rib. It functions in a similar manner to the string on an archer’s bow. Because tied arch bridges have only two arches and two tie girders, tied arch bridges are considered fracture critical since a failure of one tie girder will directly lead to a failure of its associated arch. The tie girder may also behave as a bending member, in conjunction with the ribs, to deliver dead and live gravity loads to the pier. Primary and secondary members of tied arches are similar to those of through arches, although the arch ribs are typically solid box-shaped members. Floor beams frame directly into the webs of the tie girders, and cables or hangers (solid or hollow) directly support the tie girder. The hangers may be oriented vertically or diagonally.
The inspection of steel arch bridges should include the following items:

1) View down the member’s length to check vertical and horizontal alignments, as well as for any canting (lateral bending or twisting). This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.

2) Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas under deck joints and details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

3) Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note and measure any deformation of plates.
4) Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

5) Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

6) Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

7) Look for local compression overload damage in the form of local member component buckling, plate waviness, or crippling.

8) Look for global buckling which will take the form of longitudinal rib misalignment.

9) Inspect the longitudinal bracing members of braced rib arches. These members should be inspected in a manner similar to truss members (see Subsection 4.2.2). They are designed to take compressive loads, tensile loads, or both.

10) Examine the rib splice plates for loose fasteners and excessive corrosion.

11) Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel.
12) Inspect the hinge pins for corrosion and excessive wear.

13) Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

14) Inspect cables and rods in accordance with Part 4, 4.2.7.2.

Subsection 4.2.4 Steel Rigid Frame Bridges

Steel rigid frame bridges are structures in which the structure’s inclined supporting “legs” are integrated with the girders to form a rigid frame. Rigid frames are usually constructed using welded plate girders and legs to form a “K” shape or triangular delta shape. Though the legs are used as bridge piers, the legs are actually part of the superstructure because of their rigid connection to the girders. This rigid intersection of the leg and girder is referred to as the knee and allows both the girders and legs to resist bending moments. Large moments and shear forces are resisted by the knee, resulting in a complex arrangement of stiffeners in this area. The legs are pinned at grade, and the girder ends supported by conventional abutments. Rigid frame bridges may use two or more frames to support the deck. The girders, legs, and bearings are all primary members on multi-rigid frame bridges. The diaphragms, cross-frames, longitudinal stiffeners, transverse stiffeners, and radial stiffeners are all secondary members. On two-frame bridges, the girders, legs, stringers, floor beams, and bearings are all primary members. Secondary members include the lateral bracing, longitudinal stiffeners, transverse stiffeners, and radial stiffeners. Spans of 50 to 200 feet are attainable using rigid frames.

Two-frame bridges are considered fracture critical. The curvature of the deck should be checked periodically to monitor for flattening and to check for sag. Check for uplift of the ends of short-end spans when the center span is loaded.

The inspection of steel rigid frame bridges should include the following:

1) View down the member's length to check vertical and horizontal alignments, as well as for any lateral bending or twisting. This type of damage may be due to overloads, corrosion, traffic impact, or support settlement.

2) Periodically survey the curvature of the deck to monitor flattening.
3) Examine all members and bearings for corrosion and loss of cross-sectional area. Particular attention should be given to areas under the deck expansion joints and to details that trap water. The inspector should remove as much rust as possible, using a chipping hammer or paint scraper, and record the section loss. Some corrosion is so severe that holes are created through the steel plate. This should be recorded as through thickness section loss. If any section loss over 10 percent on a primary member is found, the District Engineer or the Inspection Consultant should be notified and the bridge should be re-rated for load.

4) Look for pack rust, noted by individual plate bending between fasteners. The amount of plate separation caused by pack rust should be measured and recorded. Note and measure any deformation of plates.

5) Document all cracks. The District Engineer or the Inspection Consultant should be notified of newly discovered cracks in primary steel members. Include dates of when the crack was discovered, confirmed, and re-examined; its location, length, and width; and the location of crack tips. This information should be written directly on the cracked member with a permanent marker or a paint stick on weathering or corroded steel for easy reference and relocation at later dates. Sketches and photographs should be used to indicate the location, orientation, and length. Record the dimensions and details of the member containing the crack, any opening or closing of the crack as vehicles pass, corrosion conditions at the crack, and whether or not dirt or debris is found on the cracked steel surfaces.

6) Check rivet/bolt heads on built-up components. Corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

7) Check all fasteners. Signs of fatigue include rust bleeding/powder under the fastener head or nut, gaps between the connected parts and the fastener head or nut, a dull sound when the head is tapped with a hammer, and missing fasteners.

8) Look for overload damage in the form of compression flange buckling and tension flange elongation or fracture.

9) Look for web crippling, a permanent wrinkling or buckling of the web due to overloads.

10) Look for signs of impact damage, including scrapes on member undersides, distorted members, and nicks or gouges on plate edges or member corners. Particularly strong collisions may tear the steel.

11) Inspect pins or pin-and-hanger assemblies in accordance with Part 4, 4.2.7.1.

12) Inspect cables and rods in accordance with Part 4, 4.2.7.2.

13) Look for uplift of the girders at the abutments and for misaligned bearings due to uplift.

Subsection 4.2.5 Steel Cable-Stayed and Suspension Bridges

Steel Cable-Stayed Bridges: Steel cable-stayed bridges are typically long span structures that use one or two planes of inclined stay cables as their main means of
support. The stay’s opposite ends are attached to, or carried over, pylons, which deliver the cable forces to the foundation. The cables are tension members. Cable-stayed bridges are always considered complex bridges in Indiana and may be fracture critical.

**Basket Handle, Cable-Stayed Arch Bridges:** Indiana has one basket handle, cable-stayed steel arch bridge carrying I-65 over State Route 46. On a basket handle cable-stayed bridge, the arches supporting the cable are connected at the top.

![Basket Handle, Cable-Stayed Arch Bridge](image1)

Figure 4:4-21: Basket Handle, Cable-Stayed Arch Bridge

![Cable-Stayed Bridge](image2)

Figure 4:4-22: Cable-Stayed Bridge

**Suspension Bridges:** Suspension bridges are typically long span structures that support the deck from vertical cable hangers attached to two or more catenary main suspension cables. The main suspension cables are draped over towers and their ends
are fixed to gravity anchors. Suspension bridges are always fracture critical and are considered complex bridges in Indiana.

Figure 4:4-23: Steel Pedestrian Suspension Bridge

As complex bridges, steel cable-stayed and suspension bridges will have their own operation and maintenance manuals to guide the inspector during routine evaluations. The reader is referred to the Federal Highway Administration (FHWA) publication HI-94-033, *Safety Inspection of In-Service Bridges Participant Notebook, Volume 3* for additional guidance.

**Subsection 4.2.6 Moveable Steel Bridges**

Movable steel bridges are discussed in detail in Part 5 of this manual.

**Subsection 4.2.7 Inspection of Special Details in Steel Superstructures**

**4.2.7.1 Pins or Pin-and-Hanger Assemblies**

Pins and pin-and-hanger assemblies are primary load-carrying connection assemblies found in many steel superstructures. Individual bridge pins are located on multi-span girders where it is necessary to locate a non-expansion hinge away from a pier. Pin-and-hanger assemblies, consisting of two pins and two hangers, are found on multi-span girder bridges where it is necessary to locate the expansion hinge away from a pier. The assemblies are placed at the tip of a girder’s cantilever span and are used to suspend an adjacent span. Cantilevered trusses also use pin-and-hanger assemblies. On two-girder system bridges, pin-and-hanger assemblies are fracture critical members. All bridges with pin-and-hanger details and all trusses with pin and eyebar details are considered complex bridges in Indiana.

Hangers are designed to act as links and are consequently intended to be tension-only members. At least two are used per connection, one on each side of the girder web.
Hangers may be shaped as simple flat plates or as eyebars.

Hanger plates are susceptible to damage when corrosion freezes the pins and prevents free rotation. When this occurs the assembly ceases to behave as a hinge and begins to carry bending moments. These moments introduce bending stresses in the hangers in addition to the tensile stress for which the hangers were designed. Torsional forces in the pin can cause cracks and pin failure. Out-of-plane bending stresses may also be generated from girder misalignment or pack rust. As a result, overstress cracks may develop in the hanger plate(s).

On trusses, pins are normally employed to connect the ends of eyebars or loop rods, although large pins can connect the ends of modern built-up members. On girders, pins pass through web plates to form a non-expansion hinge. Pins are intended to be frictionless connections that allow for member rotation, but are not designed to carry any torsion. They are fabricated in a variety of sizes. The smallest are solid and use cotter pins to prevent the pin from walking out of the connection under vibratory loads. Medium diameter pins are also solid, but their ends are threaded so that self-locking nuts can be used to prevent the pin from walking out. Sometimes holes are drilled through the center axis of medium-sized pins. The largest pins have holes drilled through their center axis, through which passes a threaded rod. The rods also pass through pin end cap plates. Nuts are threaded onto the rod to retain the cap plates and the pin.

The inspection of pins and pin-and-hanger assemblies should include the following items:

1) Carefully check all edges and surfaces of all hangers, especially the ends beyond the pin centerlines, and the forged areas of any eyebars for cracks or corrosion. Forged areas will usually be near the eyebar head and body junction.

2) Check both sides of the hanger for cracks, if possible. A flashlight and inspection mirror can help.

3) Use NDT methods (dye penetrant, magnetic particle, ultrasonic, etc.) to look for cracks. NDT should be performed as part of an In-Depth Inspection.

4) Immediately report any cracks or section loss greater than 10 percent to the District Engineer or the Inspection Consultant. The nature of pin-and-hanger assemblies is such that a failure of one assembly may cause a domino effect failure on multi-girder bridges.
5) Tap the pin or threaded rod nut with a hammer to check for looseness. If the pins are excessively loose, notify the District Engineer or the Inspection Consultant immediately. A bridge inspector should never unscrew a pin nut or remove a cap plate to get a better look at the pin. Disassembly is not part of a Routine Inspection. Doing so could be catastrophic if pack rust between the girder web and hanger has placed the assembly on the verge of failure. Disassembly is only undertaken as part of an In-Depth Inspection program and only after proper auxiliary joint support is in place.
6) Examine all pins for signs of the desired member rotation about the pin, such as powdery orange or red rust (fretting rust) near surfaces that rub or bear, cracked paint between the pin and member, or physical movement as traffic crosses the bridge.

7) Measure the amount of pin wear on truss or girder hanger expansion hinge assemblies. Since access may be difficult due to closely spaced members or cap plates, creative measurements must be made. Two measurements must be taken at each pin to obtain adequate information of pin or member wear. Measure the distance from the centerline of the pin to the end of the hanger, (shown as Dimension 1 in Figure 4:4-27) and measure from the center of the pin to the inside flange surface of the girder through which the pin passes (shown as Dimension 2 in Figure 4:4-27). These readings will give measurements for wear at the pin/hanger interface and pin/web interface, respectively. Make these measurements from the centerline of the threaded rod on pins using cap plates.

8) Measure the amount of pin wear on non-expansion hinges. Measure from the center of the pin to the inside surface of the girder’s top and bottom flanges. These readings will give measurements for wear at the bottom of pin/web interfaces and top of pin/web interfaces, respectively (shown as Dimensions 3 and 4 in Figure 4:4-27). Make these measurements from the centerline of the threaded rod on pins using cap plates.

9) Compare these measurements to the distances shown on the original design drawings, accounting for the pinhole tolerance (usually 1/32 inch). Wear of 1/8 inch or greater should be brought to the attention of the District Engineer or the Inspection Consultant. If the original design drawings are not available, record the measurement for comparison to measurements taken on future inspections. If possible, a wire or stiff steel rule should be used to probe between the plies of plates to measure the distance from the pin surface to the surfaces described above.
10) Look for fretting corrosion between the hanger and girder web, which will be evident by dusty-looking reddish rust around the plates’ interface. Fretting corrosion is caused by two tightly fitting plates rubbing against each other.

11) Check for ratcheting. On new structures, rotations are accommodated by the girder web sliding on the pin surface. Fretting corrosion between the web hole and pin surface will advance, eventually “locking up” the web/pin movement. After this occurs, rotations take place by the hanger sliding on the pin surface. This is known as ratcheting, and is evidenced by a broken paint film, wear marks, and corrosion between the pin nut and hanger plate.

![Figure 4:4-27: Pin Connection Measurements](image)

12) Look for pack rust between the girder web and hanger. Pins connecting plate hangers or tightly packed eyebars are difficult to access and often do not receive proper cleaning or painting during maintenance operations. Excessive corrosion may
lock up the joint, introducing unintended bending stresses into the pin-and-hanger or superstructure member. Note any deformation of plates.

13) Check the cap plates for flatness.

14) Check to make sure adjacent girder flanges and webs are in alignment.

15) Measure the distance between the hanger and girder web at several locations. A variation of 1/8 inch or more could mean hanger twist or lateral movement.

16) Bridges with pin-and-hanger type connections should be clearly identified in the Central Database. Currently, the Indiana Department of Transportation (INDOT) hires a consultant to inspect and perform NDT on all pin-and-hanger connections on all state- and county-owned bridges that carry vehicular traffic on a five-year cycle. The Indiana Toll Road hires a separate consultant to perform the same level of inspection for bridges under its jurisdiction on a four-year cycle.

Figure 4:4-28: Pin Shear Failure

4.2.7.2 Cables and Rods

Cables and rods are tension-only members used in suspension, cable-stayed, post-tensioned concrete, tied arch, and some timber bridges.

Cables may be used as vertical suspenders, angled cable stays, catenaries, or post-tensioning strands. Unlike solid rods, many individual wires are helically spun together and placed parallel to each other, or spun into rope to build up the size of the cable. End anchorages are usually made by brooming or spreading apart the cable wires inside a steel fitting. The conical-shaped steel fitting is then filled with a socketing medium, such as molten zinc, to lock the wires in place. For smaller diameter cables or individual strands, jaws (wedges) can be placed around the strand to provide anchorage. These jaws grip and anchor the strand as the strand is pulled and seated into a conical-shaped anchor block.
Rods are most often used to longitudinally post-tension concrete box girders and to transversely post-tension timber slab bridges. Normally, only the ends of the rods are visible for inspection, although early examples of post-tensioned concrete box girders left the entire rod exposed within the cells.

Corrosion is the primary enemy to any steel cable or rod. Note that corrosion has a more profound structural effect on cables than it does on solid members. Because cables have a much greater surface area than a solid rod with the same cross-sectional area, surface corrosion on the wires will reduce a cable’s cross-sectional area more than on a similarly sized solid member.

Inspection of rods and cables should include the following:

1) Look for broken wires. Broken wires may be caused by fatigue due to bending near the anchorages and excessive section loss due to corrosion or abrasion against the cable guide.

2) Look for corrosion and document its extent. Severe corrosion may also form pack rust between individual wires or between the wires and end fittings.

3) Inspect the end fittings, especially lower end fittings, where water would tend to accumulate. Check for any cracks in the end casting.

4) Note if any rods or cables are vibrating excessively due to wind or traffic loads and note the amplitude, the wind speed, and the wind direction.

5) Check for cable loosening or slippage at the end fittings. Signs of this condition may be wire abrasion and/or corrosion.

6) Note any slipping or unraveling of the main cable banding on suspension bridges.
SECTION 4.3 CONCRETE SUPERSTRUCTURES

Concrete has been used to construct bridges in the United States since 1889. With the exception of arches, conventional reinforced concrete was initially limited to use for short, single-span bridges. The development of prestressed concrete in the middle part of the 1900s, with the subsequent development of post-tensioned concrete boxes, allowed concrete to gain acceptance for use on medium- and long-span bridges. Concrete superstructures can be configured in many different ways, including slab bridges, reinforced girder bridges, concrete arch bridges, and box beam bridges.

Subsection 4.3.1 Cast-in-Place Slab Bridges

Cast-in-place slab bridges are the simplest type of concrete bridge. The slab acts as a single, wide beam spanning from substructure unit to substructure unit. There are no individual beams with this type of bridge, and the slab also acts as the deck. Slabs are used for simple spans up to approximately 45 feet. Continuous slab bridges can be built with slightly longer span lengths. To attain greater negative bending strength on continuous bridges, the slab may be thickened (haunched) over the piers. The main reinforcing steel is placed parallel to traffic and located near the bottom of the slab in positive bending regions, and towards the top of the slab in negative bending regions. On older and more complex structures, continuous cast-in-place slabs may contain voids to lighten the dead load of the bridge.
Inspection of a concrete slab superstructure should include the following:

1) Check for cracks and note their location, orientation, length, maximum width, and type. Cracks to note include:

2) Transverse flexural cracks on the top side of the slab adjacent to, and over, piers and where reinforcement bars end. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.

3) Diagonal or transverse temperature/shrinkage cracks. These will be found on most concrete decks and can provide a means for chlorides to reach steel reinforcement.

4) Diagonal shear cracks on the copings over or near the bearing areas at piers/abutments.

5) Check for pop-outs, scaling, abrasion, and rutting. This may be most evident in the gutters and around the drains.

6) Look for spalls and note any large individual spalls.

7) Look for signs of corroding reinforcing steel, such as rust stains.

8) Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, or exposed reinforcement.

9) Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.

10) Check for areas of delaminations. Loose concrete can fall and cause serious damage or injury.

11) Check for excessive dead load deflection.

12) Note the condition of repaired areas.
13) Check for water leakage. Water leakage frequently appears on support structures, under drains, or under expansion joints.

14) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

15) Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.

16) Check for missing tie rods, bolts, or nuts.

**Subsection 4.3.2: Reinforced Concrete Girder Bridges**

Reinforced concrete girder bridges (sometimes called Tee Beam bridges in other states) were commonly constructed in the early half of the 20th century. They are cast-in-place structures, with the deck cast monolithic with the beams. The “T” shape is created by the rectangular beam stem below the deck, with the deck forming the top flange. Because the deck acts as the top flange, deterioration will affect the superstructure rating. The fascia beams on some reinforced concrete girder bridges are upturned, doubling as parapets. Reinforced concrete girder bridges are most commonly used for simple spans, although they may be made continuous by haunching the beam stems over the piers. Individual spans may reach 50 feet in length, with the beams spaced from about three to eight feet. Common beam depths range from 18 to 24 inches. The main reinforcing steel is placed longitudinally near the bottom of the beam in positive-bending regions and longitudinally within the deck in negative-bending regions. Vertical stirrups placed along the beams serve as shear reinforcing.
Figure 4:4-33: Reinforced Concrete Girders

Figure 4:4-34: Reinforced Concrete Girder Bridge with Buttressed Fascia Girders
The inspection of a reinforced concrete girder bridge superstructure should include the following:

1) Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each. Look for transverse flexural cracks on the underside of the beams between supports and on top of the deck over the piers on continuously supported bridges. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.

2) Check for deteriorated concrete in the flexural zones that is causing debonding of the reinforcing steel. This is critical near the ends of the reinforcing steel bars since a certain length of the bar must be embedded within sound concrete to fully develop its strength. Delaminations, spalls, and longitudinal cracks can all cause debonding.

3) Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member may be supported by the reinforcing stirrups.

4) Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, delaminations, or exposed reinforcement.

5) Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.

6) Investigate the bearing areas for spalled concrete due to friction from thermal movement or crushed concrete due to bearing pressure overloads.

7) Check the member under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

8) Check previously repaired areas for soundness by hammer tapping.
9) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

10) Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions will expose several reinforcing bars.

**Subsection 4.3.3 Concrete Through Girder Bridges**

Concrete through girder bridges were constructed in the early half of the 20th century. They are cast-in-place structures, with the deck cast monolithic with the girders. Two deep girders are normally used and also serve as the bridge parapets. Through girder bridges are used for short simple spans. The deck is connected to the lower portion of the girders. Because the deck must span between the girders, through girder bridge widths rarely exceed 24 feet. The girders themselves are fairly large, usually 18 to 30 inches wide, and four to six feet deep. The main reinforcing steel is placed longitudinally near the bottom of the girders, while the main deck reinforcing steel is placed transversely in the deck bottom. Vertical stirrups placed along the girders serve as shear reinforcing.

The inspection of a reinforced concrete through girder bridge should include the following:

1) Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each.

2) Look for transverse flexural cracks on the underside of the girder between supports. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks wider than 1/8 inch on a primary concrete member.

3) Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed as this may indicate permanent deformation of the stirrups.

4) Check for deteriorated concrete in the flexural zones that is causing debonding of the reinforcing steel. This is especially critical near the ends of the reinforcing steel bars since a certain length of the bar must be embedded within sound concrete to fully develop its strength. The deterioration causing the debonding may be delaminations, spalls, or longitudinal cracks.

5) Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be supported by the reinforcing stirrups.

6) Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains, spalling, or exposed reinforcement.

7) Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. These defects can grow into larger problems such as delaminations and spalls.
8) Investigate the bearing areas for spalled concrete due to friction from thermal movement, or crushed concrete due to bearing pressure overloads.

9) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

10) Check the member under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

11) Check previously repaired areas for soundness by hammer tapping.

12) Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.

Figure 4:4-36: Reinforced Concrete Through Girder Bridge

Subsection 4.3.4 Precast Concrete Channel Beam Bridges

Channel beam bridges use precast channel beams as the primary load-carrying members. Channel beam bridges can be designed using standard reinforcing steel or as prestressed members, although most channel beam bridges in Indiana were constructed using standard reinforcing steel. The channels are placed on the substructure units so that they form an upside down “U,” with the vertical legs forming the beams and the horizontal top slab forming the deck. The channels are placed tightly side-by-side and should be transversely connected by tie rods or bolts so that the beams act as a unit under live loads. Grouted shear keys also help the beams to act together. Channel beam bridges are used for simple spans up to about 50 feet. Widths of the individual beams usually range from three to four feet. The main reinforcing steel is placed longitudinally near the bottom of the channel legs, while the main deck reinforcing steel is placed transversely in the top slab. Generally, this reinforcing is hooked at the end, but sometimes straight bars were used. Inspectors should note any evidence of hooks. Vertical stirrups may be placed along the channel legs to serve as shear reinforcing.
Inspection of precast concrete channel beam bridges should include the following:

1) Sight down each beam and check for excessive or differential deflections, or leaking and efflorescence between channel beams. This may indicate a beam is losing its prestressing force and is unable to carry the loads for which it was designed. This may also indicate failed shear keys. Once the shear keys have failed, live loads cannot be shared between adjacent beams.

2) Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each.

3) Look for transverse flexural cracks on the beam underside in the positive moment regions. Their presence indicates a serious structural overload. Measure the crack widths and lengths and document their location. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.

4) Examine the beam ends for evidence of cracked or spalled concrete, sometimes accompanied by corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing steel.

5) Look for diagonal shear cracks on the beam sides near the abutments and piers.

6) Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting beam movement.

7) Examine the underside of each beam for parallel longitudinal cracks. These usually occur along the reinforcing and may occur due to corrosion or inadequate concrete cover. Rust stains that accompany the cracks suggest that the reinforcing is corroding and debonding.
8) Check the beams, especially the fascias, for traffic impact damage. Severe impacts that expose several reinforcing bars or prestressing strands may justify replacement of the beam.

9) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

10) Verify that any drains are open.


12) Measure and record the diameter of exposed reinforcing.

13) Check for missing tie rods, bolts, or nuts.

Subsection 4.3.5 Reinforced Concrete Arch Bridges

Reinforced concrete arch bridges are constructed in either open-spandrel or closed-spandrel configurations.

Open-spandrel arch bridges use either cast-in-place arch ribs, or a single arch ring as the primary load-carrying members. The arches resist a combination of axial compression and bending moments. The deck and floor system are placed above the arches, and spandrel columns and caps (bents) deliver these loads to the arch. The space between the deck and arch, called the spandrel, is left open. Since the arch acts primarily as a compression member, longitudinal steel is uniformly distributed around its perimeter, contained by transverse ties. The spandrel bent columns are reinforced in a similar manner. Spandrel bent caps act as fixed end beams, so reinforcing steel is placed near the bottom, between the columns, and near the top, above the columns. Vertical stirrups placed along the cap serve as shear reinforcing. The deck and floor system loading the spandrel arches are designed and reinforced similar to other reinforced concrete beams. Arch components are shown in Figure 4:4-38.
Closed-spandrel arch bridges use a single, cast-in-place arch ring or barrel as the primary load-carrying member, with the arch resisting a combination of axial compression and bending moments. The spandrel area is enclosed by solid walls, usually built above the arch ring edges. Some spandrel walls are set outside of the arch ring and are tied to the arch ring with reinforcing bars. Over time, this reinforcing corrodes and the spandrel wall can be pushed out and away from the arch ring, accelerating deterioration and loss of fill. See Figure 4:4-40 below.
Closed spandrel arches are considered underfill structures when the level of soil or fill is higher than the level of the copings or headwall/spandrel walls. Underfill structures are discussed in Part 4, Chapter 9.

The deck/roadway is always placed above the arches, and the spandrel area may be filled or vaulted (open). In filled spandrels, the roadway pavement bears on fill material that occupies the spandrel area. This fill is contained by solid spandrel walls built above the barrel edges. Main reinforcing steel for solid spandrel walls retaining fill is placed at the back or fill side of the wall and cannot be inspected. The fill makes it impossible to inspect the top of the arch. In vaulted (open) spandrels, the structural deck and floor system transfers loads to the arch by way of transverse spandrel walls or spandrel bents. In this configuration, the spandrel walls are nonstructural. The spandrel bents, deck, and floor system are reinforced similar to open spandrel arches. Arch barrels are reinforced with longitudinal steel distributed around the perimeter, contained by transverse ties. The top side of the barrel cannot be inspected, unless access is provided in vaulted, closed-spandrel arch bridges. Most arches have construction joints three to four feet in from the copings. These areas are subjected to cracks, delamination, spalls, leaching, and leakage.
Inspection of reinforced concrete arch bridges should include the following:

1) Inspect all concrete for cracks, noting the location, orientation, length, maximum width, and type of each. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/8 inch.

2) Examine the bearing areas for signs of concrete crushing, since the highest compressive forces experienced by an arch are found at the spring line. Crushing results in a loss of arch cross-sectional area, increasing the axial stresses.

3) Look for longitudinal cracking along the arch axis. Longitudinal cracks indicate a possible structural overload or differential settlements.

4) Check the entire arch and spandrel wall for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.

5) Check the entire arch for transverse cracks. These are the result of excessive bending moments or arch support settlements.

6) Look for leaching and rust stains along the entire arch and spandrel wall.

7) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

8) Check areas exposed to drainage and roadway runoff. The runoff may cause scaling, spalling, and concrete contamination.

9) Check to make sure weep holes in closed-spandrel arch structures are functioning.

10) Check to make sure surface drains are functioning properly so that water does not penetrate the fill. This is especially important in closed-spandrel arch bridges.

11) Examine previous repair areas for soundness by hammer tapping.
12) Check the arch/spandrel column interface for transverse flexural cracks. These cracks may extend up several feet above the arch rib. They are an indication of excessive column bending due to overloads or differential arch deflection.

13) Check the spandrel bent cap/spandrel column interface for horizontal or diagonal flexural cracks. These cracks will originate at the inside corner of the cap/column junction and are another sign of excessive bending due to overloads or differential arch deflection.

14) Check the mid-height of the column for flexural cracks, as this is another sign of structural overloads or differential arch deflection.

15) Examine the entire column for longitudinal cracks and crushed concrete. This indicates a serious structural overload.

16) Check columns for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.

17) Check for traffic impact damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member.

18) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.
Subsection 4.3.6  Prestressed Concrete Arch Bridges

Prestressed concrete arch bridges are not common in Indiana. Arches carry axial compressive stresses, as well as bending, tension, and compressive stresses. Normally, the axial loads are great enough on an arch that there are no net tensile stresses due to bending. When bending stresses are large enough to produce net tension, post-tensioning is used to pre-compress the arch cross section. This keeps the entire cross section in compression, eliminating any net tensile stress.

Figure 4.4-42: Open-Spandrel, Prestressed Arch Bridge

Inspection of prestressed arch bridges should include the following:

1) Inspect all concrete for cracks, noting the location, orientation, length, maximum width, and type of each.

2) Look for transverse flexure cracks along the arch. Their presence indicates a serious structural overload, loss of prestressing/post-tensioning force, or arch support settlements.

3) Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.

4) Examine the bearing areas for signs of concrete crushing since the highest compressive forces experienced by an arch are found at the spring line. Crushing results in a loss of arch cross-sectional area, increasing the axial stresses.

5) Look for longitudinal cracking along the arch axis. Longitudinal cracks indicate a structural overload.

6) Check the entire arch for delaminations, spalls, and exposed reinforcing steel. These defects reduce the member cross-sectional area, resulting in higher stresses.

7) Look for leaching and rust stains along the entire arch. These defects can grow into larger problems such as delaminations and spalls.
8) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

9) Check for impact damage, including scrapes, chips, cracks, spalls, or missing concrete.

10) Check areas exposed to drainage and roadway runoff. The runoff may cause scaling, spalling, and concrete contamination.

11) Examine previous repair areas for soundness.

Subsection 4.3.7 Concrete Rigid Frame Bridges

Rigid frame bridges are structures in which the vertical or inclined supporting “legs” are cast monolithically with the girders or slab to form a rigid frame. These bridges are usually single-span structures constructed to form an inverted channel, usually of a slab design. Multiple span bridges may also be constructed by forming a rectangular shape, a “K” shape, or a triangular delta shape. Though the legs are used as bridge piers, the vertical or inclined legs are actually part of the superstructure because of their rigid connection to the horizontal slab or girders. This rigid intersection of the leg and horizontal member is referred to as the knee and allows both members to resist bending moments. Main reinforcing steel in the horizontal members is placed longitudinally near the bottom of the slab or girder between the abutments and legs. At the knees, it is placed longitudinally near the top on continuous bridges and around the outside or the corner on single-span bridges. Main reinforcing steel is placed vertically on both frame leg faces on continuous bridges and only on the traffic face of single-span bridges. Vertical stirrups placed along the horizontal member of beam frames serve as shear reinforcing, while transverse ties are placed along the legs. Spans of 50 to 200 feet are attainable using rigid frames. Figure 4:4-43 shows a concrete rigid frame bridge.
Inspection of rigid frame bridges should include the following items:

1) Inspect all members for cracks, noting the location, orientation, length, maximum width, and type of each.

2) Look for transverse flexural cracks in members carrying moments. Cracks over 1/8-inch wide in the flexural region may indicate a serious structural overload.

3) Check for deteriorated concrete in the flexural zones that may be causing debonding of the reinforcing steel. This is especially critical near the ends of the reinforcing steel bars, since a certain length of the bar must be embedded within sound concrete to fully develop its strength. The deterioration causing the debonding may be delaminations, spalls, or longitudinal cracks.

4) Check for shear cracks. Shear cracks will be diagonal, located near the end of a span, and inclined towards the center top. Shear cracks may also occur in the knee area angled down into the legs. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be supported by the reinforcing stirrups.

5) Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.

6) Look for efflorescence, and note if it is stained with rust since this condition suggests reinforcing steel corrosion.

7) Check the bearing areas for spalled concrete due to friction from thermal movement, or crushed concrete due to bearing pressure overloads.

8) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

9) Check members under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

10) Check previously repaired areas for soundness by hammer tapping.

11) Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose several reinforcing bars.

**Subsection 4.3.8 Precast Concrete Slab and Box Beam Bridges**

In precast, concrete, voided slab bridges, each slab acts as a single, wide beam spanning from substructure unit to substructure unit. Precast slabs will generally have two or three elliptical or circular voids to reduce material weight, although solid slabs may be used for shorter spans. The precast slab may act as the superstructure and the deck. Precast voided slabs are manufactured in a plant and pre-tensioned. Each slab or plank is usually three or four feet wide, with depths ranging from about 15 to 26 inches. Slabs are placed tightly side-by-side and transversely clamped together so that the individual planks act as a unit under live loads. Grouted vertical shear keys also help the beams to act together. Precast voided slabs are used for spans up to 100 feet. The main steel prestressing strands are placed parallel to traffic and located near the bottom of the slab.
Prestressed box beam bridges are similar to precast voided slabs. However, precast box beams contain only a single void. In early applications, the top flange of the box beam acted as the deck. Asphalt overlays were also common. These were generally placed directly on the beams, but were sometimes placed over a membrane.

INDOT has not allowed asphalt overlays on box beam bridges on state routes since 1980, except for short-term repairs. Any box beam bridge with an asphalt overlay on a state route is considered as a temporary bridge and is coded as such in the National Bridge Inventory (NBI) database.

Sometimes a concrete deck is placed on top of box beams. These concrete decks often act compositely with the box beams.

Each beam is usually three or four feet wide, and 12 to 60 inches deep. The beams may be placed tightly side-by-side and transversely clamped together so that the individual beams act as a unit under live loads. Grouted shear keys also help the beams to act together. The beams may also be spaced two to six feet apart to form a bridge similar in appearance to a reinforced concrete girder bridge. In this configuration, a structural deck is constructed on top of the beams.

Prefabricated box beam bridges are used for simple spans up to 130 feet in length. The main steel prestressing strands are placed parallel to traffic and located in the bottom flange of the box. Conventional reinforcing steel ties are placed transversely along the beam for shear reinforcement.
Inspection of precast slab and box beam bridges should include the following:

1) Sight down the length of the slabs or box beams to check for sagging. Sagging is a sign that the beam is losing its prestressing force and may be unable to carry the loads for which it was designed.

2) Check for differential deflection between slabs or beams placed next to each other. This is a sign that the slabs or boxes are not acting as a unit and may be unable to carry the design loads. It may also indicate failed shear keys. Once these keys have failed, live loads cannot be shared between adjacent beams.

3) Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each.

4) Examine the beam underside for parallel longitudinal cracks. These usually occur along the prestressing strands and may occur due to inadequate concrete cover. Rust stains that accompany the cracks suggest that the prestressing strands are corroding and debonding. Document any exposed strands.

5) Document any prestressing strand corrosion. Visual evidence of prestressing strand corrosion includes rust staining, delaminations, and spalls exposing corroded reinforcement. NDT allows detection before visual signs are present. Refer to Part 6 for a discussion of relevant NDT techniques.

6) Look for longitudinal cracks at the interface of the web and top flange of a box beam that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.

7) Look for transverse flexural cracks on the slab or box beam underside in the positive moment regions. Their presence indicates a serious structural overload or loss of prestressing/post-tensioning force. Measure and document the crack widths and lengths and document their location.

8) Look for diagonal shear cracks on the beam sides near the abutments and piers.

9) Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting beam movement.

10) Document box beam top flange transverse flexural cracks and any leaching and rust staining that may accompany them. This will usually be performed during a Special Inspection, as the underside of a box beam’s top flange can only be seen from inside the cell.
11) Evaluate barrier and utility connections. These connections can act as entry points for water and chlorides, thereby creating a corrosive environment deep inside the beam.

12) Check for any super elevation irregularities on curved box beam bridges. This is a sign that torsional distress has occurred.

13) Examine the slab or beam ends for evidence of cracked or spalled concrete, sometimes accompanied by corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing or prestressing steel. It may also be the result of a lack of non-prestressed reinforcement in the zone of prestressing force transfer.

14) Check the slabs and beams, especially the fascias, for traffic impact damage. Severe impacts that expose several prestressing strands may justify replacement of the beam.

15) Check for leakage and efflorescence between the longitudinal joints of slabs or box beams placed next to each other. This condition, along with reflective longitudinal cracking on the deck surface, suggests that the grouted shear keys between the members have failed. Leakage may indicate an increased likelihood of prestressing strand corrosion.

16) Check for excessive deflection under live loads and listen for unusual sounds with the passage of live loads.

17) Verify that the drain holes are present and open. Recommend clearing clogged drain holes. Trapped water may cause strand corrosion and longitudinal cracking as the water freezes and thaws.
18) Look for delaminations, spalls, and exposed reinforcing steel. Identify areas of delaminated concrete by sounding.

19) On slabs or box beams with no additional wearing surface, document the condition of the concrete on the top of the slab or box as part of the superstructure.

20) Verify that tie rods are present and functioning properly.

Figure 4:4-46: Prestressed Concrete Box Beams with Heavy Deterioration and Severed Strands

Subsection 4.3.9 Prestressed Concrete Beam Bridges

Prestressed I-beams, T-beams, modified T-beams, and U-beams are commonly used as precast members. They use material efficiently by concentrating the concrete away from the beam's neutral axis where it is needed most for stiffness and strength. Concrete decks are often designed to act compositely with the beams, using shear connectors in the top flanges of the beams. They are used for simple spans up to about 150 feet in length. They may also be made continuous over piers. This is done by placing conventional reinforcing steel longitudinally in the deck over the piers to resist negative bending. The main steel prestressing strands are placed parallel to traffic and are located in the bottom flange of the beam, though some strands can be inclined upwards toward the beam ends. These are called draped or harped strands. Conventional reinforcing steel ties are placed transversely along the beam for shear reinforcement. Prestressed beam bridges generally include concrete diaphragms at the abutments and piers and either steel or concrete diaphragms within the spans.
Inspection of prestressed concrete beam bridges should include the following:

1) Sight down the length of the beams to check for sagging. Sagging is a sign that the beam is losing its prestressing force and may be unable to carry the loads for which it was designed.
2) Inspect each beam for cracks, noting the location, orientation, length, maximum width, and type of each. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.

3) Look for transverse flexural cracks on the beam underside in the positive moment regions. Their presence indicates a serious structural overload or loss of prestressing/post-tensioning force. Measure the crack widths and lengths and document their location.

4) Look for longitudinal cracks at the interface of the web and top flange that are not substantially closed below any surface damage. This indicates permanent deformation of the stirrups.

5) Examine the beam underside for parallel longitudinal cracks. These usually occur along the prestressing strands and may occur due to inadequate concrete cover. Rust stains that accompany the cracks suggest that the prestressing strands are corroding and debonding.

6) Examine the beam ends for evidence of cracked or spalled concrete, sometimes accompanied with corroded reinforcing strands. This may occur due to leaking expansion joints that corrode the reinforcing or prestressing steel. It may also be the result of a lack of non-prestressed reinforcement in the zone of prestressing force transfer.

7) Look for diagonal shear cracks on the beam sides near the abutments and piers.

8) Look for vertical cracks on the beam sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting girder movement.

9) Check the beams, especially the fascias, for traffic impact damage. Severe impacts that expose several prestressing strands may justify replacement of the beam.

10) Look for delaminations, spalls, and exposed reinforcing steel.

Subsection 4.3.10 Concrete Box Girder Bridges

Box girder bridges are used for very long structures and curved spans. The sections are very large, and a single box can be used to carry an entire roadway. The inside of each box is usually large enough for an inspector to enter.

Traditional box girders are cast-in-place and may be conventionally reinforced or post-tensioned. Cast-in-place box girders will often contain several internal vertical webs and are referred to as multi-cell box girders.

The main reinforcement of post-tensioned box girders is a combination of conventional steel reinforcement and post-tensioning tendons. The post-tensioning tendons may be placed in the bottom flange, in the web walls, in both the bottom flange and the web walls, or not in the concrete at all. The post-tensioning tendons are normally placed within galvanized steel ducts that are filled with grout after stressing. Conventional reinforcing steel ties are placed transversely along the beam for shear and torsion reinforcement. In newer design, the deck is also post-tensioned, especially if there are
wide cantilevers of the deck past the girder web walls.

Segmental box girder bridges are similar to traditional box girders. However, the segments of segmental box girders are manufactured at a precast plant or on-site and erected individually. They commonly have a trapezoidal shape, with the top flange cantilevering over inclined webs. They normally contain only one cell and all are post-tensioned.

Inspection of reinforced concrete box girders should include the following:

1) Inspect each girder for cracks, noting the location, orientation, length, maximum width, and type of each. Document the location, length, and width of all cracks on sketches or prepared templates.

2) All cracks should be checked to see if they are full-depth. Ultrasonic V-meter testing can be used to check for full-depth cracking, or the location of cracks inside and outside the box can be compared from the sketches or templates.
3) Mark crack locations with the date the crack was found on the concrete.

4) Look for transverse flexural cracks on the underside of the beam between supports and on top of the deck over the piers on continuously supported bridges. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on a primary concrete member wider than 1/16 inch.

5) Check for deteriorated concrete in the flexural zones that may be causing debonding of the reinforcing steel. This is especially critical near the ends of reinforcing steel bars, since a certain length of the bar must be embedded within sound concrete to fully develop its strength.

6) Examine the support areas for shear cracks. Shear cracks will be diagonal, extending up from the bearing towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be hanging from the reinforcing stirrups.

7) Check interior concrete diaphragms over pier bearings. Cracks here often extend full-depth through the web walls and floor.

8) Look for vertical cracks on the girder sides near the abutments and piers. Vertical cracks in these areas suggest the bearing assemblies are restricting girder movement.

9) Check the entire member for signs of corroding reinforcing steel, as indicated by rust stains or exposed reinforcement.

10) Look for efflorescence. Note if it is stained with rust since this condition suggests reinforcing steel corrosion. Investigate the bearing areas for spalled concrete due to friction from thermal movement or crushed concrete due to bearing pressure overloads.

11) Check members under drains or leaking expansion joints for cracks, delaminations, spalls, and exposed reinforcing steel.

12) Verify that any drain holes are open.

13) Look for delaminations, spalls, and exposed reinforcing steel.

14) Check previously repaired areas for soundness by hammer tapping.

15) Document any box girder top flange transverse flexural cracks and any leaching and rust staining that may accompany them. This will usually be performed during an in-depth inspection, as the underside of a box girder’s top flange can only be seen from inside the cells.

16) Look for collision damage, including scrapes on member undersides, chips, cracks, spalls, or a missing section of a member. Strong collisions may expose the reinforcing.
The inspection of post-tensioned box girders should include all of the above items, as well as the following:

1) Check for transverse flexural cracks on the girder underside in the positive moment regions. Post-tensioned members are in axial compression, so any transverse flexural crack indicates a structural overload or loss of post-tensioning force. Notify the District Engineer or the Inspection Consultant of any flexural or shear cracks on the girder.

2) Sight down the length of the girders to check for sagging. Sagging is a sign that the beam is losing its post-tensioning force and may be unable to carry the loads for which it was designed.

3) A detailed survey along the gutter lines and centerline should be conducted periodically as a part of a Special Inspection to compare measurements with as-built and previously measured elevations to assess sagging.

4) Check for any super elevation irregularities on curved box girder bridges. This is a sign that torsional distress has occurred.

5) Examine the girder underside for parallel longitudinal cracks. These may indicate reinforcing corrosion.

6) Inspect the concrete at the anchorage zone for localized cracking. This may indicate inadequate detailing to resist the stressing forces.

Inspection of tension rods or post-tensioning cables should include the following:

7) Look at the tensioning steel anchorages for lack of bearing or slip of the cable through the wedge. Sudden losses of force may allow the rod/cable to snap and shoot out of the anchorage.
8) Pull/shake rod ends to check for looseness. Looseness indicates a complete loss of prestressing force.

9) Lightly tap the tensioned length of the rod/cable (if accessible) with a rubber mallet. Similar to the strings of a guitar, tensioned members should ring, while detensioned members will produce a dull thud. As an alternative, the rods/cables may be shaken. Tensioned members should be taught. While performing these procedures, stand out of the way of the rod/cable in case it suddenly fails.

10) Check any grouted anchors for soundness of the grout.

11) Look for corrosion and document its extent.

12) Look for broken rods/cables.

13) Check section loss on the threads at the ends of a rod.

14) Inspect the anchorage nuts for cracks or other damage.

Figure 4:4-52: Post-Tensioning Rods

Above: Note Protruding from the Anchorage, Indicating a Loss of Tensioning Force
Figure 4:4-53: Protruding Post-Tensioning Rod
SECTION 4.4 TIMBER SUPERSTRUCTURES

Timber was probably the earliest material ever used to construct a bridge. Modern timber can be configured into many superstructure types, including slab bridges, multi-beam bridges, arch bridges, and trusses.

Subsection 4.4.1 Timber Slab Bridges

Timber slab bridges are constructed using either glued laminated or nail-laminated sawn lumber placed longitudinally between supports. The slab acts as a single wide beam spanning from substructure unit to substructure unit. There are no individual beams with this type of bridge, so the slab acts as the deck and the superstructure. Slabs are used for simple spans of about 35 feet or less and for continuous spans of slightly greater lengths. Common glued laminated slab depths range from 6-3/4 inches to 14-1/4 inches thick, using individual strips of dimensional lumber 3/4 to two inches thick to form 42-inch to 54-inch wide panels. Nail-laminated slab depths range from eight inches to 16 inches deep, using two-inch to four-inch dimensional lumber. Timber slabs may have transverse distributor beams attached to their undersides as a method to distribute live loads across the bridge width. Steel transverse post-tensioning rods may also be used for this purpose, as well as to keep the planks in alignment on glued laminated slabs.

Inspection of timber slab superstructures should include the following:

1) Examine the slab’s top surface for signs of wear and abrasion, splitting, crushing, and decay.

2) Examine all timber for accumulated moisture, staining, and vegetation.

3) Examine all timber for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fungi or plant life and depressed areas of the wood surface. Probe suspect areas. Drill or bore suspect planks to estimate the extent of decay.

4) Examine all timber for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects, and a hollow sound when the beam is tapped with a hammer.

5) Check the underside of the slab at the bearing areas. Crushing of the wood is usually the result of decay, but overloads may cause crushing of sound wood.

6) Check the underside of the slab in tension areas for excessive deflections, fractures, and transverse cracks. These indicate excessive flexural stresses and overloads.

7) Hammer tap random and suspect areas to evaluate the wood’s soundness. A dull sound indicates deterioration.

8) Probe test areas suspected to be experiencing decay. Lift a small sliver of wood from the surface using an awl, ice pick, or pocketknife. Wood that lifts up and splinters is sound, while wood that breaks up upon lifting the tool is decaying.
9) Drill or bore suspect planks to estimate the extent of decay. Holes should be plugged with treated dowels after the inspection to prevent water and parasites from entering the timber’s interior.

10) Look for collision damage, including scrapes, cracks, or crushed areas.

11) Look for fire damage, especially near the piers or abutments where fires can be built close to the beams. Fire damaged members that exhibit large strain deformations should be reported immediately to the District Engineer or the Inspection Consultant.

12) Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check suspect fasteners for looseness by striking with a hammer. The location of any missing fasteners should be noted.

13) Sight along the length of the beam under traffic loads to look for excessive vertical or lateral deflections. Excessive deflections may indicate that the member cannot carry its original design load, or that other bridge members are damaged and additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.

14) Listen for unusual sounds with the passage of live loads.

15) Examine any overlay for signs of wear, abrasion, cracks, potholes, and impending potholes.

Subsection 4.4.2 Timber Multi-Beam Bridges

Timber, solid, sawn multi-beam bridges are constructed using three or more beams as the primary members. Span lengths are limited by the longest available length of solid lumber, so they are usually used for bridge spans from 15 to 30 feet. Typical beam dimensions are four to eight inches wide and 12 to 18 inches deep. Solid wood blocking or bridging is normally placed between the beams to keep the beam in proper alignment. Due to the limited availability of large timbers of this size and the ready availability of high-quality glued laminated beams, solid, sawn multi-beam bridges are rarely built today.
Timber glued laminated multi-beam bridges are similar to sawn multi-beam bridges, except that the beams are pre-manufactured members. The beams are made by bonding several strips of wood together with a waterproof structural adhesive to form a built-up beam. By using 3/4-inch to two-inch thick strips of wood for the laminations, natural wood defects may be placed in a non-critical location or may be eliminated completely from the final product. The result is a fairly uniform beam with strength properties greater than solid wood of similar dimensions. Standard three-inch to 14-1/4-inch wide beams are common, and depths are limited only by transportation and pressure treating considerations. Clear spans up to 150 feet have been attained, though spans less than 80 feet are more common.

Inspection of timber beam bridges should include the following:

1) Notify the District Engineer or the Inspection Consultant of any transverse crack or notable deflection on any timber beam.

2) Check for member crushing at the abutments and piers. These are the most suspect areas because they tend to collect and retain the most moisture and debris, creating ideal environments for plant and fungal growth and insect attack. Overloads can cause crushing of sound wood. Notify the District Engineer or the Inspection Consultant of excessive crushing.

3) Look for shear-related damage at and near the supports. Overloads result in high-shear stresses that cause horizontal splits to form along the length of the beam, approximately mid-height.

4) Examine the high-flexural regions of the beam for signs of overload damage such as crushing of surfaces in compression and transverse cracking of surfaces in tension.

5) Examine all timber for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for fungi or plant life and depressed areas of the wood surface. Probe suspect areas. Drill or bore suspect members to estimate the extent of decay.
6) Look for any delaminations of individual wood strips in glued laminated beams. Because debonding that extends through the beam width changes the original deep, stiff member into two smaller flexible members, this type of deterioration can be especially serious.

7) Examine all members for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the beam is tapped with a hammer.

8) Look for fire damage, especially near the abutments where fires can be built close to the beams. Document any section loss.

9) Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check suspect fasteners for looseness by striking with a hammer. The location of any missing fasteners should be noted.

10) Sight along the length of the beam under traffic loads to look for excessive vertical or lateral deflections. Excessive deflections may indicate that a member cannot carry its original design load or that additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.

11) Listen for unusual sounds with the passage of live loads.

12) Examine any overlay for signs of wear, abrasion, cracks, potholes, and impending potholes.

13) Look for collision damage, including scrapes, cracks, or crushed areas.

Subsection 4.4.3  Timber Trusses, Covered Bridges, and Arches

Timber truss bridges are structures with two parallel trusses as the main load-carrying members. Covered bridges are truss bridges with a wood covering to prevent decay of the superstructure. Spans up to 250 feet are attainable. The deck is typically placed between the trusses. These are called through trusses when there is overhead lateral bracing, or pony trusses when there is no overhead lateral bracing. The deck may also be placed on top of the trusses. These are called deck trusses. Modern connections are made with steel bolts and gusset plates. Older trusses generally used bolts or wooden peg connections. To keep the two trusses in line longitudinally, secondary lateral bracing members diagonally connect the bottom chords. For deck and through trusses, the top chords are braced diagonally as well. Lateral bracing may be made of wood, wrought iron, or steel. Sway bracing keeps the two trusses in line laterally. On deck and through trusses, sway bracing transversely frames between the truss verticals. On pony trusses, sway bracing is usually placed as a transverse diagonal on the outsides of the trusses. It connects the top chord to transverse “outrigger” floor beam extensions and functions to prevent buckling of the top chord. Sway bracing is normally made out of wood. Truss members are theoretically loaded in either pure tension or pure compression. Truss diagonals and verticals may be timber or a combination of timber for compression members, and steel or wrought iron rods for tension members. Loads are delivered to the trusses by way of floor beams spanning transversely between these main load-carrying members. Figure 4:4-57 provides several elevation views of typical
timber covered bridges.

Modern timber arch bridges are constructed of curved glued laminated main members. Wood arches use two hinges for spans up to approximately 80 feet and three hinges for spans up to approximately 300 feet. Wood arches are most commonly used as pedestrian bridges, although they have been built for highway use. Many older timber arches are constructed with a series of individual truss-like arched segments.

Arch bridges may be deck arch, though arch, or tied arch structures and are loaded in combined compression and bending. Loads are delivered to the arches by way of floor beams spanning transversely between these main load-carrying members. Many old timber covered bridges in Indiana are composed of both a truss and an arch that work together in carrying dead load and live load.

![Figure 4:4-56: Timber Covered Bridge](image)
Figure 4:4-57: Common Timber Covered Bridge Elevations
Most covered bridges contain numerous members oversized for the original design load. Ease of fabrication and construction was a primary concern for these bridges and efficiency in member sizing was often not a consideration. These bridges were often designed for the controlling diagonal member and, thus, all subsequent diagonal members were made the same size. This practice was followed for all the members. This means only one or two of each member type are controlled by design loads, and the remaining members are progressively oversized. This provided uniform connection types and dimensions throughout the structure. A schematic illustrating the typical locations for the maximum forces in a Burr arch truss are provided in Figure 4:4-58.

![Figure 4:4-58: Typical Burr Arch Truss](image)

The Town lattice truss provides a unique design feature. Due to the redundancy in the members, each main truss member can globally be considered as one large timber beam. The top and bottom chords can be considered flanges of a simple beam, and the diagonals can be considered the web. Figure 4:4-59 demonstrates this concept. The extensive redundancy in this design permits the truss to function well after several members show signs of deterioration or damage.

![Figure 4:4-59: Town Lattice Truss](image)

Historically, the majority of timber truss failures were due to failure of a connection, not
the member. Failure of a connection may prove detrimental to the entire bridge if adequate redundancy is not present. Movement over time, deterioration, large loadings, and poor details all are factors that lead to connection problems. The notching of vertical members to accommodate the connection to the diagonal is a common example of a poor detail that can contribute to a failure. This notching minimizes the section of the vertical member in an area where large compression and tension forces place this detail in a high shear zone. Figure 4:4-60 and Figure 4:4-61 illustrate this type of failure.

Another typical area for connection weakness is the bottom portion of the vertical member at the floor beam or lower chord. This area is subject to high shear forces and may be exposed to high water and debris damage, as well as the elements. Often the members are notched to allow for the connection, further weakening the member. Weakening of this connection may lead to the failure of the floor beam or lower chord at the connection. Figure 4:4-62 illustrates a heavily damaged vertical member/floor beam connection.
Most covered bridges require splices of the lower chord, upper chord, and arch. These areas are subject to high stresses and often have a smaller cross-sectional area due to the notching required to form the splice. Splices can either occur in a member, or within the connection and should be reported accordingly. The splices will often indicate signs of overstressing or signs of deterioration from any movement or separation of the members. Timber splitting adjacent to the splice may be present and should be monitored for deterioration.

Bearing areas often show signs of deterioration. Numerous timber trusses utilized bearing beams. The original designers often used these beams as a sacrificial detail that would be exposed to dirt and debris, while keeping the main structural members free from deterioration. The designer anticipated these members would be replaced when they deteriorated. In practice, many of these members were left in place. This deterioration could prove detrimental to the main structural members. Figure 4:4-64 illustrates typical sacrificial bearing members.
Secondary members such as cross bracing, sway bracing, and the roof members also play a role in the overall integrity of the bridge and should not be overlooked in an inspection. These members provide lateral stiffness in the bridge and help prevent movement of members and joints. Secondary members help resist loads such as snow and wind loads that are negligible in most bridges, but can serve as potentially fatal loading conditions in covered bridges. The large surface area exposed to wind promotes large horizontal loads that can contribute to the failure of a covered bridge.

The roof may collect heavy snow that can lead to large additional gravity loads on the bridge. The additional snow load, in conjunction with a large live load, can overstress the connections or members of a covered bridge.

Inspection of timber trusses, covered bridges, and arches should include the following:

1) Thoroughly inspect all connections and document any deficiencies or movement in each member.

2) Check the truss bottom chord members for crushing at the abutments. These are the most suspect areas because they tend to collect and retain the most moisture and debris, creating ideal environments for plant or fungal growth and insect attack. Overloads can cause crushing of sound wood. Notify the District Engineer or the Inspection Consultant of excessive crushing.

3) Look for any delaminations of individual wood strips in glued laminated members. Debonding occurring in the vicinity of connectors can be serious if the member is carrying tensile loads.

4) Examine the entire member for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects, and a hollow sound when the member is tapped with a hammer.

5) Look for fire damage, especially near the abutments and arch bearings where fires can be built close to the primary load-carrying members. Document any section loss.
6) Check fasteners (nails, bolts, lag screws, deck clips, etc.) for corrosion or slipping. Check for loose fasteners by striking with a hammer. The location of any missing fasteners should be noted.

7) Sight along the length of a truss or arch under traffic loads to look for excessive vertical or lateral deflections and out-of-plumb members. Excessive deflections indicate that the member may not be able to carry its original design load, or that other bridge members are damaged and additional load has shifted to the member in question. The measured or estimated amount of deflection should be recorded.

8) Examine each member for signs of decay. Signs include discolored wood with a soft, rotted texture. Look also for brooming and depressed areas of the wood surface. Probe areas suspected to be experiencing decay. Drill or bore suspect planks to estimate the extent of decay.

9) Look for collision damage including scrapes, cracks, or crushed areas.

10) Check the arch/spandrel column interface for bearing failures. Bearing failures on timber members loaded parallel to the grain will “broom out.”

11) Check the mid-height of the spandrel columns for flexural cracks, which is a sign of structural overloads or differential arch deflection.

12) Look for any splitting of sawn timber members. Excessively long or wide splits may be a sign of a structural overload.

13) Sight all columns to check for bowing. Excessive deflections indicate that the member has been overstressed or that the bridge is experiencing differential settlements. The measured or estimated amount of deflection should be recorded.

14) Note any protective systems such as preservatives or retardants.

Figure 4:4-65: Lateral Displacement of Members
Subsection 4.4.4 Rods and Cables Used in Timber Superstructures

Rods and cables are used as truss members, to post-tension timber structures, or to support timber members. These members may be considered to be fracture critical if a failure would result in a collapse or partial collapse of the bridge. The inspection of any rods and cables should include the following:

1) Check for corrosion and document its extent. Severe corrosion will produce section loss and an increase in tensile stresses.

2) Look for broken rods/cables.

3) Pull/shake rod ends to check for looseness. Looseness indicates a complete loss of post-tensioning force.
4) Lightly tap the tensioned length of the rod/cable (if accessible) with a rubber mallet. Similar to the strings of a guitar, tensioned rods and cables should ring, while detensioned members will produce a dull thud. As an alternative, the rods/cables may be shaken. Tensioned members should be taught. While performing these procedures, stand out of the way of the rod/cable in case it suddenly fails.

5) Inspect the anchorage nuts for cracks or other damage.

6) Inspect anchorage and bearing areas for signs of crushed wood.

Figure 4:4-68: Anchor Bolts for Steel Vertical Tie Rod

Figure 4:4-69: Steel Vertical Tie Rods on Timber Covered Bridge
Subsection 4.4.5  Special Inspections for Timber Covered Bridges

Indiana requires a Special Inspection for each timber covered bridge. These bridges are not load-path redundant. They generally have low load-carrying capacities, and a more detailed inspection supports the preservation efforts of these historical bridges. The Special Inspection report will help identify problems and assist the owner in maintaining and preserving the bridge.

All main load-carrying members and connections/panel points are inspected and documented as a part of the Special Inspection. Floor beam connections are also inspected and documented as a part of this inspection. There are many connection details and connection types and it is up to the Inspection Team Leader to determine and distinguish between the member and the connection. Typically, the connection is defined as being 12 inches outside of the connection bolt, connection plate, or change in cross-sectional area for the connection, and the remaining portions are defined as the actual member. Figure 4:4-72 provides guidance on several common typical connection details.

Secondary members such as lateral bracing, roof members, stringers, and floor beams should be thoroughly inspected during the Routine Inspection and are not considered part of a Special Inspection. It is recommended, but not required, that a brief discussion of secondary members and associated repairs and conditions be provided in the Special Inspection report.
The guidelines listed in this section are the minimum reporting requirements for acceptance of a Special Inspection. Although, these minimum requirements must be met for acceptance of the report by INDOT, the inspecting agency may provide alternate report formats meeting internal guidelines as long as the criteria set forth in this chapter are met. An example inspection report has been provided in Appendix C. A Special Inspection report must include the following as a minimum:
1) An inspection Plan of Action should include the following:

2) Sketches of the superstructure with locations of main members and connections clearly identified, along with an elevation view for trusses with locations labeled by letters and numbers similar to the nomenclature indicated in Part 4, Chapter 11

3) A north arrow on the sketch

4) A list of all members and connections to be inspected

5) A brief historical fact statement

6) All inspection tools and access equipment required for the inspection

7) Traffic control requirements

8) Bridge cleaning requirements

9) Other items that should be reviewed and made available to the inspector, if available, prior to the inspection, including the following:

10) Existing bridge plans and any repair/rehabilitation plans

11) Prior load ratings

12) Historical data and maintenance history of the bridge

13) Prior inspection reports

14) A general statement discussing inspection procedures

15) Date, temperature, and weather conditions of the inspection

16) Time duration of the inspection

17) Inspection Team Leaders and Inspection Team Members present at the inspection

18) A summary of inspection results for all members and connections that show deterioration, deficiencies, or required monitoring

19) Documentation of inspection results for each individual member, panel point, connection, and/or component, including the following:

20) Individual member rating

21) Noted deficiencies

22) A brief statement discussing the presence or lack of distress

23) Testing performed and locations of the tests

24) Recommendations for repairs and maintenance, highlighting urgent repairs and listing programmed repairs and maintenance

25) Photographs of the bridge, including an approach and elevation photograph, and any posting signs

26) Photographs of members or components assigned a condition rating of 4 (Poor) or less
27) Photographs of problem areas warranting repair and/or monitoring

28) Recommended inspection interval
SECTION 4.5  MASONRY ARCHES

The only masonry bridge superstructure form is the arch. Masonry arches have been used for building and bridge construction since ancient times. Current use of some of these structures is a testament to their durability. See Figure 4:4-73 for a picture of a masonry arch, and Figure 4:4-74 for masonry arch components.

![Masonry Arch](image)

Figure 4:4-73: Masonry Arch

Stone masonry arches receive both compressive and bending moments. Since an arch carries a high degree of compressive load, there should be little, if any, net tension along its cross section. Because of this, there should be no cracking at any of the masonry mortar joints due to bending moments.

Masonry arches are closed spandrel structures that have a single, solid barrel forming the primary load-carrying member. Fill material is placed on top of the arch to support the roadway, and spandrel walls are used to retain this fill. Spandrel wall failure would cause the fill to spill out, resulting in roadway settlement.
Inspection of masonry arches should include the following:

1) Examine the bearing/spring line areas for signs of crushed masonry, since the highest compressive forces experienced by an arch are found at the spring line. Missing or crushed masonry units result in a loss of arch cross-sectional area, increasing the axial stresses.

2) Look for crushed or missing masonry units and mortar. This would suggest a possible overload. Missing or crushed mortar results in a loss of arch cross-sectional area, increasing the axial stresses, and allows masonry units to move relative to one another.

3) Check the arch and spandrel wall surfaces for bulges. This defect suggests unstable soil, and the roadway above will also likely show signs of settlement. A bulge or flatness in the arch indicates that it is not functioning properly. Significant areas of bulging should be reported immediately to the District Engineer or Inspection Consultant.

4) Look for cracked, broken, or deteriorated masonry units and mortar. This would suggest weathering due to freeze/thaw effects.

5) Check the entire arch for transverse mortar cracks. These are the result of excessive bending moments or arch support settlements.

6) Check for longitudinal cracks in the abutments. These indicate differential settlement. Contact the District Engineer or Inspection Consultant if cracks over 1/8 inch wide are found.

7) Look for flattening of the arch.
8) Check for cracks in the spandrel walls near the quarter points. These indicate flexibility of the arch barrel over the center half of the span.

9) Look for leaching along the entire arch and the spandrel walls. This indicates water is flowing through the mortar joints and leaching minerals. Long-term leaching will weaken the mortar.

10) Check areas exposed to drainage and roadway runoff. The runoff may cause scaling.

11) Check to make sure weep holes in the arch are functioning.

12) Check to make sure surface drains are functioning properly and are not allowing water to penetrate the fill.

13) Check for loss of fill material. Potholes in the roadway indicate loss of fill.

14) Look for collision damage, including scrapes, cracks, or crushed areas.

15) Examine previous repair areas for soundness.

Figure 4:4-75: Closed-Spandrel Masonry Arch
SECTION 4.6  NBI SUPERSTRUCTURE RATING

The NBI numeric condition rating describes the existing superstructure components as compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition, and 0 describing failed components that cannot, or should not, be repaired.

Because only a single number is used to rate the superstructure, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, such as isolated heavy corrosion, or a bent flange due to a traffic impact. However, widespread heavy corrosion or widespread cracked welds would certainly influence the rating. A proper rating will consider deterioration severity, plus the extent to which it is distributed throughout the superstructure.

NBI ratings are used to evaluate the state of deterioration of the superstructure material. Postings or original design capacities less than current legal loads will not influence the rating. Similarly, temporary superstructure support does not change or improve the condition of the superstructure material and will not influence the superstructure rating.

Decks that are built integral with the superstructure, such as steel or concrete box girders and decks of reinforced concrete girder bridges, are rated as separate components from the superstructure, but the superstructure rating may be affected by the deck condition. The resultant superstructure condition rating may be lower than the deck condition rating where the girders have deteriorated or been damaged.

On slab bridges, the deck is the same structural component as the superstructure, and the NBI condition ratings for the deck and superstructure must be the same.

Indiana has developed supplemental rating guidelines to assist the inspector in properly assigning condition ratings to specific components constructed of the most commonly used materials. The general condition ratings, along with the Indiana supplemental rating guidelines for superstructures, are as follows:

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
</table>
| N             | NOT APPLICABLE:  
Supplemental Rating Guidelines: Used for underfill structures only. |
| 9             | EXCELLENT CONDITION:  
Supplemental Rating Guidelines: Superstructures are properly constructed and in new condition. |
8 **VERY GOOD CONDITION:** No problems noted.

**Supplemental Rating Guidelines:**

**Concrete Superstructure** – There are no noteworthy deficiencies which affect the structural capacity of the members.

**Prestressed Concrete Superstructure** – There are no cracks, stains, or spalls.

**Steel Superstructure** – There are no noticeable or noteworthy deficiencies which affect the condition of the superstructure.

**Timber Superstructure** – There are no noteworthy deficiencies which affect the structural capacity of the members.

7 **GOOD CONDITION:** Some minor problems exist.

**Supplemental Rating Guidelines:**

**Concrete Superstructure** – Some minor problems are present. Nonstructural hairline cracks without disintegration may be evident. The load-carrying capacity of structural members is unaffected.

**Prestressed Concrete Superstructure** – Nonstructural hairline cracks less than 0.015-inch may be present. No rust stains are present.

**Steel Superstructure** – Some rust may be evident without any section loss.

**Timber Superstructure** – Minor decay, cracking, or splitting of beams or stringers at noncritical locations may be present.

6 **SATISFACTORY CONDITION:** Structural elements show some minor deterioration.

**Supplemental Rating Guidelines:**

**Concrete Superstructure** – Structural members show some minor deterioration or collision damage. Hairline structural cracks or spalls may be present with evidence of efflorescence. Minor water saturation marks may be present. Generally, the reinforcing steel is unaffected.

**Prestressed Concrete Superstructure** – Minor concrete damage or deterioration is less than five percent. Few shrinkage cracks are present, and those that exist are tight and narrow. No shear cracks are present. Nonstructural cracks are over 0.015-inch. Isolated and minor exposure of mild steel reinforcement may be present. No prestressing strands are exposed.

**Steel Superstructure** – Rusting is evident, but with minor section loss of less than two percent of thickness in critical areas.

**Timber Superstructure** – Some decay may be present, along with cracking or splitting of beams or stringers. Fire damage is limited to surface scorching with no measurable section loss.

5 **FAIR CONDITION:** All primary structural elements are sound, but may have minor section loss, cracking, spalling, or scour.

**Supplemental Rating Guidelines:**

**Concrete Superstructure** – Structural members are generally sound, but may have evidence of deterioration or disintegration. Numerous hairline structural cracks or spalls may be present, with minor section loss of reinforcing steel possible.

**Prestressed Concrete Superstructure** – Up to five percent of prestressing strands are
exposed. Less than 15 percent of any area is spalled or delaminated. Multiple shrinkage cracks are present. No shear cracks or transverse cracks are present. Hairline longitudinal cracks may be present across the bottom flange. There is leakage at the joints with light efflorescence, but no staining.

**Steel Superstructure** – There is section loss, but less than five percent of the thickness in critical areas of primary members. Fatigue or out-of-plane distortion cracks may be present in noncritical areas. Hinges may be showing minor corrosion problems.

**Timber Superstructure** – Moderate decay, cracking, splitting, or minor crushing of beams or stringers may be present. Fire damage is limited to surface charring with section loss of less than five percent of the member section.

4 **POOR CONDITION:** Advanced section loss, deterioration, spalling, or scour may be present.

**Supplemental Rating Guidelines:**

**Concrete Superstructure** – There is extensive deterioration. There are measurable structural cracks or large spall areas. Corroded reinforcing steel is evident with measurable section loss. Structural capacity of some members is diminished.

**Prestressed Concrete Superstructure** – Five to 15 percent of prestressing strands are exposed. Fifteen to 25 percent of the area is spalled or delaminated. Multiple shrinkage cracks are present, including enlarging with possible minor spalls. Tight shear cracks may be present. Hairline transverse flexural cracks across the bottom flange may also be present. Longitudinal cracks with minor efflorescence or minor rust stains may be present along the bottom flange. Transverse tendons may be loose or heavily rusted. There may be leakage at the joints with heavy efflorescence or minor rust stains. Vertical or diagonal web cracks are less than three-inches long near the open joints in the barrier.

**Steel Superstructure** – There is significant section loss between five percent and 25 percent of the member section in critical areas of primary members. Fatigue or out-of-plane distortion cracks may be present in critical areas. Hinges may be frozen from corrosion. Load-carrying capacity of structural members may be affected. There may be local buckling in compression members or connections. Tension flanges or members may show elongation.

**Timber Superstructure** – Extensive decay, cracking, splitting, crushing of beams or stringers, or significant fire damage may be present. A diminished load-carrying capacity of members is evident. Member section loss is between five percent and 25 percent.

3 **SERIOUS CONDITION:** Loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in the steel or shear cracks in the concrete may be present.

**Supplemental Rating Guidelines:**

**All Superstructures** – Bearing movement or deterioration threatens the stability of the superstructure.

**Concrete Superstructure** – There is severe deterioration and/or disintegration of primary concrete members. Large structural cracks may be evident. Reinforcing steel is exposed with advanced corrosion and significant section loss. Local failures or loss of bond are possible.

**Prestressed Concrete Superstructure** – Any sagging or loss of camber may be present. Severed, heavily corroded, or deformed prestressing strands, with over 15 percent of prestressing strands exposed, may be present. Over 25 percent of the area may be spalled or delaminated. Multiple shrinkage cracks are present and are wide with
spalls. Some moderate-width shear cracks are present. Open transverse flexural cracks in the bottom flange may be present. Longitudinal cracks with minor efflorescence or minor rust stains may be present across the bottom flange. Vertical or diagonal web cracks greater than three-inches long may be present.

**Steel Superstructure** – Severe member section loss of over 25 percent, or cracking in critical areas of primary members, may be present. Minor failures may have occurred. Significant weakening of the primary members is evident. There may be global buckling of a primary member or connection. A primary member has a crack of two inches or longer. There are cracks in a gusset plate or welds that have, or may have, propagated into primary members. There are cracks in a hanger assembly member. The connection between railroad flat cars has failed.

**Timber Superstructure** – Severe decay, cracking, splitting, crushing of beams or stringers, or major fire damage may be present. Member section loss is over 25 percent. Load-carrying capacity is substantially reduced. Local failure may be evident.

### 2 CRITICAL CONDITION: Advanced deterioration of primary structural elements may be present. Fatigue cracks in steel or shear cracks in concrete may be present, or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

**Supplemental Rating Guidelines:**

**Concrete Superstructure** – Advanced deterioration of primary concrete members may be present. There is concrete disintegration around reinforcing steel with loss of bond. Some reinforcing steel may be ineffective due to corrosion or loss of bond. Numerous large structural cracks may be present. Localized failures of bearing areas may exist.

**Prestressed Concrete Superstructure** – Critical damage to the concrete or the reinforcing structures may be present. Multiple shrinkage cracks, spalls with exposed reinforcing, and/or rust may be present. Wide shear cracks and/or rust may also be present. Open cracks across the bottom flange and possibly into the web may exist. An abrupt lateral offset as measured along the bottom flange or lateral distortion of exposed prestressing strands. Excessive vertical misalignment may be present. Longitudinal cracks at the interface of the web and top flange that are not substantially closed below the surface damage (this indicates permanent deformation of the stirrups) may be present.

**Non-Composite Prestressed Concrete Adjacent Box Beams** – Any condition worse than described for Condition 3, above, is present.

**Steel Superstructure** – Severe section loss of over 50 percent of thickness is present at numerous locations with through thickness section loss at some critical locations of primary members. Extensive fatigue cracking may also be present.

**Timber Superstructure** – Severe decay, cracking, splitting, crushing of beams or stringers, or major fire damage has resulted in significant local failures. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

### 1 “IMMINENT” FAILURE CONDITION: Major deterioration or section loss is present in the critical structural components or obvious vertical or horizontal movement affecting structural stability is present. The bridge is closed to traffic, but corrective action may put it back into light service.

**Supplemental Rating Guidelines:**

**Concrete Superstructure** – The bridge is closed to traffic. There is major deterioration or section loss present on primary structural elements. Obvious vertical or horizontal
movement is affecting the structure’s stability.

**Prestressed Concrete Superstructure** – Critical damage requiring the replacement of a member is present. The bridge is closed to traffic. Temporary falsework to safeguard the public and the bridge should be installed.

**Steel Superstructure** – The bridge is closed.

**Timber Superstructure** – The bridge is closed.

### 0 FAILED CONDITION: The bridge is out-of-service and beyond corrective action.

One method of establishing a superstructure rating is to identify phrases within the guideline language that describes a superstructure condition more severely than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

Another method to help narrow down the superstructure rating number is to group the numbers in general categories. Ratings of 9 to 7 apply to superstructures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition and the bridge being closed to traffic. There is a significant change from a superstructure in condition rating 5 (minor section loss, but structural elements sound) to condition rating 4 (advanced section loss and advanced deterioration).
SECTION 4.7 ADDITIONAL SUPERSTRUCTURE RATINGS

For state-owned bridges, each of the following items shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 59, the NBI superstructure condition rating. Each item shall be rated as follows unless noted:

N  Not Applicable
9  Excellent Condition
8  Very Good Condition
7  Good Condition
6  Satisfactory Condition
5  Fair Condition
4  Poor Condition
3  Serious Condition
2  Critical Condition
1  Imminent Failure Condition
0  Failed Condition

ITEM 59A.01 – BEARING RATING

Bearings carry the dead loads and live loads from the superstructure members to the substructure and accommodate bridge rotation, expansion, and contraction. Bridge movement can result from temperature changes, substructure movement, live and dead load deflections, wind loads, or quick braking of a vehicle. Movable (expansion) bearings accommodate superstructure longitudinal and rotational movements. Fixed bearings accommodate superstructure rotational movements only. Many bearing types are used in Indiana, including elastomeric bearings, rocker bearings, roller bearings, pot bearings, and various sliding plate type bearings.

Inspection of bearings should include the following items:

1) Check for overall deterioration of the bearing.

2) Check for bearing misalignments. Improper alignments suggest a failing bearing, excessive superstructure movement, substructure settlement, or improper construction. Signs of improper alignment include:

3) A superstructure that is tight against the backwall of the abutment.

4) Excessive overhang of the top sliding plate over the bottom sliding plate. The sole plate of a sliding plate bearing should normally line up with the masonry plate between temperatures of 60 to 70 degrees Fahrenheit.

5) Unstable or improperly tipped rockers. The top of the rocker should be tipped away from the fixed bearing on hot days and towards the fixed bearing on cold days.
Rockers are normally set vertical between temperatures of 60 to 70 degrees Fahrenheit.

6) Improperly positioned rollers. Rollers should be rolled away from the fixed bearing on hot days and towards the fixed bearing on cold days. Rollers are normally positioned on the centerline of the masonry plate between temperatures of 45 to 65 degrees Fahrenheit.

7) Measure the distance from the girder/beam/truss to the backwall of the abutment.

8) Measure the longitudinal movement on bearings that are improperly aligned. Examples of measurements to be taken are shown in Figure 4:4-78. Record the ambient temperature at which the expansion/contraction measurement was taken. Notify the District Engineer or the Inspection Consultant of any severely misaligned bearing or rocker bearing in danger of tipping over during extreme temperatures.

Note No Room for Further Expansion
Figure 4:4-78: Longitudinal Movement Measurements

(A) Rocker Plate Bearing
(B) Roller Bearing
(C) Rocker Bearing
(D) Elastomeric Bearing
(E) Pot Bearing
9) Measure the height at the front and back of an elastomeric bearing or pot bearing if the rotation is noticeable. Record the height measurements and the length of the bearing. An angle of rotation can then be calculated. The rotation calculation and examples of the measurements to be taken are shown in Figure 4:4-79.

\[ \alpha = \text{bearing rotation in degrees} = \tan^{-1}\left(\frac{b-a}{l}\right) \]

Figure 4:4-79: Bearing Rotation Measurement

10) Record the ambient temperature at which measurements were taken.

11) Check for detachment of the masonry plate or fixed shoe from the substructure.

12) Look for bent anchor rods or anchor rods which have risen up above the masonry plate.

13) Check for out-of-place bearing pads. Often elastomeric pads with waxed lubricant will walk out from under the beam/girder and should be replaced.

14) Note debris that may be hindering movement.

15) Check for any broken keeper bars, pintels, or retainer angles.

16) Check for missing or loose anchor rod nuts.

17) Check the bearing assembly for pack rust between components, or corrosion of the bearing device or anchor bolts.

18) Look for full and even contact of all bearing components.
19) Look and listen for signs of bearing looseness, such as movement or rattling under live loads, uplift, and loose or missing fasteners/welds.

20) Look for signs of proper movement/wear on sliding plates.

21) Check for excessive bulging on the sides of the elastomeric pads. Bulging in excess of about 15 percent of the pad’s thickness is a cause for concern.

22) Check for any uplift.

23) Look for splits or tears in elastomeric pads. These may be oriented vertically or horizontally. Horizontal splits in a laminated pad indicate a serious condition and should be reported.

24) Check for variable thickness of the elastomeric pads in the lateral direction, suggesting lateral rocking of the girder. This would be an unusual occurrence and when this happens, look for signs of distress in other parts of the bridge.

25) Check for neoprene pad extrusion above the pot rim on pot bearings. This indicates serious distress.

Figure 4:4-80: Bearing Failure
Figure 4:4-81: Elastomeric Bearing with Uplift at the Corner

Figure 4:4-82: Steel Rocker Bearing
26) Look for wear or binding on guide bars. Guide bars are sometimes used on expansion pot bearings to restrict lateral movements in the transverse direction.

27) Check for proper pot bearing alignment. Signs include:

28) A superstructure that is tight against the backwall of the abutment.

29) Exposure of the piston top or top surface of the top aluminum alloy casting.

30) Excessive overhang of the top sliding plate over the piston or top aluminum alloy casting. The top plate and pot should normally line up between temperatures of 60 to 70 degrees Fahrenheit, although this could vary for any individual bridge.

31) Look for cracked welds.

32) Look for loss of bearing area or deterioration of bearing area.
Figure 4:4-84: Tipped Pot Bearing (Type N)

Figure 4:4-85: Steel Rocker Bearing (Type E)

Note the loss of bearing under the masonry plate in Figure 4:4-85.
Figure 4:4-86: Hold-Down/Restraining Bearing

Figure 4:4-87: Steel Roller Bearing (Type D)

Note the critical misalignment and distance from the beam to backwall in Figure 4:4-87.
ITEM 59A.01A – BEARING TYPES AT ABUTMENTS

Enter the appropriate code for the bearing type at the abutments. The letter code for different bearing types is shown below. Enter the minimum distance between the abutment/backwall and the end of the beam or girder. Enter the approximate air temperature and the longitudinal movement, as shown in Figure 4:4-178. Enter the angle and direction of movement if applicable.

ITEM 59A.01B – BEARING TYPES AT INTERMEDIATE SUPPORTS

Enter the appropriate code for the bearing type at intermediate supports. The letter code for different bearing types is shown below. Enter the approximate air temperature and the longitudinal movement, as shown in Figure 4:4-178. Enter the angle and direction of movement if applicable.

<table>
<thead>
<tr>
<th>Code</th>
<th>Bearing Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>Steel Plates</td>
</tr>
<tr>
<td>C</td>
<td>Steel Curved Plates</td>
</tr>
<tr>
<td>D</td>
<td>Steel Rollers</td>
</tr>
<tr>
<td>E</td>
<td>Steel Rockers</td>
</tr>
<tr>
<td>F</td>
<td>Steel/Bronze Curved Plates</td>
</tr>
<tr>
<td>G</td>
<td>Steel/Teflon</td>
</tr>
<tr>
<td>H</td>
<td>Elastomeric – Plain</td>
</tr>
<tr>
<td>I</td>
<td>Elastomeric – Steel Plate Reinforcement</td>
</tr>
<tr>
<td>J</td>
<td>Elastomeric – Polytetrafluoroethylene (PTFE) Plane</td>
</tr>
<tr>
<td>K</td>
<td>Spherical</td>
</tr>
<tr>
<td>L</td>
<td>Stainless Steel Plate</td>
</tr>
<tr>
<td>M</td>
<td>Resilient, Fiber-Free Pad with Teflon</td>
</tr>
<tr>
<td>N</td>
<td>Pot</td>
</tr>
<tr>
<td>O</td>
<td>Disc</td>
</tr>
<tr>
<td>P</td>
<td>Cylindrical</td>
</tr>
<tr>
<td>T</td>
<td>Integral</td>
</tr>
<tr>
<td>Z</td>
<td>Other</td>
</tr>
</tbody>
</table>

ITEM 59A.01C – SEISMIC RESTRAINTS

There are many types of seismic restraints used in Indiana due to changing codes and thoughts on how to restrain bridges. Check if seismic restraints have been installed.
ITEM 59A.02 – STEEL GIRDERS

Steel girders have built-up webs and flanges and are generally much deeper than steel beams. These can be built-up either by welding, bolting, or riveting individual members together to make the structural member. They can be used as primary longitudinal or transverse members. When used as floor beams, they are rated under Item 59A.16. Girders often have many welded attachments, including web stiffeners, which can create local areas of stress. Inspection should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the girders and their ability to function as designed.
ITEM 59A.03 – STEEL BEAMS

Steel beams are considered to be “rolled” members. These can be rolled “I” shapes, channel shapes, or “H” shapes. Beams rated under 59A.03 are used as the primary longitudinal members. When used for stringers or floor beams, they are rated under items 59A.15 and 59A.16. Inspection should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the steel beams and their ability to function as designed.
ITEM 59A.04 – STEEL DIAPHRAGMS

Diaphragms are generally perpendicular to the roadway and provide bracing between the longitudinal girders or beams. Diaphragms are secondary members. Diaphragms include solid diaphragms such as channel sections and I-beams.

The inspection of diaphragms should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the diaphragm and its ability to function as designed. Note the type of diaphragm.
ITEM 59A.05 – STEEL CROSS BRACING

Cross bracings are diaphragms constructed using angles or structural tees. Cross bracings are secondary members. See Items No. 59A.26, 59A.27, 59A.28, and 59A.29 for lateral bracing.

The inspection of steel cross bracing should follow the guidelines detailed in Part 4, Section 4.2, Steel Superstructures. Rate the physical condition of the cross bracing and its ability to function as designed. Note the type of bracing members. Look for out-of-plane bending cracks whenever the cross-bracing is staggered. Look for vertical cracks in the web along vertical web stiffeners and longitudinal cracks in web-flange welds. Look for spider web cracking on back side of the web.

ITEM 59A.06 – CONCRETE GIRDERS

Girders are generally cast-in-place concrete members other than slabs. These are sometimes called Tee Beams in other states. In Indiana, post-tensioned concrete boxes and slabs are also referred to as girders. Inspection should follow the guidelines detailed in Part 4, Section 4.3, Concrete Superstructures. Rate the physical condition of the girders and their ability to function as designed. For reinforced concrete girder bridges in Indiana, the concrete deck is a structural part of the girder.
Figure 4:4-95: Reinforced Concrete Girder Bridge with Minor Rust Staining

Figure 4:4-96: Reinforced Concrete Box Girder with Exposed Steel and Hole
ITEM 59A.07 – CONCRETE BEAMS

Concrete Beams are precast concrete members. Inspection should follow the guidelines detailed in Part 4, Section 4.3, Concrete Superstructures. Note the type of beam: I-beam, channel beam, T-beam, bulb T-beam, modified bulb T-beam, “U,” or closed box.
Figure 4:4-99: Delaminated and Spalled Precast Beam with Exposed Steel

Figure 4:4-100: Prestressed Channel Beams

Note Exposed Strands, Longitudinal Cracks, Efflorescence, and Rust Staining
Figure 4:4-101: Prestressed Girder with Impact Damage

Figure 4:4-102: Prestressed I-Beams and Diaphragms in Good Condition
ITEM 59A.08 – CONCRETE DIAPHRAGMS

Reinforced concrete diaphragms are secondary members placed transversely between the main load-carrying members. Their cross sections are normally rectangular and are constructed with the bridge deck concrete pour. They are used between both cast-in-place and prestressed beams.

Diaphragms serve several purposes, depending on their location along the span. Intermediate diaphragms are located between the bridge supports. They serve to laterally support the beams and help distribute the live load among them so that they will act as a unit. Diaphragms over piers are considered intermediate diaphragms on continuous spans only.

End diaphragms, also called mudwalls, are located at abutments. Diaphragms are also located at piers under expansion joints. When there are no joints over the piers, these are called integral pier diaphragms or curtain walls. These diaphragms serve to keep the beams’ ends in alignment and to strengthen the end of the deck. They act as simple beams transversely spanning between the main members to deliver wheel loads to the bearings.

Rate the overall condition of concrete diaphragms and their ability to function as designed.

ITEM 59A.09 – CONCRETE SLABS

On concrete slab bridges, the deck is also the superstructure, so the rating of the deck and superstructure must be the same. This rating must match the rating for NBI Item 58.

ITEM 59A.10 – CONCRETE SLABS INTEGRAL WITH PIER

Check “Y” (yes) if the slab is constructed integral with the pier cap for interior piers only. Check “N” (no) if not. Integral abutments are covered under Items 60.01, 113 B.02, and 113 B.03.

ITEM 59A.11 – TIMBER SUPERSTRUCTURE

Rate the overall condition as detailed in Part 4, Section 4.4, Timber Superstructure. This rating must match the rating for NBI Item 59.
ITEM 59A.12 – ARCHES

Rate the overall condition of all the arch members, including the arch ring, spandrel walls, and columns. This rating must match the rating for NBI Item 59.

ITEM 59A.13 – ARCH RING

Rate the overall condition of the arch ring.
ITEM 59A.14 – SPANDREL WALLS

Rate the overall condition of the spandrel walls.

ITEM 59A.15 – STRINGERS

Stringers are generally longitudinal members used in conjunction with a floor system in a truss or two-girder bridge. Rate the overall condition of the stringers.
ITEM 59A.16 – FLOOR BEAMS

Floor beams are generally transverse members used in conjunction with a floor system in a truss or a two-girder bridge. Floor beams and their connections to trusses or two-girder systems may be fracture critical. If there are fracture critical members, they must be inspected at arm's-length. Rate the overall condition of the floor beams.

ITEM 59A.17 – KNEE BRACES

A knee brace is a short member, engaging at its ends two other members that form a right angle or a near right angle to stiffen the connecting joint. Rate the overall condition of the knee braces. Most knee braces in Indiana are located over and under floor beam connections.

ITEM 59A.18 – TRUSSES

Rate the overall condition of the trusses in accordance with Part 4, Section 4.2 for steel trusses and in accordance with Part 4, Section 4.4 for any timber trusses.
ITEM 59A.19 – TRUSS EYEBARS

Check the box marked yes if the truss is constructed using eyebars.

ITEM 59A.20 – TRUSS VERTICALS

Rate the overall condition of the truss verticals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.
ITEM 59A.21 – TRUSS DIAGONALS

Rate the overall condition of the truss diagonals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.22 – TRUSS UPPER CHORDS

Rate the overall condition of the truss upper chords in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.
ITEM 59A.23 – TRUSS LOWER CHORDS

Rate the overall condition of the truss lower chords in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.24 – UPPER BRACINGS

Rate the overall condition of the truss upper bracings in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.25 – PORTALS

Rate the overall condition of the truss portals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.26 – TOP LATERALS

Rate the overall condition of the top laterals in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.27 – LATERAL STRUTS

Rate the overall condition of the lateral struts in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.28 – SWAY BRACING

Sway bracing keeps two trusses parallel. Rate the overall condition of the sway bracing in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.29 – LOWER BRACING

Rate the overall condition of the lower bracing in accordance with the appropriate guidelines in Part 4, Sections 4.2 and 4.4 or Chapter 11.

ITEM 59A.T1

Rate the condition of some part of the truss not identified above.

ITEM 59A.T2

Rate the condition of some part of the truss not identified above.

ITEM 59A.30 – CONNECTION PLATES

Rate the overall condition of the connection plates. Note any deformation in any connection plate.
ITEM 59A.31 – GUSSET PLATES

A gusset plate is any plate used to transfer load from one member to another. Rate the overall condition of the gusset plates. Note any cracks or deformation. See Chapter 11, Fatigue and Fracture Critical Inspections.

Figure 4:4-112: Bolted Gusset Plate

Figure 4:4-113: Riveted Gusset Plate
ITEM 59A.32 – STAY/BATTEN PLATES

Stay/batten plates are tie plates or diagonal bracing designed to prevent relative movement between components of a built-up member. Rate the overall condition of the stay or batten plates.

ITEM 59A.33 – LACINGS

Lacings, sometimes called lattice, are small flat plates, usually with one rivet at each end, used to tie individual sections of built-up members. Rate the overall condition of the lacings.

ITEM 59A.34 – RIVETS

Rate the overall condition of the rivets.

![Figure 4:4-114: Rivets in Sound Condition](image)

ITEM 59A.35 – BOLTS

Rate the overall condition of the bolts.

ITEM 59A.36 – SPLICE PLATES

Rate the overall condition of the splice plates.

ITEM 59A.37 – BRACKETS

Rate the overall condition of the brackets.

ITEM 59A.38 – TACK WELDS

Rate the overall condition of the tack welds.
ITEM 59A.39 – FULL WELDS
Rate the overall condition of the full welds.

ITEM 59A.40 – OTHERS
Rate the overall condition of other connection details or types. Note the type.

ITEM 59A.41 – HANGERS
Rate the overall condition of the hanger connection system, including pins or U-bolts.

Figure 4:4-115: Hangers on Through-Truss Arch Bridge

ITEM 59A.42 – TOTAL NUMBER OF HANGERS
Enter the total number of hangers or hanger assemblies.

ITEM 59A.43 – HINGES
Rate the overall condition of the hinges.

ITEM 59A.44 – PINS
Rate the overall condition of the pins.

ITEM 59A.45 – TOTAL NUMBER OF PINS
Enter the total number of pins.

ITEM 59A.46 – NUTS
Rate the overall condition of the nuts for the pins.
ITEM 59A.47 – HANGER BARS

Rate the overall condition of the hanger bars, straps, links, or U-bolts.

ITEM 59A.48 – WEB PLATES

Rate the overall condition of the web plates at pin-and-hinges or pin-and-hangers connections.

ITEM 59A.49 – MUDWALLS

Mudwalls, often called backwalls, are the vertical face of the abutment above the bearing seat. Rate the overall condition of the mud walls.

![Mudwall with Efflorescence](Figure 4:4-116: Mudwall with Efflorescence)

ITEM 59A.50 – CURTAIN WALLS

Curtain walls are concrete diaphragms over piers without a joint. They extend down to the pier cap. Rate the overall condition of the curtain walls.

ITEM 59A.51 – COLLISION DAMAGE

Rate the overall condition of any member damaged by collision.
ITEM 59A.52 – ALIGNMENT OF MEMBERS

Rate the overall alignment of the members.
ITEM 59A.53 – DEFLECTIONS
Rate any deflection of the structure.
ITEM 59A.54 – VIBRATIONS
Rate any vibration of the structure.
ITEM 59A.55 – IMPACT
Rate the overall condition of the members damaged by the impact onto and off of the bridge deck by trucks traveling at highway speed.
ITEM 59A.56 – NOISE
Rate any noise made by the structure.
ITEM 59A.OTH1 – ADDITIONAL ITEMS
Describe and rate the condition of any additional items.
ITEM 59A.OTH2 – ADDITIONAL ITEMS
Describe and rate the condition of any additional items.
SECTION 4.8 PAINT AND TONNAGE OF STEEL

Paint acts as a physical barrier between the steel and environment. By preventing oxygen, moisture, deicing chemicals, and pollutants from coming in contact with the steel, the paint coating prevents the rust-producing electrochemical reaction from starting. Two to four paint layers typically make up the coating system and include the prime coat and one or more top coats. On older bridges, the prime coat usually contains lead, easily discerned by its orange/red-orange color in the first or second coat of paint. The paints in newer systems are usually lead-free and impregnated with zinc that acts as an additional level of protection. On painted steel, rust indicates a coating failure.

Weathering steel is not intended to be painted or galvanized. It is intended that it be left exposed to the atmosphere, developing a dense, protective oxide coating. If weathering steel remains wet for extended periods or is exposed to a corrosive atmosphere, the protective oxide coating will not form and the weathering steel will corrode. The signs of corrosion on weathering steel include deep pitting, laminar rust, flaking, or a course texture. If the weathering steel is corroding, rate the paint condition as if the steel was painted and note the type of steel.

ITEM 59B.01 – PAINT

Rate the overall condition of the paint.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Not applicable – no paint or weathering steel</td>
</tr>
<tr>
<td>9</td>
<td>Excellent Condition – recently painted – good seal</td>
</tr>
<tr>
<td>8</td>
<td>Very Good Condition – may be several years since painting; good seal; minor chalkiness</td>
</tr>
<tr>
<td>7</td>
<td>Good Condition – few areas of light rust; some chalkiness and peeling</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory Condition – light rust in many areas; extensive chalkiness and some peeling</td>
</tr>
<tr>
<td>5</td>
<td>Fair Condition – light rust in many areas with localized areas of medium rust buildup; crackling, peeling, and blistering over a large area</td>
</tr>
<tr>
<td>4</td>
<td>Poor Condition – many areas of medium rust and localized areas of heavy rust; significant peeling, cracking, and blistering</td>
</tr>
<tr>
<td>3</td>
<td>Very Poor Condition – many areas of heavy rust</td>
</tr>
<tr>
<td>2</td>
<td>Very Poor Condition – many areas of extremely heavy rust</td>
</tr>
<tr>
<td>1</td>
<td>Total Paint Failure – large areas of extremely heavy rust; little or no paint remains</td>
</tr>
<tr>
<td>0</td>
<td>Total Paint Failure – large areas of extremely heavy rust; little or no paint remains</td>
</tr>
</tbody>
</table>
ITEM 59B.02 – TYPE OF PAINT (PRIMER)

Enter the type of primer used.

- **Blank** – none or not known
- **Lead**
- **Zinc**
- **Other**

ITEM 59B.03 – PAINT SYSTEM

Enter the type of paint system used.

- **Blank** – none or not known
- **Three-coat system**
- **Two-coat system**
- **Other**
ITEM 59B.04 – PAINT COLOR

Enter the color of the top coat.

Blank – none or not known

Blue

Green

Silver

Red

Pink

Orange

ITEM 59B.05 – ESTIMATED REMAINING LIFE OF PAINT AND PAINT YEAR

Enter the estimated remaining life of the paint. Enter the month and year when the entire superstructure was painted. This date should be painted on the superstructure. If portions were painted after this date, this should be noted in a comment.

ITEM 59B.06 – PAINT CONTRACT NUMBER

Enter the paint contract number.

ITEM 59B.07 – WEATHERING STEEL

Enter whether weathering steel was used or not.

Blank – none or not known

Y – weathering steel was used

N – weathering steel was not used

ITEM 59C.01 – TONS OF STEEL

Enter the tons of steel used in the superstructure. Note the square footage of steel, if this has been calculated. Document all quantities from the last painting contract for future work.

OTHER COATINGS AND SEALANTS

Enter the type and condition of any coatings and sealants that are not paint.
CHAPTER 5 SUBSTRUCTURE

SECTION 5.1 INTRODUCTION

A bridge substructure includes all members that support the superstructure. Substructures deliver the superstructure reaction loads to the foundation soil or bedrock. Substructures must also control deflections and settlements that might create serviceability problems or unintended overloads of the superstructure. There are three main substructure components: abutments, piers, and wingwalls. Mechanically stabilized earth systems are sometimes constructed as part of an abutment or in place of a wingwall. The components and the materials used to construct substructures are discussed in this chapter.
Abutments support the ends of a bridge adjacent to the approach roadway and retain the soil fill under the approach. Abutments must resist vertical loads from the superstructure dead and live loads, and lateral loads due to soil pressure under the approach. Lateral loads may also come from superstructure longitudinal forces including temperature effects, vehicle braking forces, and friction from expansion bearings. An abutment is designed to resist these longitudinal forces only at locations with fixed bearings. Unintended superstructure longitudinal forces are delivered to the abutment when abutment expansion bearings have frozen due to corrosion or debris accumulation.

To resist these loads, abutments must act as both compression and bending elements. For short abutment heights, up to approximately five feet, bending due to lateral soil pressure is not significant. For taller abutment heights, the bending becomes a significant factor in the structure’s design.

Almost any material may be used to construct an abutment. The most common is reinforced concrete, although masonry, timber, plain concrete, mechanically stabilized earth, and steel abutments have been built.

The most common abutment types are sill, full-retaining, semi-retaining, pile-encased, and timber. These are described below and shown in Figure 4:5-1.

**Sill abutments** are short abutments that use a single row of vertical piles for support. In Indiana, these are sometimes called end bents. They are placed at the top of the embankment and use a sloped berm or a mechanically stabilized earth wall in front of the abutment to contain the soil under the approach. Sill abutments can also be constructed as integral abutments with the piles and the ends of the superstructure encased in concrete.

**Full-retaining abutments** are tall structures designed as cantilever retaining walls to hold back soil under the approach. Because of this function, the main reinforcing steel is placed vertically at the back face of the abutment. A spread footing, supported by the soil or two rows of piles, anchors the abutment stem below grade.

**Semi-retaining abutments** are similar to full-retaining abutments. They are shorter than full-retaining abutments and utilize small sloped berms to minimize the height of the stem.

**Pile-encased** or **integral abutments** use piles that are driven into the ground and left extending the full abutment height. The piles are then encased in concrete, forming part of the abutment stem. This type of abutment is called integral because the superstructure is locked to the top of the abutment, allowing the superstructure and substructure to act as a unit.

Timber abutments can be constructed using timber piles, timber cribs, or steel piles combined with timber caps and backwalls. These are discussed further in Section 5.5.
Figure 4:5-1: Common Abutment Types

(A) Reinforced Concrete Sill
(B) Reinforced Concrete Full-Retaining
(C) Reinforced Concrete Semi-Retaining
(D) Reinforced Concrete Pile-Encased or Integral
(E) Timber

Figure 4:5-2: Reinforced Concrete Sill Abutment
Subsection 5.2.2  Piers and Bents

Piers and bents are intermediate support points for a bridge, used mainly for medium to long structures. Piers and intermediate bents must resist vertical live loads, the weight of the superstructure, and sometimes superstructure longitudinal forces. A pier or bent is designed to resist these longitudinal forces only if the bearings are fixed. Unintended superstructure longitudinal forces are delivered to the pier or bent when the pier expansion bearings have frozen due to corrosion or debris accumulation. To resist the above loads, piers and bents must act as both compression and bending elements. Piers and bents must also resist lateral forces transverse to the bridge centerline. These forces come from wind pressures against the girders, centrifugal effects of traffic on curved bridges, and stream flows. Most piers and bents act as cantilever beams to resist loads longitudinal to the bridge centerline. Piers and bents may be configured to behave as frames, cantilever beams, or shear walls to resist loads transverse to the bridge centerline. Figure 4:5-2 shows some common pier and bent types.
Almost any type of material may be used to construct a pier or bent. The most common material is reinforced concrete, although masonry, timber, steel, and unreinforced concrete have been used.

A bent cap is the horizontal component of a bent where the bearing devices for the superstructure are placed. It also acts to tie the pillar tops together on multi-pillar bents to form a frame for resisting loads transverse to the bridge centerline. When used on a multi-pillar bent, bent caps behave as bending members. The highest shear stresses are located at the pillars. When used above solid pier walls, bent caps are simply an architectural feature formed by thickening the wall, although bending may come into play if the cap cantilevers over the ends of the wall.
Hammerheads are the horizontal component of a single pier where bearing devices for the superstructure are placed. Hammerheads act as bending members that cantilever over either side of the pier.
Pillars, sometimes called columns, are the vertical components of a bent. Pillars are commonly used with bent caps to form frames that resist loads transverse to the bridge centerline. In Indiana, a single vertical shaft supporting one or more lines of girders is called a pier. Pillars and piers directly support bent caps, hammerheads, and sometimes girders. They are primarily compression members, but they must also resist lateral bending moments due to wind loads, eccentric loading at their tops, superstructure transverse and longitudinal forces, seismic forces, and differential substructure settlements.

Hammerheads are the horizontal component of a single pier where bearing devices for the superstructure are placed. Hammerheads act as bending members that cantilever over either side of the pier.

A solid pier wall is a wide, solid shaft of constant thickness that behaves primarily as a compression member. It must also resist lateral forces due to wind and seismic loads, and bending moments due to eccentric loading at their tops, superstructure longitudinal forces, and differential structure settlements. They are often used in streams or rivers because they offer less resistance to water flow than multi-pillar piers, and offer fewer locations for drift to collect.

Web walls are full height concrete walls constructed between the pillars of multi-pillar piers. The thickness of the web wall is always less than the widths of the adjacent pillars. They change multi-pillar pier lateral behavior from a frame to a shear wall, but use less concrete than required for a solid pier wall. In Indiana, if the web wall extends to the top of the pillars, this substructure unit is called a pier. If the web does not extend to the top of the pillars, this substructure unit is called a bent.
Crash walls can be placed between the pillars of multi-pillar bents or between the stems of two individual piers supporting separate bridges. They are designed to protect the base of the pillars or piers from rail car, ship, or vehicle impacts. Normally, the thickness of a crash wall is the same as the width of the adjacent pillar or pier to prevent snagging during a collision. Crash walls extend from approximately three to eight feet above grade.
Subsection 5.2.3 Wingwalls

Wingwalls are required at abutment ends to retain the approach fill. Without them, the approach fill would spill or wash out, causing settlement of the roadway. Wingwalls resist lateral pressure from the approach fill and carry no vertical loads other than dead weight. Three geometries are commonly used to retain the fill: straight wings parallel to the abutment, U-shaped wings parallel to the roadway, and flared wings that form an acute angle between both the roadway and abutment. Wingwalls may be rigidly attached to the abutment. Wingwalls are only considered a part of the substructure if integral with abutment.

Almost any type of material may be used to construct a wingwall. The most common is reinforced concrete, although masonry, timber, and steel wingwalls have been built. Mechanically stabilized earth walls have also been constructed as wingwalls.

Cheek walls are concrete walls placed at either end of the abutment to protect the fascia bearings from the elements. They also serve as architectural features to hide the bearings. Cheek walls should be coded as wingwalls.

Subsection 5.2.4 Foundation Types

Two foundation types are commonly used to support substructure elements: piles and footings. Piles are structural members that transmit the bridge live and dead loads into the underlying soil or bedrock. They are often used when the soil immediately below the substructure unit is inadequate to resist the bearing pressures or to satisfy settlement criteria. They are driven into the ground with a pile driver and rely on soil friction and/or end bearing to deliver the bridge loads into the earth. Piles may be driven vertically or at a batter (angle) to resist lateral loads. Materials used for piles include steel, reinforced concrete, timber, and prestressed concrete. A bent cap, usually of reinforced concrete, is used to transfer loads from the bent pillars or the abutment stem (breastwall) to the piles.

Footings are located at the base of the substructure unit, and are sized to transmit the
bridge live and dead loads directly to the supporting soil or bedrock. They also prevent sliding or overturning of the pier or abutment due to lateral soil pressures. Foundations are usually buried underground and should not be visible when the bridge is in service.

Pile bents are essentially multi-pillar bents with the piles extending above grade to act as pillars. After driving, the pile tops are tied together with a conventional bent cap.

**Subsection 5.2.5 Navigation Protection**

Piers over navigable water must be protected from traffic on the water. There are many types of protection, including dolphins and fenders. The inspection team should verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.
Figure 4:5-12: Timber Pile Cluster Dolphins

Figure 4:5-13: Substructure-Supported Timber Fender
SECTION 5.3 STEEL SUBSTRUCTURES

Steel is not commonly used for substructure elements in new designs, except as piles. However, it was often used in the past to form the bents or bent towers of large bridges.

Steel bent caps may work in conjunction with steel pillars to form a frame, or they may bear on top of individual concrete bent pillars. Hot-rolled beams have been used as bent caps for smaller bridges with multi-pillar bents. To carry large girder reaction loads, steel bent caps are often fabricated into box shapes. Bent cap boxes are usually large enough for an inspector to enter and examine the interior.

Figure 4:5-14: Steel Box Bent Cap

Steel bent caps should not be confused with steel cross girders. Bent caps are elements separate from the superstructure. Superstructure cross girders sit on bearings, which sit on the bent cap’s top flange. The cross girders are part of the superstructure. The longitudinal superstructure girders are directly connected to the cross girder web by welding or bolting. Any bearing devices are located on the underside of the cross girder.

Figure 4:5-15: Fracture Critical Riveted Steel Bent Cap

(Note: The superstructure girders bear on the bent cap's top flange by way of bearing devices.)
Steel bents will consist of two or more steel pillars connected along their tops by a bent cap built of steel or reinforced concrete. Most steel bent caps use vertical bearing stiffeners at their supports. Steel pillars may be rolled or built-up shapes, pipes, or fabricated box shapes. Steel pillars will normally bear on top of a concrete pedestal, supported by the foundation. No bearing will be visible if the pillars are above grade extensions of the foundation piles.

Lateral bracing transverse to the centerline of the bridge is normally used for steel pile bents or bent towers. Lateral bracing prevents bent racking due to lateral wind loads, seismic loads, and centrifugal forces.

Some abutment types may use exposed steel piles, most notably timber abutments. Steel piles are driven with sufficient length to extend above the ground to the abutment cap elevation. An abutment cap (usually reinforced concrete) is placed on the piles, and timber lagging is placed at the back face of the piles up to the bent cap. Backfill is placed behind the lagging. These steel abutment piles must resist vertical loads from...
the superstructure and bent cap, and lateral soil pressures from the fill under the approach. In this sense, the piles are acting as beam/columns to resist axial compressive loads and bending moments. Maximum bending stresses occur near the ground line, which is also where corrosion is most likely to take place.

![Figure 4:5-18: Steel Abutment](image)

The most common defect found in steel substructures is corrosion, and the heaviest corrosion is generally found at the ground line, at the water line, and below failed or leaking expansion joints. The inspector should look for signs of corrosion on all steel surfaces, but problem areas are usually places subject to traffic spray or water, or with accumulated debris or bird waste.

The inspector should look for cracks at details prone to fatigue damage. Detection of these cracks will most often occur during arm's length inspections. Fatigue cracks usually show up as rust stains or rusty breaks in the paint. Nondestructive testing (NDT), such as dye penetrant or ultrasonic testing, may be required to confirm the presence of a crack. Any crack or suspected crack will be oriented perpendicular to the direction of stress.

Though welded structures are most often associated with fatigue concerns, mechanically fabricated members are also susceptible to fatigue damage. As with welded members, the connections are the most vulnerable locations.

All members should be checked for overload damage. Buckled compression members or components, yielded tension members or components, and crippled webs at a support all indicate overload damage.

Steel components must also be inspected for fire damage when a fire occurs on or under a bridge.

Collision or traffic impact damage can be caused by trucks, railroad cars, or ships. Signs of impact damage include scrapes, distorted members or components, and nicks or gouges on plate edges or member corners. A damaged steel pillar can be especially
serious if there are only two or three pillars in the bent. Even if a complete pillar failure does not occur at the time of impact, one may occur later during an overload.

Figure 4.5-19: Impact Damage to Steel Substructure

Inspection of steel substructure components should include the following items:

1) Sight down the member’s length for unusual dips and sweeps, as well as for any lateral bending or twisting. This type of damage may be due to overloads, traffic impact, or support settlement.

2) Check all pillars and walls for plumb, either visually, or with a level or plumb bob.

3) Look for rotation in the bent cap.

4) Check corroded areas for section loss. Particular attention should be given to members adjacent to the splash zones of roadways, bearing areas, near the water line for water crossings, at the ground line, and any detail that would tend to trap water and debris.
5) Examine the flexure zones and tension flanges for corrosion and loss of cross-sectional area. Section loss of five percent or greater may raise the stress level an appreciable amount.

6) Remove spot areas of accumulated debris accumulation to check for corrosion.

7) Check rivet/bolt heads on built-up components, as corrosion on the heads may indicate corrosion along the entire fastener length, reducing structural integrity.

8) Look for pack rust, noted by an individual plate bending between fasteners. Pack rust may be present between the plies of riveted/bolted connections, such as field splices or built-up member connections.

9) Look for damage in the form of plate waviness, compression flange buckling, or tension flange elongation or fracture in the high moment flexural regions. This could be the result of a structural overload, or differential pier or bent settlement. Check near the ground line of abutment piles where maximum bending compressive stresses occur.

10) Examine suspect fasteners for looseness by striking the heads with a hammer.

11) Look for welded repairs which reduce the member’s fatigue strength. These include patch plates fillet-welded over corroded areas, producing sudden geometric changes, and poor quality plug welds used to fill mis-drilled bolt holes.
12) Look for stress risers on tension flanges, such as tack welds, gouges, and indiscriminately placed attachment welds. Flaws such as these should be marked, recorded, and ground smooth, if possible. Until the areas are repaired, the member should be closely monitored to spot crack development.

13) Look for bearing stiffeners welded to a tension flange. These welds act as stress risers and could be a crack initiation point. Carefully check the welds and flange on these components for cracks.

14) Investigate groove welds used to join the ends of web plates or different size flange plates.

15) Examine intersecting welds for cracks.

16) Investigate back-up bars that are welded together end-to-end and are located within tension or stress reversal zones for fatigue cracks.

17) Investigate any web or flange longitudinal stiffeners that are welded together end-to-end and are within tension or stress reversal zones. Pay particular attention to all questionable details located along the tension flanges.

18) Check all welded attachments, including the transverse stiffeners and diaphragms.

19) Look for fire damage, especially near the piers, bents, or abutments where fires can be built close to the beams. Fire-damaged members that exhibit large strain deformations should be reported immediately to the District Engineer or the Inspection Consultant.

20) Inspect submerged substructure members visually and by probing to check for scour and erosion.

21) Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.

**Subsection 5.3.1 Fracture Critical Steel Substructures**

A fracture critical member is one that is in tension or with a tension element whose failure would probably cause a portion of or the entire bridge to collapse. The most common steel substructure member classified as fracture critical is a single I-girder or box girder bent cap supported by two pillars. The fracture critical element is the tension flange of the bent cap. See Part 4, Chapter 11 for information on Indiana’s Fracture Critical Inspection procedures.
Concrete is the most common material used to construct bridge substructures. Around the turn of the 20th century, massive concrete substructures were built to replicate the more commonly used masonry substructures. The ease of placement, formability, and long-term durability of concrete was quickly recognized, and this led to the near cessation of building masonry substructures.

Subsection 5.4.1 Unreinforced Concrete Piers and Abutments

Although unreinforced concrete substructures are no longer built, some older and generally smaller bridges are supported by unreinforced concrete piers and abutments. Inspection of these substructures is the same as for reinforced concrete substructures. Since these substructures are generally larger in mass than comparable reinforced construction, cracking may be of less consequence. These generally older structures may have more freeze/thaw deterioration and deterioration from sulfate attack and reactive aggregates than newer structures.
Subsection 5.4.2  Reinforced Concrete Piers, Bents, and Abutments

Concrete pier, bent, and abutment elements are generally constructed using cast-in-place methods. Pillars, piers, bents, and abutments provide support for the superstructure’s gravity loads, as well as bridge lateral and longitudinal loads.

Figure 4:5-23: Reinforced Concrete Abutment

Figure 4:5-24: Reinforced Concrete Multi-Pillar Bents
Traffic impact damage is caused by trucks, railroad cars, or ships. Signs of impact damage include scrapes, spalling, cracking, and misalignment. A damaged bent pillar can be especially serious if there are only two or three pillars for a bent. If a complete pillar failure does not occur at the time of impact, one may occur during an overload.

Figure 4:5-25: Pillar Spall with No Exposed Rebar

Inspection of reinforced concrete substructures should include the following:

22) Sight down the superstructure parapet to look for unusual dips or sweeps.

23) Check for tipping or rotation by using a plumb bob and laterally sighting the element from a distance.

24) Look for bridge components that do not line up with one another, such as wingwalls that have shifted laterally relative to the abutment at an expansion joint.

Figure 4:5-26: Tipped Wingwall

25) Check and measure the alignment of expansion bearings relative to the masonry plate and backwall. Excessive superstructure expansion in hot weather or contraction in cold weather may actually be a sign of substructure rotation or sliding.
26) Investigate all cracks. Measurements and the dates taken should be recorded in the Central Database and written with a lumber crayon directly on the element.

27) Check the base of all pillars, shafts, or walls for transverse flexural cracks. These cracks indicate excessive bending. This bending may be from expansion bearings that have locked up, or from wind or centrifugal effects.

28) Check the mid-height of walls and pillars for flexural cracks. This is a sign of structural overloads or differential substructure settlement.

29) Examine all walls for diagonal cracks which can indicate excessive lateral shear.

30) Examine all walls, pillars, or shafts for vertical cracks and crushed concrete. This could be the result of a serious structural overload.

Figure 4:5-27: Transverse Flexural Cracks at the Base of a Pillar
31) Examine all bearing seats for cracking and spalling. The pedestals and grout pads under the bearings should also be checked for cracking, spalls, and deterioration that reduce the bearing area.

32) Check the bent cap/pillar interface for horizontal or diagonal flexural cracks in the pillar. These cracks will originate at the inside corner of the cap/pillar junction and are a sign of excessive lateral bending.

33) Look for shear cracks in the bent caps over and near the supports. Shear cracks will be diagonal, extending up from the pillar towards mid-span. Wide shear cracks suggest the loss of aggregate interlock, meaning the member could be hanging from the reinforcing stirrups. Maximum crack widths should be measured and noted on the bridge inspection report. The District Engineer or Inspection Consultant should be contacted immediately if shear cracks with possible loss of aggregate interlock are found.

34) Look for vertical flexural cracks in the bent caps, either on the underside between pillars, or top side above pillars or shafts. Wide cracks in a flexural region indicate a serious structural overload.
35) Check for shear cracks near the tops of pillars.

36) Check the construction joint between the abutment backwall and bearing seat for deterioration and leakage.

37) Check all surfaces for delaminations, spalls, and exposed reinforcing steel. Suspect areas are in roadway splash zone or bridge drainage areas, at water lines for water crossings, and at grade.
38) Look for efflorescence, and note if it is stained with rust since this suggests reinforcing steel corrosion.

39) Note any abrasion of the concrete surface located within a waterway.

40) Note if any soil, rock or debris has been piled against the walls or pillars. This may cause lateral forces on the member not originally accounted for in the original design.

41) Look for granular soil deposits outside the base of the wall caused by failed weep holes or excessive joint gaps.

42) Check previously repaired areas for soundness by hammer tapping.

43) Drag or scrape a probing rod along the surface of any submerged concrete to check for the presence of cracks, spalls, or abrasion.

44) Check for deteriorated concrete in the flexural zones that could be causing debonding of the reinforcing steel.

45) Look for the presence of debris or standing water on the bearing seat. Debris suggests a failed or leaking expansion joint. Standing water indicates that the bearing seat is dished. Salt-laden standing water will eventually migrate to the reinforcing steel, causing corrosion, delaminations, and spalls.
46) Check that any weep holes present are clear and functioning properly.

47) Inspect submerged substructure members visually and by probing to check for scour and erosion.

48) Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.
SECTION 5.5 TIMBER SUBSTRUCTURES

Timber bents, abutments, and wingwalls are most often constructed using sawn lumber.

![Figure 4:5-33: Timber Abutment and Wingwalls](image)

Note the lead sheets on the piles in Figure 4:5-33

Timber pillars are almost exclusively round piles that extend above the ground line. Pillars for timber bents may also bear on reinforced concrete pedestals located at the ground line. Bents of either type are laterally stabilized through the use of timber bracing. The tops of the timber pillars are tied together with a timber, reinforced concrete, or rolled steel bent cap to help create a frame and to deliver the superstructure loads to the bent pillars. Since timber pillars are vertical members, the permeable end grain is directly exposed to rain. Thin lead or zinc sheets are often draped over the ends to keep them dry.

Timber cross-bracing is used to support timber bents against the forces of lateral loads. It is also sometimes used for longitudinal bridge support. The bracing forms an “X” shape, with each brace starting near one end of the bent at the cap and ending at the opposite end near grade or the water surface. The braces are most often bolted to each timber pillar they cross. Cross-bracing is needed to prevent bent racking due to lateral wind loads, seismic loads, and centrifugal forces. Sawn solid members are usually used for bracing.
Steel piles are also used with wood lagging in timber abutments. The inspection of these piles is covered in Section 5.3 of this chapter.

Timber abutments are generally designed as one of two common structure types. The first is a timber bent abutment. It is built by driving timber or steel piles into the ground. These piles extend above the grade approximately to the girder bearing elevation and receive vertical bearing loads from the superstructure through the abutment cap. Sawn timber lagging is then placed along the back face of the piles to the abutment cap, forming a wall. The embankment is then created by backfilling behind the lagging wall. The timber lagging holds back the soil by spanning between the piles. The piles act as beams/columns to resist axial compressive loads and bending moments. Maximum bending stresses occur near the ground line, which is also where decay is most likely to take place. Timber or reinforced concrete caps are used to tie the abutment piles together.

Timber crib abutments are the second common type of timber abutment. Rectangular timber elements are stacked to form a cell, similar to how a log cabin is built. This cell is then filled with soil to form the embankment. Timber crib abutments act as gravity-retaining devices, using the mass of the crib and the contained fill material to resist sliding from exterior soil lateral pressures. There are no piles used in this type of abutment.
Timber wingwalls are almost exclusively used in conjunction with timber abutments, using similar construction to the abutment. Their purpose is to retain the approach backfill at the abutments.

Inspection of timber substructure members should include the following:

1) Sight all substructure members for plumb visually, or using a plumb bob.

2) Sight along all pillars and walls to check for bowing. Excessive deflections indicate that the member has been overstressed or that the bridge is experiencing differential settlements. The measured or estimated amount of deflection should be recorded.
3) Examine all timber members for signs of decay. Signs include discolored wood with a soft, rotted texture. Look for fungi and depressed areas of the wood surface.
4) Perform probe tests in areas of suspected decay. Using an awl, ice pick, or pocketknife, lift a small sliver of wood from the surface. Wood that lifts up and splinters is sound, while wood that breaks up upon lifting the tool is decaying. Drill or bore suspect members to estimate the extent of decay.

5) Examine all timber members for signs of insect attack. Signs include piles of sawdust, small holes in the wood surface, insects themselves, and a hollow sound when the member is tapped with a hammer.

6) Look for any splitting of sawn timber members. Excessively long or wide splits may be a sign of a structural overload. Splits along a bolt line may render the member ineffective to carry the load.

7) Check the cap/pillar interface for bearing failures. Bearing failures on timber members loaded parallel to the grain will “broom out.”
8) Check the mid-height of all pillars and walls for flexural cracks, which are signs of structural overloads or differential deflection.

9) Check for cap crushing at girder bearings, piles, or pillars. These areas tend to collect and retain moisture and debris, creating ideal environments for fungal growth and insect attack.

10) Look for shear-related damage in timber caps at and near the supports. Overloads result in high-shear stresses that cause horizontal splits to form along the length of the cap, at approximately mid-height. Splits will allow fungi and insects access to the untreated interior of a cap.

11) Examine the high flexural regions of the cap for signs of overload damage, such as crushing near the compression surface, and transverse cracking at the tension surface.

12) Sight along the length of the cap for excessive vertical or lateral deflections. Check for cap rotation that may be caused by eccentric beam loading. The measured or estimated amount of deflection should be recorded.

13) Check the lagging or cribbing for excessive deflections. Excessive deflections may allow the soil behind the boards to spill or wash out, causing settlement to the approach above.

14) Look for any rotted or broken lagging boards. This may occur at a weak spot in the wood, such as a knot.

15) Look for fire damage, noting the depth, extent, and location of any charring.

16) Check the fasteners (bolts, lag screws, etc.) for corrosion or slipping. Check for loose fasteners by striking with a hammer. A dull sound indicates a loose fastener. The location of any missing fasteners should be noted.

17) Examine the bearing seat for dirt or debris.

18) Inspect submerged substructure members visually, and by probing, to check for scour and erosion.

19) Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.
Figure 4:5-41: Timber Pillars, Cap, and Cross-Bracing
Masonry has been used for bridge substructures for thousands of years. Even after steel and reinforced concrete gained favor over masonry arches in the 1800s, masonry was still used for piers, abutments, and wingwalls. Eventually, concrete substructures won favor over masonry, and new masonry bridge substructure construction is mostly limited to use as a decorative effect on small, local bridges.

Concrete form liners, having the look of old masonry, are becoming popular. Coatings and pigmented concrete can make these elements look realistic when viewed from a distance. The inspector should be careful to inspect these substructures as reinforced concrete.

Subsection 5.6.1 Masonry Substructure Members

Masonry piers are solid, unreinforced masonry walls, built wide and heavy enough so that tensile stresses due to bending are virtually eliminated. Masonry abutments and wingwalls are solid, unreinforced masonry walls that act as gravity retaining walls to contain the soil located under the approach. They rely on dead weight and any soil bearing on top of them to provide enough frictional resistance at their footings to prevent sliding. They are built wide and heavy enough so that tensile stresses due to bending from lateral soil pressures are virtually eliminated.

Figure 4:5-42: Masonry Abutment
Inspection of masonry substructure components should include the following:

1) Look for cracked, split, spalled, loose, or missing stone masonry units. This would suggest weathering due to freeze/thaw effects. Missing or crushed masonry results in a loss of cross-sectional area, increasing the axial stresses.

2) Look for deteriorated, loose, or missing mortar. This would suggest weathering due to freeze/thaw effects. Missing or deteriorated mortar results in a loss of cross-sectional area, increasing the axial stresses.

3) Look for efflorescence. This indicates water is flowing through the mortar joints, leaching out cementations minerals. Extended efflorescence will weaken the mortar.

4) Check areas exposed to drainage and roadway runoff. The runoff may cause scaling of the masonry units.

5) Check the abutment and wingwall surfaces for bulges. This defect suggests unstable soil. The roadway above may also show signs of settlement.

6) Check to make sure surface drains are functioning properly and do not allow water to penetrate the approach fill behind the abutment.

7) Check to make sure weep holes are functioning.

8) Examine previous repair areas for soundness.

9) Check tall substructure units for plumb visually, or using a plumb bob.
10) Look for vegetation growing inside of cracks, or between the mortar and masonry unit. Plant roots can exert prying forces that further deteriorate these materials.

11) Note any abrasion of the masonry for pier walls located within a waterway.

12) Examine the top surface (bearing seat) of pier walls and abutments for cracking and spalling. Deterioration in these areas may be caused by frozen expansion bearings that transmit lateral forces not anticipated in the original design.

13) Note if any soil, rock, or debris has been piled against any wall. This will cause lateral forces not accounted for in the original design.

14) Examine the bearing seat for dirt or debris.

15) Inspect submerged substructure members visually and by probing to check for scour and erosion.

16) Verify that any protection required to shield the bridge from traffic on navigable waters is in place and note the condition.
Figure 4:5-45: Masonry Arch
SECTION 5.7  MECHANICALLY STABILIZED EARTH WALLS

Mechanically stabilized earth walls use precast concrete panels in conjunction with steel straps to reinforce the fill under the approach. The steel straps act as shear reinforcing for the soil, forcing it to act as a large mass rather than as many individual particles that could easily slide. In this way, a gravity retaining wall is made of soil. The concrete panels prevent the fill from washing out.

When mechanically stabilized earth walls are used on bridges, there is no physical connection to the abutment. They are not considered wingwalls or abutments. Generally, sill abutments supported on either spread footings or piles are placed on top of the soil mass at the top of the wall. The precast panels carry no vertical loads. For inspection and coding purposes, information on the condition of mechanically stabilized earth walls should be entered in the Central Database under the associated abutment or under wingwall, as appropriate. Structural concerns should be reported immediately to the District Engineer or the Inspection Consultant.

Inspection of mechanically stabilized earth walls should include the following items:

1) Note any wall lean or misalignment.
2) Check that any weep holes present are clear and functioning properly.
3) Note if any precast concrete panels are bulging out or tipping.
4) Note any mechanically stabilized earth wall panels that are shifting out of place or allowing fill to wash out.

Figure 4:5-46: Sill Abutment and Mechanically Stabilized Earth Wall
SECTION 5.8 SLOPE PROTECTION

On many bridges, an embankment of soil is placed in front of the abutments to retain soil under the approach from spilling through the abutment, to protect and provide support for the abutment piles, and to protect the abutment from errant vehicles on the roadway below.

Sometimes vegetation is used to stabilize the embankment. If vegetation cannot grow on these slopes, the embankment is extremely vulnerable to the erosive effects of rain, runoff, and wind. Because the embankment receives little direct sunlight, most plants do not grow well. Without plant roots to anchor the soil, slope protection is required under most bridges. The slope protection shields the embankment from erosive effects caused by the environment.

Concrete slope protection is usually constructed using relief-jointed, cast-in-place panels. Concrete slope protection is typically used in urban areas when the aesthetics of a bridge is deemed important, and in areas where crushed aggregate slope protection may lead to vandalism.

Figure 4.5-47: Eroded Bare Slope

Figure 4.5-48: Concrete Slope Protection
Older concrete slope protection may be constructed using individual, rectangular, concrete slabs or masonry pavers that cover the slope in front of the abutment. Animals often dig underneath the slabs and water flows through these holes, eroding deep voids underneath concrete slabs. Often, the individual slabs or pavers will settle and crack. If cracks open up, runoff water can undermine the panels. This can lead to additional cracking, buckling of the panels, and the erosion of the slope.

Asphaltic slope protection is often used in rural settings. A continuous mat of asphalt covers the entire slope. Often the mat will settle and crack as the slope consolidates and settles beneath it. Once cracks open, runoff water can undermine the mat, which can lead to additional cracking, buckling, and erosion of the slope.

Riprap slope protection is often used to protect slopes, especially at stream crossings. Riprap is large, crushed rock. The size of rock used depends on the flow velocity, but riprap between six inches and two feet in diameter is normally used. Revetment riprap is used for general erosion and minor scour protection. Class-1 and Class-2 riprap are larger and are used for higher velocity flow to protect against scour, or to fill deep erosion holes. A geotextile fabric is placed underneath the riprap to prevent the underlying soil from eroding away. Riprap slope protection relies upon its mass and the interlocking properties of the stone to prevent sliding down the slope.
Inspection of slope protection should include the following:

1) Look for signs of undermining or erosion of the slope.

2) Look for washed-out soil at the base of the slope. If water runoff or drainage is causing damage to the slope or slope protection, note the source of the water and the condition of the drainage element, if any. Common sources include leaking expansion joints; deteriorated, leaking, or incorrectly located surface drains and down spout pipes; and poor approach pavement drainage.

3) Notify the owner if slope protection erosion deposits soil on the roadway or sidewalk underneath the bridge.

4) Look for missing protection on the slope and at the toe of the slope. Note whether additional material should be placed on the slope.

5) Check to see if areas of stone or asphalt have slid down the slope.

6) Look for cracked or deteriorated concrete.

7) Check for concrete panels that have settled, buckled, or moved.

8) Check for cracks, settling or buckling of asphalt.
9) Confirm that any vegetation is well-established and is actively stabilizing the slope.

10) Note any bare areas.

Figure 4:5-51: Bare Slope
SECTION 5.9  SOIL AND FOUNDATION FAILURES

Settlement of piers, bents, abutments, and wingwalls is caused by the same forces for all substructures, regardless of the material used to construct the substructure.

Figure 4.5-52: Tipped Reinforced Concrete Wingwall

Subsection 5.9.1  Soil Failures

Common to all foundation types, soil failures can occur due to excessive soil bearing stresses, long-term consolidation, slope failures, soil characteristic changes, and erosion.

**Soil bearing:** Under design loads, soils under spread footing foundations will behave similar to a linearly elastic spring; deflection is proportional to the load applied. Bearing capacity failures occur when loads are so great that the soil becomes overstressed, ceasing to behave as a linear spring. Large deflections will occur with little increase in the applied load. These failures may be seen in the field as heaving of the soil surface in the footing vicinity, as well as soil cracking adjacent to the footing.

**Consolidation:** Consolidation is the long-term compression of cohesive soils (clays and silts) under static loads. This gradual compression results in the settlement of spread footings. Since consolidation occurs primarily under dead loads, excessive settlements are usually the result of improper design.

**Slope failure:** Abutments and wingwalls are susceptible to lateral movements due to slope failures. Slope failures occur when the weight of the embankment being retained
exceeds the shear strength resistance of the soil below. Slope failures typically begin when the toe of the slope fails. The mass of soil slips downward, carrying the abutment or wingwall along with it. Slope failures cause settlement of the approach and heaving in front of the abutment or wingwall.

**Soil characteristic changes:** Changes in soil characteristics include frost action and saturation. When water within the soil freezes, it causes the soil mass to expand. This expansion can heave up substructure elements if the frost extends below the footing, or it can push laterally on retaining elements, causing them to tilt. Excessive water within the soil mass under an approach, or behind or in front of a retaining wall, can saturate the soil. This can reduce the soil strength or increase soil weight and lead to slope failures. Excessive water can cause additional lateral pressures on abutments or wingwalls for which they may not have been designed.

**Erosion:** Soil embankments placed in front of abutments or wingwalls may be required by design to help restrain these elements against sliding. If this embankment is washed away during floods or heavy rain, the retaining elements may slide laterally due to horizontal earth pressures behind.

**Subsection 5.9.2 Foundation Deficiencies**

Foundation failures are rare, with the exception of those attributable to scour. Deterioration of a spread footing will cause it to lose bearing area. This results in increased soil bearing stresses and a possible bearing capacity failure or increased settlement. Piles not driven to sufficient depth may also allow substructure settlements. Short piles may not have enough area to reduce pile/soil frictional stresses to an acceptable level, thereby allowing the pile to slip. If the water table rises, it could cause liquefaction under a substructure.

Differential settlement is a primary cause of bridge damage. It occurs when abutments, piers, or bents vertically settle different amounts than adjacent substructure units. This can cause great strains and overstresses to superstructure and substructure members, particularly in continuous bridges. Uniform settlement may have little, if any, structural effect on the bridge. This occurs when all substructure units settle approximately the same amount, merely lowering the bridge elevation or slightly tipping the piers.

Inspection of substructures for soil and foundation deficiencies should include the following:

1) Look for any sign of vertical superstructure misalignment by sighting along the bridge.

2) Look for expansion joints which have opened up excessively at abutments and have either closed completely or opened up above the piers or bents. These may indicate differential settlement.

3) Check and measure the clearance between the girder ends and abutment backwall.

4) Check and measure the clearance between the girder ends on bridges with multiple simple spans.
5) Look for embankment erosion in front of abutments and wingwalls and mechanically stabilized earth walls.

6) Look for heaving in front of abutments, wingwalls, and mechanically stabilized earth walls.

7) Look for settlement of approaches.

8) Look for bridge components that do not line up with one another, such as wingwalls that have shifted laterally relative to the abutment at an expansion joint.

9) Check for pier or bent tipping or rotation using a plumb bob and laterally sight the bridge from a distance.

10) Check for standing water or wet areas in front of wingwalls or abutments.

11) Check for vertical cracks.

12) Check for rotation or leaning in the substructure element. Note the location and magnitude.

13) Check for bearing tipping in the opposite direction of what temperature dictates; this could be an indication of substructure movement.
SECTION 5.10 NBI SUBSTRUCTURE RATING

Part of every Routine Inspection is rating the substructure according to the Federal Highway Administration (FHWA) General Condition Rating Guidelines. The numeric condition ratings of these guidelines describe existing bridge components as compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in excellent condition and 0 describing failed components.

The rating must characterize its overall general condition of the superstructure. It should not be used to describe local areas of deterioration, such as isolated heavy spalling. However, widespread heavy spalling would influence the rating. A proper rating will consider the severity of deterioration, plus the extent to which it is distributed throughout the substructure. The rating given to Item 60 should be consistent with the one given to Item 113 whenever a rating of 2 or below is determined for Item 113.

National Bridge Inventory (NBI) ratings are used to evaluate the state of deterioration of the substructure material. Postings or original design capacities less than current legal loads will not influence the rating. Temporary substructure supports do not improve the condition of the substructure material and will not influence the substructure rating.

Indiana has developed supplemental rating guidelines to assist the inspector in properly assigning condition ratings to specific components constructed of the most commonly used materials. The general condition ratings, along with the Indiana supplemental rating guidelines for substructures, are as follows:

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td></td>
<td><strong>Indiana Supplemental Rating Guidelines:</strong> Used for underfill structures, culverts, and spandrel arches where footings cannot be seen.</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION</td>
</tr>
<tr>
<td></td>
<td><strong>Indiana Supplemental Rating Guidelines:</strong> There are no noticeable or noteworthy deficiencies that affect the condition of the substructure. There may be insignificant scrape marks caused by drift or collision.</td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – No problems noted.</td>
</tr>
<tr>
<td></td>
<td><strong>Indiana Supplemental Rating Guidelines:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Concrete Substructure</strong> – There may be shrinkage cracks, light scaling, or insignificant spalling which does not expose the reinforcing steel. There may be insignificant damage caused by drift or collision with no resulting misalignment.</td>
</tr>
<tr>
<td></td>
<td><strong>Steel Substructure</strong> – There may be insignificant damage caused by drift or collision with no resulting misalignment.</td>
</tr>
<tr>
<td></td>
<td><strong>Timber Substructure</strong> – There may be insignificant damage caused by drift or collision with no resulting misalignment.</td>
</tr>
<tr>
<td></td>
<td><strong>Masonry Substructure</strong> – There may be insignificant spalling of the masonry units. Damage caused by drift or collision may have occurred, but with no resulting misalignment.</td>
</tr>
</tbody>
</table>
7 **GOOD CONDITION** – Some minor problems may be present.

**Indiana Supplemental Rating Guidelines:**

**Concrete Substructure** – There may be minor cracking or spalls with no detrimental effect on the bearing area. Minor scouring may have occurred.

**Steel Substructure** – Leakage of expansion devices may have started minor rusting without measurable section loss. Minor scouring may have occurred.

**Timber Substructure** – Insignificant decay, cracking, or splitting may be present. Minor scouring may have occurred.

**Masonry Substructure** – There may be minor cracking of the mortar or spalls/cracking of the masonry units with no detrimental effect on the bearing area. Minor scouring may have occurred.

6 **SATISFACTORY CONDITION** – Structural elements show some minor deterioration.

**Indiana Supplemental Rating Guidelines:**

**Concrete Substructure** – Minor deterioration or disintegration, spalls, cracking, or efflorescence with little or no loss of bearing area may be present. Shallow, local scouring may have occurred near the foundation.

**Steel Substructure** – Corrosion, but no measurable section loss may be present. Shallow, local scouring may have occurred near the foundation.

**Timber Substructure** – Minor decay, cracking, or splitting may be present. Fire damage is limited to surface scorching with no measurable section loss.

**Masonry Substructure** – Minor deterioration or disintegration and spalls or cracking of the masonry units or mortar with little or no loss of the bearing area may be present. Shallow, local scouring may have occurred near the foundation.

5 **FAIR CONDITION** – All primary structural elements are sound, but may have minor section loss, cracking, spalling, or scour.

**Indiana Supplemental Rating Guidelines:**

**Concrete Substructure** – Measurable, but minor, section loss may exist, with possible exposed reinforcing steel. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

**Steel Substructure** – Corrosion with measurable, but minor, section loss of less than five percent may be present. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

**Timber Substructure** – Moderate decay, cracking, or splitting may be present. A few secondary members may need replacement. Fire damage is limited to surface charring with minor, measurable section loss. There may be some exposure of piles as a result of erosion, reducing penetration.

**Masonry Substructure** – Minor deterioration or disintegration and spalls or cracking of the masonry units and mortar with little or no loss of the bearing area may be present. Scour may be progressive and/or is becoming more prominent with possible top of footing exposure. However, no misalignment or settlement is noted.

4 **POOR CONDITION** – Advanced section loss, deterioration, spalling, or scour may be present.
Indiana Supplemental Rating Guidelines:

Concrete Substructure – Structural cracks or settlement with advanced deterioration may be present. Additional backfilling is required. Extensive scouring or undermining of the footing is affecting the stability of the unit and requires corrective action. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present, along with wingwall rotation, causing roadway settlement. Severe impact damage may be present.

Steel Substructure – Corrosion with extensive section loss, between five percent and 10 percent, may be present. Extensive scouring or undermining of the footing is affecting the stability of the unit and requires corrective action. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present, along with wingwall rotation, causing roadway settlement. Severe impact damage may be present.

Timber Substructure – Substantial decay, cracking, splitting, or crushing of primary members may be present, requiring replacement. Section loss of greater than five percent may be present. Extensive exposure of piles as a result of erosion, thus reducing penetration and affecting the stability of the unit, may also be present. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present, along with wingwall rotation, causing roadway settlement. Severe impact damage may be present.

Masonry Substructure – Structural cracks or settlement with advanced deterioration of the masonry units and mortar may be present. Additional backfilling is required. Extensive scouring or undermining of the footing is affecting the stability of the unit and requires corrective action. Settlement that is causing stress on the structure, or is creating a hazardous riding surface on the roadway above, may be present, along with wingwall rotation, causing roadway settlement. Severe impact damage may be present.

3 SERIOUS CONDITION – Loss of section, deterioration, spalling, or scour have seriously affected primary structural components, making local failures possible. Fatigue cracks in steel or shear cracks in concrete may be present.

Indiana Supplemental Rating Guidelines:

Concrete Substructure – Severe disintegration may be present. The reinforcing steel is exposed with advanced stages of corrosion. There is severe section loss in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.

Steel Substructure – There is severe section loss of greater than 10 percent in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.

Timber Substructure – There is severe section loss in critical stress areas and section loss of greater than 10 percent of the cross-sectional area. Bearing areas are seriously deteriorated with considerable loss of bearing. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.
**Masonry Substructure** – Severe disintegration of the masonry units and mortar may be present. There is severe section loss in critical stress areas. Bearing areas are seriously deteriorated with considerable loss of bearing. Severe scouring or undermining of the footings affects the stability of the unit. Settlement may have occurred. Shoring is considered necessary to maintain the safety and alignment of the structure. There is severe undermining of a spread footing. Severe impact damage may be present.

![Figure 4:5-53: Railroad Bridge with Settled Pier](image)

**2 CRITICAL CONDITION** – Advanced deterioration of primary structural elements exists. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

**Indiana Supplemental Rating Guidelines:**

**Concrete Substructure** – The concrete cap is soft and spalling, with reinforcing steel exposed with no bond to concrete. The top of the cap is split, or a pillar has undergone a shear failure. Scouring is sufficient and the substructure is near a state of collapse. Piers or bents have settled.

**Steel Substructure** – Members have critical section loss. Holes in the web and/or knife-edged flanges are typical. Scouring is sufficient and the substructure is near a state of collapse. Piers or bents have settled.

**Timber Substructure** – The primary members are crushed or split and ineffective. Piers or bents have settled. Section loss of greater than 20 percent of the cross-sectional area may be present.

**Masonry Substructure** – Scouring is sufficient and the substructure is near a state of collapse. Piers or bents have settled.

**1 “IMMINENT” FAILURE CONDITION** – Major deterioration or section loss is present in critical structural components, or obvious vertical or horizontal movement affecting structural stability is present. The bridge is closed to traffic, but corrective action may put it back in light service.

**0 FAILED CONDITION** – The bridge is out-of-service and beyond corrective action.

One suggested method for establishing a substructure rating is to identify phrases
within the general condition/Indiana supplemental guideline language that describe a substructure condition more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose a reinforced concrete substructure has extensive delaminations, plus spalling with exposed reinforcing steel. The spalls occur on the tension side of the caps and on random sides of the piers or pillars, but section loss of the reinforcing steel is minimal. Condition rating 4 indicates that there is advanced deterioration and spalling. Condition rating 3 indicates that deterioration and spalling have seriously affected the primary structural components, and that the reinforcing steel is in the advanced stages of corrosion. Using the method described above, Condition rating 3 describes a situation more severe than what actually exists on the substructure. Therefore, a rating of 4 would be appropriate.

Another way to help narrow down the substructure rating number is to group the numbers in more general categories. Ratings of 9 to 7 apply to substructures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition. It is important to note that there is a significant change from a substructure in condition rating 5 (minor section loss, but structural elements sound) to condition rating 4 (advanced section loss and advanced deterioration). A reduction in load-carrying capacity can be calculated when a substructure enters condition rating 4.
SECTION 5.11 ADDITIONAL SUBSTRUCTURE ITEMS

Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 60, the NBI substructure condition rating. Each item shall be rated as follows unless noted:

- N  Not Applicable
- 9  Excellent Condition
- 8  Very Good Condition
- 7  Good Condition
- 6  Satisfactory Condition
- 5  Fair Condition
- 4  Poor Condition
- 3  Serious Condition
- 2  Critical Condition
- 1  Imminent Failure Condition
- 0  Failed Condition

ITEM 60.01 – ABUTMENT BRIDGE SEAT

The bridge seat, sometimes called a bearing seat, is the top surface of the breastwall (stem) upon which the bearing devices for the superstructure are placed. Pedestals are sometimes constructed on the bridge seat, generally built when the bearing device was changed in a rehab. Pedestals should be noted when rating this item.

![Diagram of Backwall, Bridge Seal, and Breastwall (Stem)](image-url)
Figure 4:5-55: Bridge Seat and Pedestal with No Noteworthy Deficiencies

Figure 4:5-56: Bridge Seat with Deterioration, Spalls, and Cracking
ITEM 60.02 – ABUTMENT BACKWALL

Backwalls are the section of an abutment or end bent that retains the soil under the approach from spilling onto the bearing seat. The back side, the side away from the bridge, may also provide support for concrete approaches and provide anchorage for expansion joint devices. This is sometimes incorrectly referred to as a mudwall. However, mudwalls are end diaphragms between beams/girders that bear directly on a bridge seat, when no bearing devices are used. Mudwalls serve the same function of retaining soil from the approach.

Figure 4:5-57: Abutment Backwall with Vertical Crack

ITEM 60.03 – ABUTMENT BREASTWALL

The breastwall, or stem, is the main body of the abutment. It functions to deliver the superstructure reaction loads to the foundation and to retain much of the soil behind the abutment.
ITEM 60.04 – ABUTMENT BENT CAP

On pile abutments, a bent cap ties the piles together and also functions as a bridge seat. There are many types of bent caps. On newer integral concrete abutments, where the cap is only partly visible, it can be difficult to determine where the pile cap ends and the superstructure begins.
ITEM 60.05 – WINGWALLS

Rate the condition of any bridge wingwalls. Note the type of wingwall. Wingwalls for culverts and underfill structures are coded under Item 62.11, described in Part 4, Chapter 9 of this manual. For integral abutments, use this to rate the condition of the cheek wall. If piles are used, and visible, describe them here and rate them under Item 60.07. Note any visible piles here.

![Masonry Wingwall in Good Condition](image)

**Figure 4:5-60: Masonry Wingwall in Good Condition**

![Wingwall with Mortar Deterioration](image)

**Figure 4:5-61: Wingwall with Mortar Deterioration**
Figure 4:5-62: Reinforced Concrete Wingwall in Good Condition

Figure 4:5-63: Concrete Wingwall with Advanced Deterioration
Figure 4:5-64: Reinforced Concrete Wingwall

Figure 4:5-65: Timber Wingwall in Good Condition
ITEM 60.06 – FOOTINGS

Rate the condition of any visible footings. Note the type and size of any footings.

ITEM 60.07 – PILES

Describe and rate the condition of any exposed piles, including piles used as pillars in a bent and piles used on the wingwalls. Note if the piles are on the wingwalls.
Figure 4:5-68: Concrete Pile with Severe Section Loss

Figure 4:5-69: Wood Piles
ITEM 60.08 – SCOUR/UNDERMINING FOR ABUTMENTS

Rate the condition of the scour or undermining for abutments in the water. This will be coded “N” if the structure is not over water. This is a rating of the conditions noted in the field and is not the scour assessment rated under Item 113.

- **8** Pile-supported footing with channel bottom above the footing
- **5** Pile-supported footing; channel bottom within the footing; no undermining; spread footing with channel bottom above the footing; unknown footing with channel bottom above the footing
- **3** Spread footing with channel bottom within the footing; no undermining
- **1** Footing is undermined

ITEM 60.09 – EROSION/UNDERMINING FOR ABUTMENTS

Rate the condition of the erosion or undermining for abutments and wingwalls not in the water.
ITEM 60.10 – CONCRETE SLOPE WALLS

Rate the condition of the concrete slope walls, paver stones on slope walls, and blocks on slope walls.

Figure 4:5-71: Concrete Slope Wall with Cracks

Figure 4:5-72: Concrete Slope Wall with Displacement
ITEM 60.11 – SETTLEMENT OF THE ABUTMENTS

Rate any noticeable settlement of the abutments. Notes and measurements are required for any rating of 5 or less.

7    Good Condition – no noticeable settlement
6    Satisfactory Condition – barely noticeable settlement
5    Fair Condition – minor settlement
4    Poor Condition – settlement affects structure
3    Serious Settlement
2    Critical Settlement
1    Imminent Failure Condition
0    Failed Condition

ITEM 60.12 – INTERMEDIATE PIER: PIER CAP

A pier or bent cap is the horizontal component of a pier where the bearing devices for the superstructure are placed. Rate the condition of the pier caps for any intermediate piers and note the material used: steel, timber, reinforced concrete, prestressed concrete, or post-tensioned concrete.

Figure 4:5-73: Concrete Bent Cap with Widespread Spalling
Figure 4:5-74: Bent Cap with Delaminations

Figure 4:5-75: Bent Cap with Corrosion
ITEM 60.13 – INTERMEDIATE PIER: COLUMN (SOLID STEM)

Rate the condition of the intermediate piers and pier walls. Rate the pillars in a multi-pillar bent under Item 60.14.
ITEM 60.14 – INTERMEDIATE PIER: CONCRETE PILLARS

Rate the condition of the concrete pillars in intermediate bents.
ITEM 60.15 – INTERMEDIATE PIER: CONCRETE PILES

Describe and rate the condition of any exposed concrete piles, including piles used as pillars in a bent.
ITEM 60.16 – INTERMEDIATE PIER: TIMBER PILES

Describe and rate the condition of any exposed timber piles, including piles used as pillars in a bent.

Figure 4:5-82: Timber Pile with Serious Decay at Ground Line

Figure 4:5-83: Split Timber Pile with Rot

Note the penetration of the screw driver in Figure 4:5-83.
ITEM 60.17 – INTERMEDIATE PIER: STEEL PILES

Describe and rate the condition of any exposed steel piles, including piles used as pillars in a bent.

ITEM 60.18 – INTERMEDIATE PIER: FOOTING

Rate the condition of any visible footings for intermediate piers.

ITEM 60.19 – INTERMEDIATE PIER: CRASH WALLS

Rate the condition of the crash walls for any intermediate bents.
ITEM 60.20 – INTERMEDIATE PIER: BRACINGS

Rate the condition of the bracings used for any intermediate bents.

ITEM 60.21 – INTERMEDIATE PIER: EROSION/UNDERMINING
Rate the erosion or undermining for any intermediate piers or bents. Erosion and undermining occur when water from the roadway washes away supporting material. This is a 0 to 9 condition rating and is not the scour assessment rated under Item 113.

**ITEM 60.22 – INTERMEDIATE PIER: SCOUR/UNDERMINING**

Rate the condition of the scour or undermining for any intermediate piers or bents units in the water. This will be coded "N" if the structure is not over water. This is a rating of the conditions noted in the field and is not the scour assessment rated under Item 113.

8  Pile supported footing with channel bottom above the footing
5  Pile supported footing; channel bottom within the footing; no undermining; spread footing with channel bottom above the footing; unknown footing with channel bottom above the footing
3  Spread footing with channel bottom within the footing; no undermining
1  Footing is undermined

**ITEM 60.23 – INTERMEDIATE PIER: SETTLEMENT**

Use the following scale to rate any noticeable settlement for intermediate piers and bents. Notes and measurements are required for any rating of 5 or less.

7  **Good Condition** – no noticeable settlement
6  **Satisfactory Condition** – barely noticeable settlement
5  **Fair Condition** – minor settlement
4  **Poor Condition** – significant settlement
3  **Serious Settlement**
2  **Critical Settlement**
1  **Imminent Failure Condition**
0  **Failed Condition**

**ITEM 60.24 – GENERAL DETERIORATION: CONCRETE**

Rate the general condition of the substructure concrete.
ITEM 60.25 – GENERAL DETERIORATION: STEEL

Rate the general condition of the substructure steel.
ITEM 60.26 – GENERAL DETERIORATION: TIMBER

Rate the general condition of the substructure timber.

ITEM 60.27 – GENERAL DETERIORATION: EPOXY COATING

Rate the general condition of the epoxy coating of any coated steel in the substructure.

ITEM 60.28 – GENERAL DETERIORATION: DEBRIS ON BRIDGE SEATS
Rate the amount of debris on the bridge seats, using the following guidelines:

9 No debris
7 Minor debris, but not affecting action of the bearings
5 Significant debris, but not affecting action of the bearings
3 Debris is affecting action of the bearings or is trapping moisture
1 Debris has caused failure of the bearing

Figure 4:5-92: Debris on Bridge Seat, Trapping Moisture

ITEM 60.29 – GENERAL DETERIORATION: COLLISION DAMAGE

Rate the damage to the substructure from collisions. Note all scrapes. When one member has been hit, check all members beyond the point of impact for damage. The full extent of damage may not be noticeable immediately after impact.
ITEM 60.30 – PLUMB: ABUTMENTS
Enter “Yes,” “No,” or “N/A.” Note direction and description of any problem in the notes.

ITEM 60.31 – PLUMB: PIERS
Enter “Yes,” “No,” or “N/A.” Note direction and description of any problem in the notes.

ITEM 113B.01 – TOTAL NUMBER OF ALL PIERS
Enter the total number of bridge piers or bents.

ITEM 113B.02 – ABUTMENT #1 TYPE
Enter the type of abutment #1 from the code list below. This will be the abutment at the south or west end of the bridge unless the bridge ends at another substructure of another bridge.

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Concrete spread footing; no piles</td>
</tr>
<tr>
<td>B</td>
<td>Timber spread footing; no piles</td>
</tr>
<tr>
<td>C</td>
<td>Stone spread footing; no piles</td>
</tr>
<tr>
<td>D</td>
<td>Concrete spread footing on piles</td>
</tr>
<tr>
<td>E</td>
<td>Concrete bent cap on soil on piles</td>
</tr>
<tr>
<td>F</td>
<td>Steel H-columns extending out of the ground</td>
</tr>
<tr>
<td>G</td>
<td>Steel shells extending out of the ground</td>
</tr>
</tbody>
</table>
H  Steel caissons extending out of the ground
I  Timber bent extending out of the ground
J  Concrete piles, plus steel shell or H-column encased
K  Concrete piles, plus steel reinforcing encased
L  None (for some multi-plate arches, etc.)
M  Other (describe)
N  Not applicable
O  Unknown foundation type
P  Timber bent cap; cap on soil; piles buried
Q  Combination A and I (pier widening)
R  Combination A and D (pier widening)
S  Other combinations (pier widening)
T  Combination A and C (pier widening)
U  Integral bent on piles on soil

ITEM 113B.03 – ABUTMENT #2 TYPE

Enter the type of abutment #2. This will be the abutment at the north or east end of the bridge unless the bridge ends at another substructure of another bridge. The code is as shown above in Item 113B.02.

ITEM 113B.05 – NUMBER OF INTERMEDIATE PIERS

Enter the number of intermediate bridge piers/units.

ITEM 113B.06A – TYPE OF INTERMEDIATE PIERS

Enter the type of intermediate pier or bent used on the bridge that is most critical for scour.

<table>
<thead>
<tr>
<th>Code</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Concrete spread footing; no piles</td>
</tr>
<tr>
<td>B</td>
<td>Timber spread footing; no piles</td>
</tr>
<tr>
<td>C</td>
<td>Stone spread footing; no piles</td>
</tr>
<tr>
<td>D</td>
<td>Concrete spread footing on piles</td>
</tr>
<tr>
<td>E</td>
<td>Concrete bent cap on soil on piles</td>
</tr>
<tr>
<td>F</td>
<td>Steel H-columns extending out of the ground</td>
</tr>
<tr>
<td>G</td>
<td>Steel shells extending out of the ground</td>
</tr>
<tr>
<td>H</td>
<td>Steel caissons extending out of the ground</td>
</tr>
</tbody>
</table>
ITEM 113B.06B – TYPE OF INTERMEDIATE PIERS

Enter the second most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

ITEM 113B.06C – TYPE OF INTERMEDIATE PIERS

Enter the third most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

ITEM 113B.06D – TYPE OF INTERMEDIATE PIERS

Enter the fourth most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.
ITEM 113B.06E – TYPE OF INTERMEDIATE PIERS

Enter the fifth most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

ITEM 113B.06F – TYPE OF INTERMEDIATE PIERS

Enter the sixth most critical for scour intermediate pier or bent used on this bridge. The code is shown above in Item 113B.06A.

ITEM 113.08 – NUMBER OF PIERS IN WATER

Enter the number of piers or bents that are currently in water. If this is different than the number normally in the water, explain in the notes. This number is used in state underwater contracts as a limit on the number of units that an Underwater Consultant can inspect without permission of the State Program Manager.

ITEM 113.09 – NUMBER OF PIERS WITH SCOUR

Enter the number of piers or bents with scour. Identify which piers or bents have scour in the notes.

ESTIMATED REMAINING LIFE

Enter the estimated remaining life, in years, of the substructure in the Central Database. Assume no repair work will be completed.
CHAPTER 6 APPROACHES

SECTION 6.1 INTRODUCTION

Approaches are the slabs or roadways located on either end of the bridge. Approaches need to be monitored because they can affect the safety and serviceability of a bridge. A poor approach can increase impact loads to the bridge deck and the end expansion joints. It can also reduce the safety of the bridge, leading to vehicle impacts to the structure.

Figure 4:6-1: Concrete Approach
SECTION 6.2 APPROACH INSPECTION

The primary function of the approach is to provide a smooth transition between the roadway pavement and the bridge deck. This smooth transition decreases the impact forces on the bridge superstructure, increasing bridge safety and driver comfort.

The pavement structure varies with the type of approach roadway. Bituminous approaches utilize a bituminous wearing surface over a concrete or bituminous subbase. Concrete approaches are constructed with a concrete slab over an aggregate subbase and a relief joint. The subgrade material for these approaches is the prepared and compacted soil or gravel immediately beneath the approach. Gravel approaches are installed over compacted fill.

Vertical settlement of the approach is caused by the consolidation or loss of the subgrade materials. Settlement is especially a problem near the abutment. Heave or uplift can also occur due to rotation of the abutment or the expansion of frozen subgrade material.

The riding surface of any approach should be smooth, free of potholes, and properly sloped for drainage. Embankment slopes along the roadway shoulder should have adequate vegetation or riprap to provide erosion control. Roadway inlets located in the approach area should be in good condition and fully operational. Joints between the approach and the abutment backwall should be examined. Joints designed for thermal movement must be checked for movement and leaking.

Subsection 6.2.1 Concrete Approaches

A concrete approach is a reinforced concrete slab that bears on the abutment at one end. The opposite end bears on a sleeper slab or compacted fill. A sleeper slab is a strip footing running the width of the approach. The approach slab functions as a reinforced concrete bridge designed to span between the abutment and the sleeper slab. If there is no sleeper slab, the concrete approach slab bears on the compacted fill. If these approach slabs are not reinforced, they are subject to flexural cracking as the fill settles.

Modern design calls for a concrete approach slab to be connected to the abutment with a minimal amount of reinforcing to allow for movement of the slab. The slab is poured with the deck and saw cut over the reinforcing.

Concrete approaches on concrete roadways typically have a pavement relief joint between the approach and the roadway pavement. A relief joint is a strip of asphalt that compresses as the roadway pavement expands or migrates towards the bridge. Compression of this relief joint reduces the roadway pavement lateral load on the approach and abutment backwall.
Inspection of concrete approaches should include the following:

1) Look for settlement or heaving of the approach roadway. If settlement has occurred, check for evidence of a crack close to the center of the approach. Settlement may be caused by lost fill material under or around the abutment.

2) Look for common concrete defects in the approach, such as potholes, cracking, and dips. Cracking, unevenness, or movement under traffic in a concrete approach may indicate a void under the approach from fill settlement, erosion, or pumping.

3) Examine the joint between the approach and the abutment backwall. Some of these joints are designed for thermal movement. Determine if there is adequate clearance to provide for this movement. If the joint was designed for a water seal, determine if the seal is leaking.

4) Examine the embankments and slopes for evidence of erosion or undermining.

5) Check the drainage system for evidence that it is operating properly.

6) Notify the bridge owner of any approach settlement that forces motorists to slow down.

Figure 4:6-2: Concrete Approach with Wide Cracks
Subsection 6.2.2 Bituminous Approaches

A bituminous approach consists of asphalt paving placed over a concrete or bituminous subbase and compacted fill material. Inspection of bituminous approaches should include the following:

1) Check for approach settlement. Pronounced settling will be evident if the top corner of the abutment backwall or paving notch is exposed, or a significant dip in the approach pavement is evident. Settlement may be caused by lost fill material under or around the abutment.

2) Look for ruts in the wheel paths of the traffic lane(s).

3) Look for approach cracking.

4) Look for potholes or localized dips in the approach. Dips may be caused when fill has washed out underneath the approach pavement.

5) Check for approach raveling. Raveling is the progressive separation of aggregate from the asphalt binder. The pavement surface will have a gravel-like appearance.

6) Check for approach shoving, which will have the appearance of transverse ripples. Shoving is caused by a lack of pavement structure stability.

7) Examine the embankments and slopes for evidence of erosion or undermining.

8) Check that the drainage system is operating properly.

9) Notify the bridge owner of any approach settlement that forces motorists to slow down.

Figure 4:6-3: Bituminous Approach Roadway in Very Good Condition
Figure 4:6-4: Bituminous Approach Roadway with Cracks

Figure 4:6-5: Bituminous Approach with Wedge
Subsection 6.2.3 Gravel Approaches

Gravel approaches are used on unpaved roads in rural areas with very low traffic volumes. Inspection of gravel approaches should include the following:

1) Check for potholes or depressions. Potholes or depressions can be a safety hazard to motorists and can increase traffic impact on the bridge.

2) Look for ruts in the wheel paths of the traffic lane.

3) Check for approach gravel that has pushed onto the bridge deck.

4) Look for approach gravel material that has washed off of the roadway.

5) Examine the embankments and slopes for evidence of erosion or undermining.

6) Check that the drainage system is operating properly.
SECTION 6.3 NBI APPROACH ALIGNMENT RATING

The National Bridge Inventory (NBI) rating for the approach alignment (Item 72) is based on the adequacy of the approach roadway alignment. It identifies bridges which do not function properly or adequately due to the alignment of the approaches. The roadway alignment is compared to the existing highway alignment, not current standards.

For example, if the highway alignment requires a substantial reduction in speed, and the approach only requires a minor additional reduction in speed, the rating would be 6.

Speed reductions necessary because of the width of the bridge and not the alignment are not considered in evaluating this item.

Rate the reduction in speed over one bridge length or 200 feet, whichever is greater, in accordance with the following criteria:

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – no speed reduction required</td>
</tr>
<tr>
<td>6</td>
<td>SATISFACTORY CONDITION – a very minor speed reduction of less than five mph is required</td>
</tr>
<tr>
<td>4</td>
<td>POOR CONDITION – a speed reduction between five and 10 mph is required</td>
</tr>
<tr>
<td>3</td>
<td>SERIOUS CONDITION – horizontal or vertical alignment requires a substantial reduction of more than 10 mph in the vehicle operating speed from that on the highway section</td>
</tr>
<tr>
<td>1</td>
<td>FAILURE CONDITION – vehicles must slow to 10 mph or less before driving onto the bridge</td>
</tr>
</tbody>
</table>

The rating for NBI Item 72 must be entered in the Central Database.
SECTION 6.4 ADDITIONAL APPROACH ITEMS

The following items pertaining to the approaches are required to be rated and entered into the Central Database for state bridges. Each item shall be rated as a stand-alone item, assessing its condition independently. Each item shall be rated as follows unless otherwise noted:

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted; functioning as designed
7  Good Condition – some minor problems, but functioning as designed
6  Satisfactory Condition – minor problems, but functioning as designed
5  Fair Condition – minor deterioration, but functioning as designed
4  Poor Condition – advanced deterioration or not able to function as designed
3  Serious Condition – deterioration or inadequate to function as designed
2  Critical Condition – deterioration and inadequate to function as designed
1  Imminent Failure Condition – unsafe
0  Failed Condition – beyond corrective action

ITEM 72.01 – ALIGNMENT FOR THE ROADWAY CARRIED ON THE BRIDGE

This condition rating is the rating described in Section 6.3 for NBI Item 72. The rating reflects any speed reduction required from the speed on the highway. Rate the reduction in speed over one bridge length or 200 feet, whichever is greater, in accordance with the following:

8  VERY GOOD CONDITION – no speed reduction required
6  SATISFACTORY CONDITION – a very minor speed reduction of less than five mph is required
4  POOR CONDITION – a speed reduction between five and 10 mph is required
3  SERIOUS CONDITION – horizontal or vertical alignment requires a substantial reduction of more than 10 mph in the vehicle operating speed from that on the highway section
1  FAILURE CONDITION – vehicles must slow to 10 mph or less before driving onto the bridge

ITEM 72.02 – APPROACH SLAB FOR THE ROADWAY CARRIED ON THE BRIDGE

The condition rating reflects the overall condition of the bridge approach slabs, including settlement, potholes, cracking, dipping, rutting, shoving, pushing, and the condition of
the drainage system.

ITEM 72.03 – RELIEF JOINTS FOR THE ROADWAY CARRIED ON THE BRIDGE

A relief joint is a strip of asphalt that compresses as the roadway pavement expands or migrates towards the bridge. Compression of this relief joint minimizes the roadway pavement from pushing on the approach and abutment backwall. Rate the overall condition of the joints.

ITEM 72.04 – APPROACH GUARDRAIL FOR THE ROADWAY CARRIED ON THE BRIDGE

Rate the condition of the guardrail and the adequacy of the guardrail to redirect vehicles safely compared to new guardrail meeting existing guardrail standards.

ITEM 72.05 – PAVEMENT ON THE ROADWAY CARRIED ON THE BRIDGE

Rate the overall condition of the approach pavement for the roadway carried on the bridge, including potholes, cracking, dipping, rutting, shoving, pushing, and the condition of the drainage system. Rate the pavement over one bridge length, or 200 feet, whichever is greater.

ITEM 72.06 – SHOULDERS ON THE ROADWAY CARRIED ON THE BRIDGE

Rate the overall condition of the shoulders, including slope stability and safety.

ITEM 72.07 – MEDIAN ON THE ROADWAY CARRIED ON THE BRIDGE

Rate the median for its ability to safely separate traffic.

ITEM 72.08 – ALIGNMENT FOR THE ROADWAY UNDER THE BRIDGE

Rate the reduction in speed of the roadway passing under the bridge over one bridge length, or 200 feet, whichever is greater, in accordance with the following:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – no speed reduction required</td>
</tr>
<tr>
<td>6</td>
<td>SATISFACTORY CONDITION – a very minor speed reduction of less than five mph is required</td>
</tr>
<tr>
<td>4</td>
<td>POOR CONDITION – a speed reduction between five and 10 mph is required</td>
</tr>
<tr>
<td>3</td>
<td>SERIOUS CONDITION – horizontal or vertical alignment requires a substantial reduction of more than 10 mph in the vehicle operating speed from that on the highway section</td>
</tr>
<tr>
<td>1</td>
<td>FAILURE CONDITION – vehicles must slow to 10 mph or less before driving onto the bridge</td>
</tr>
</tbody>
</table>

ITEM 72.09 – GUARD RAIL FOR THE ROADWAY UNDER THE BRIDGE
Rate the condition of the guard rail along the roadway under the bridge and the adequacy of the guard rail to redirect vehicles safely, as compared to new guardrail meeting existing guardrail standards.

ITEM 72.10 – IMPACT ATTENUATORS FOR THE ROADWAY UNDER THE BRIDGE

Rate the ability of the impact attenuators to provide a safe cushion in a crash.

ITEM 72.11 – PAVEMENT FOR THE ROADWAY UNDER THE BRIDGE

Rate the overall condition of the roadway under the bridge, including potholes, cracking, dipping, rutting, shoving, pushing, and the condition of the drainage system.

ITEM 72.12 – SPEED REDUCTION FOR THE ROADWAY CARRIED ON THE BRIDGE

This rating reflects any speed reduction required for the roadway carried on the bridge from the speed on the highway:

1. Substantial; over five mph
2. Minor; less than five mph
3. None

ITEM 72.13 – SPEED REDUCTION FOR THE ROADWAY UNDER THE BRIDGE

This rating reflects any speed reduction required for the roadway carried on the bridge from the speed on the highway:

1. Substantial; over five mph
2. Minor; less than five mph
3. None

ITEM 72.14 – POSTED SPEED LIMIT FOR THE ROADWAY CARRIED ON THE BRIDGE

Enter the posted speed limit for the roadway carried on the bridge.

ITEM 72.15 – POSTED SPEED LIMIT FOR THE ROADWAY UNDER THE BRIDGE

Enter the posted speed limit for the roadway under the bridge. If there is more than one roadway under the bridge, input the highest speed limit and list the other speed limits in the notes.

ITEM 72.16 – EMBANKMENT

Enter the overall condition of the embankment along the roadway, not along the channel.

ITEM 72X – OVERALL CONDITION RATING

Enter the overall condition rating for the approach, including pavement condition,
alignment, and drainage. This can be different than Item 72.

ITEM 72X – RATING BASIS

Describe what item(s) governed the Item 72X rating.

ITEM 63XF – ESTIMATED REMAINING LIFE OF APPROACH FEATURES

Estimate the life in years of the approach features, assuming no work will be done. Enter this data in the Central Database.
For any structure crossing a waterway, scour, flooding, and drift or debris buildup can affect the stability of a bridge. Scour at substructure foundations can cause instability and bridge failures. Flooding can cause failures due to scour of the substructure, erosion of the embankment, or lateral water flow pressures on the bridge. Drift and debris aggradations can impart loads on substructure units for which they were not designed, as well as create conditions causing scour and flooding.

This chapter discusses the interaction between scour, the channel condition, waterway adequacy, and the bridge foundation. It also describes how to inspect the channel and channel protection, assess the waterway adequacy, inspect a bridge for scour, and prepare a scour Plan of Action.

Figure 4:7-1: Erosion Behind a Wingwall
SECTION 7.2 CHANNEL AND CHANNEL PROTECTION

Subsection 7.2.1 Introduction

Channel and Channel Protection Inspections are required to identify conditions which could damage the bridge. Bridge damage related to the condition of the channel is usually from the undermining of the substructure units and/or exposure and deterioration of the substructure units. It is imperative to record and monitor the channel and channel protection conditions for any changes caused by natural or man-made circumstances. This can help establish the scour potential of a particular bridge site and allow inspectors to monitor the bridge and channel for change.

Subsection 7.2.2 Channel Protection

Scour is the removal of material from the streambed or embankment as a result of the erosive action of stream flow. Scour and inspecting for scour are discussed further in Section 7.4 of this chapter.

To guard against the effects of scour, the channel banks must be protected and the stream must be controlled. Channel protection and hydraulic control structures include both natural and man-made features. Natural channel protection includes banks with well-established vegetation and streambeds consisting of bedrock or boulders. Man-made control structures and channel protection include the following:

Riprap – large stones or boulders placed along the bank or substructure units that rely on their mass for stability against the flow of water. Riprap may be natural or man-made. It is usually placed on a geotextile fabric to prevent erosion of the soil underneath. Designed scour countermeasures must be in accordance with the INDOT Design Manual. See Figure 4:7-2 for an example of riprap protection.

Channel lining – a layer of concrete across all or part of the channel. It provides a hard, nonerodible surface, and also increases the flow rate of the stream to drain the upstream region more quickly. See Figure 4:7-3 for an example of protection with concrete channel lining.

Erosion control mats – interconnected concrete bags or blocks placed in the channel bottom or embankments as an armor layer. Geotextile fabric can be placed under the mats.

Gabions – wire mesh baskets filled with stone. The baskets are normally tied to each other and anchored to the bank. They are used in a similar manner to riprap, but may be placed on steeper slopes.

Slope stabilization – treatment of the existing bank with plantings, geotextile, or wire mesh to prevent erosion. See Figure 4:7-4 for an example of slope protection utilizing well-established vegetation.

Guide banks/wing dams – devices that direct/control natural stream flows to protect against abutment scour.
Spur dikes – devices constructed to redirect flows smoothly through the bridge waterway opening. They are used to protect the highway embankments by forcing scour to occur at the ends of the dikes.

Figure 4:7-2: Riprap Channel Protection in Good Condition

Figure 4:7-3: Concrete Channel Lining Protection
Subsection 7.2.3 Inspection

The channel condition rating covers the areas immediately upstream, downstream, and directly under the bridge. The type of waterway has a significant influence on the condition of a channel. Fast-flowing water can cause channel changes and increase the likelihood of scour and erosion problems. Slow-flowing water can create channel obstructions and location changes due to debris and ice buildup. Lake channels are subject to aggradations and location changes. Levees are earthen flood control structures along a river and their inspection is not a part of this manual.

Channel inspection should include the following:

1) Look for stable banks upstream and downstream of the bridge. Stable banks will be gradually sloped and well-vegetated.

2) Probe around the substructure unit bases with a rod to check for areas of local scour.

3) Check for evidence of structure settlement due to scour, such as substructure rotation, differential settlement, and lateral movement or misalignment of the superstructure or railing. A plumb bob or sighting along the bridge railing can often help in making this determination.

4) Check the condition of channel protection devices. Riprap should be firmly in place on the banks and not scattered throughout the channel. Erosion control mats and channel linings should not be undermined. Guide banks and spur dikes should be stable.

5) Look for evidence of bank instability, such as sloughing due to scour and lateral steam movements.

6) Look for debris or sediment buildup that could redirect the stream flow.
7) Look for debris caught on the upstream end of piers or between pier columns. This can create localized increased water velocities and lead to scour.

8) Look for signs of streambed degradation, such as exposed bridge substructure elements or exposed utility crossings that were previously buried.

9) Note any signs of lateral stream movement. The waterway should normally be centered under the structure and flow should be parallel to the substructure units. Sketches or photographs should be taken during each inspection to monitor the alignment.

10) Check for obstructions to stream flow such as cattle guards and fences. These can trap debris, possibly causing sediment buildup and redirection of the stream flow.

11) Check for evidence of stream flow within the floodplain, such as bent plant material or waterborne debris.

12) Note obstructions within the floodplain, such as trees or buildings. These affect the main channel stream flow during floods.

13) Check if stream flow is impinging behind protective devices. For example, stream flow should not be pooling on the upstream side of a wing wall.

14) Look for evidence of overtopping by floodwaters. This may include damaged girder bottom flanges or truss bottom chords, drift or debris lodged between girders, cross-frames, bearing areas, scrape or water marks on surrounding trees, or bearings exhibiting transverse displacements.

Figure 4:7-5: Stable Upstream Channel

Subsection 7.2.4  NBI Rating for Channel and Channel Protection

The channel and channel protection condition rating, NBI Item 61, is concerned with
water flow, channel protection, channel damage due to flow, and waterway stability. Damage to any part of the bridge should be reflected in the corresponding NBI condition rating for the component that is damaged.

Rating the channel and channel protection is done according to the Federal Highway Administration (FHWA) General Condition Rating Guidelines. The numeric condition ratings describe existing channel and channel protection devices compared to their as-built condition. Ratings range from 9 to 0, with 9 describing components in new or excellent condition, and 0 describing failed devices.

A proper rating will consider the severity of the deterioration and the extent to which the deterioration affects the channel condition and performance. Because only a single number is used to rate the channel and its protection, the rating must characterize its overall condition. The rating should not be used to describe local areas of deterioration. Local areas of deterioration should be described in notes provided with the inspection. However, widespread riprap washouts or large quantities of trash/debris located within the channel, for example, would influence the rating.

The channel and channel protection general condition ratings are as follows:

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE – use only when bridge is not over a waterway</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION – no noticeable or noteworthy deficiencies which affect the condition of the channel</td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – banks are protected or well-vegetated; river control devices, such as spur dikes and embankment protection, are not required or are in a stable state</td>
</tr>
<tr>
<td>7</td>
<td>GOOD CONDITION – bank protection is in need of minor repair; river control devices and embankment protection show minor damage; banks and/or channel have minor amounts of drift</td>
</tr>
<tr>
<td>6</td>
<td>SATISFACTORY CONDITION – bank is beginning to slump; river control devices and embankment protection have widespread minor damage; minor streambed movement evident; debris is restricting the channel slightly</td>
</tr>
<tr>
<td>5</td>
<td>FAIR CONDITION – bank protection is being eroded; river control devices and/or embankment have major damage; trees and brush restrict the channel; signs of lateral movement may be present</td>
</tr>
<tr>
<td>4</td>
<td>POOR CONDITION – bank and embankment protection is severely undermined; river control devices have severe damage; large deposits of debris are in the channel; significant channel migration may be present</td>
</tr>
<tr>
<td>3</td>
<td>SERIOUS CONDITION – bank protection has failed; river control devices have been destroyed; streambed aggradation, degradation, or lateral movement has changed the channel to now threaten the bridge and/or</td>
</tr>
</tbody>
</table>
approach roadway; debris/drift piles block more than half the channel and/or flood plain

2 CRITICAL CONDITION – channel has changed to the extent the bridge is near a state of collapse; debris/drift piles completely block the channel and/or flood plain

1 IMMINENT FAILURE CONDITION – bridge closed because of channel failure; corrective action may put it back in light service

0 FAILED CONDITION – bridge closed because of channel failure; replacement necessary

One suggested method for establishing the channel and channel protection rating is to identify phrases within the general condition guideline language that describes a condition more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose the channel has extensive sloughing upstream, plus small amounts of debris within the channel. The sloughing has caused the stream to begin pooling behind one of the wing walls, but there is no evidence of scour/undermining. Condition rating 5 indicates that bank protection is being eroded, and that the embankment has major damage. Trees and brush also restrict the channel. Condition rating 4 indicates that bank and bank protection is severely undermined. River control devices have severe damage, and large deposits of debris are in the channel. Using the method described above, Condition rating 4 describes a situation more severe that what actually exists within the channel. Therefore, a rating of 5 would be appropriate.

Figure 4:7-6: Slumping Channel
Figure 4:7-7: Undermined Abutment

Figure 4:7-8: Aggradation in Front of Abutment and Debris Buildup in Front of Pier
Subsection 7.2.5 Additional Channel and Channel Protection Items

State-owned bridges must be rated for the following channel and channel protection items in addition to the items required by the NBIS. Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 61, the NBI channel and channel protection condition rating. Each item shall be rated as follows unless noted:

N     Not Applicable
9     Excellent Condition
8     Very Good Condition
7     Good Condition
6     Satisfactory Condition
5     Fair Condition
4     Poor Condition
3     Serious Condition
2     Critical Condition
1     Imminent Failure Condition
0     Failed Condition
ITEM 61.01 – SCOUR/EROSION UPSTREAM

Enter the overall condition rating for the scour and erosion upstream of the bridge. Note the location, possible causes, and observations. Show the scoured and eroded areas on any drawings made for NBI Item 113.

ITEM 61.02 – SCOUR/EROSION DOWNSTREAM

Enter the overall condition rating for the scour and erosion downstream of the bridge. Note the location, any observations, and possible causes. Show the scoured and eroded areas on any drawings made for NBI Item 113.

ITEM 61.03 – DRIFT

Enter the overall rating for drift. Drift is the accumulation of branches and logs. Identify where drift is located and any plans to remove it. Note if this is a frequent problem and if drift has been removed in the past. Keep track of when drift has been removed and any work order or contract numbers, if available. Show the location of the drift on any drawings made for NBI Item 113.

ITEM 61.04 – VEGETATION

Enter the overall condition rating for the vegetation. Recommend clearing, if necessary. Recommend that trees be cut back from truss bridges to keep leaves out of the lower chords. Trees should be cleared from around and under the bridge to prevent them from applying forces to the bridge. Trimmed vegetation under and around bridges will keep the channel, superstructure, and substructure functioning as designed. Trees must be trimmed, as needed, to allow access for the underbridge inspection machines.
ITEM 61.05 – CHANNEL CHANGE

Rate any changes in the depth of the channel, the angle of attack of the flow, or movement of the entire channel as follows:

- **N** NOT APPLICABLE – use only when bridge is not over a waterway
- **8** VERY GOOD CONDITION – no change in the depth of the channel, the angle of attack of the flow, or the location of the channel
- **6** GOOD CONDITION – less than 20 percent change in the depth of the channel; angle of attack is less than 10 degrees; minor change in the location of the channel
- **4** POOR CONDITION – less than 50 percent change in the depth of the channel; angle of attack is less than 20 degrees; significant change in the location of the channel
- **2** SERIOUS CONDITION – more than 50 percent change in the depth of the channel; angle of attack has increased to more than 20 degrees; location of the channel has moved to a point threatening a substructure unit
- **1** IMMINENT FAILURE CONDITION – bridge is closed because of changes in the channel; corrective action may put it back in light service
- **0** FAILED CONDITION – bridge is closed; replacement necessary

ITEM 61.06 – ADEQUACY OF OPENING

Rate the general condition of the waterway opening. This should match the rating given for NBI Item 71.
ITEM 61.07 – MISCELLANEOUS HYDRAULIC FEATURES

Identify the type and location of any miscellaneous hydraulic features, such as dams, weirs, or spur dikes. Enter the overall condition rating for any miscellaneous hydraulic features and how they influence the condition of the channel and channel protection.

Figure 4:7-11: Cattle Guard Trapping Debris

ITEM 61.08 – CHANNEL PROTECTION

Enter the overall condition rating for the channel protection. Note any observed deficiencies in the channel protection.

Figure 4:7-12: Natural Vegetated Channel Protection with Slumping Banks
ITEM 61.09 – TYPE

Enter the type of channel protection in place. Note and photograph any type of channel protection not listed below.

A  Riprap
B  Metal sheet piling
C  Metal retaining walls with metal piles
D  Timber retaining walls with timber piles
E  Concrete retaining walls with concrete piles
F  Sand bags
G  Earth levee*
H  Other
I  Concrete slope wall
J  Vegetation
N  N/A; None

*A levee is an earthen flood control structure along a river. It does not provide channel protection, but is included here to allow the inspection team to note its presence.

Figure 4:7-13: Riprap
Figure 4.7-14: Metal Sheet Piling Used to Deflect Debris

Figure 4.7-15: Sand Bags
Figure 4:7-16: Earth Levee

Figure 4:7-17: Other – Dam
Figure 4:7-18: Concrete Slope Wall

Figure 4:7-19: Vegetation
ITEM 61.10 – CHANNEL ALIGNMENT

Rate the channel alignment for movement and/or location as follows. Note the angle of attack.

N  Not Applicable
9  Excellent Condition – channel has not moved and is appropriately located
6  Satisfactory Condition – minor streambed movement evident
3  Serious Condition – lateral movement has changed the channel to threaten the bridge and/or the approach roadway
2  Critical Condition – channel has moved to the extent that the bridge is near a state of collapse
1  Imminent Failure Condition – bridge is closed because of channel alignment; corrective action may put it back in light service
0  Failed Condition – bridge is closed because of channel alignment; replacement necessary

Figure 4:7-20: Channel Has Migrated
Figure 4:7-21: Bridge Closed Due to Channel Change
SECTION 7.3 WATERWAY ADEQUACY

Subsection 7.3.1 NBI Rating of Waterway Adequacy

Waterway adequacy is an appraisal of the existing bridge hydraulic opening. The hydraulic opening is the opening available for water to pass under the bridge. It is essentially an area bounded by the streambed, abutment faces, and the underside of the bridge superstructure.

The waterway adequacy appraisal considers overtopping frequency, as well as the significance of traffic delays caused by overtopping. Overtopping frequency can be obtained from a review of the historic records of the bridge, or an assessment of the adequacy of the bridge opening relative to the area drained. Figure 4:7-22 explains the coding for the rating of NBI Item 71, waterway adequacy. These ratings are a function of the roadway classification.

Inspectors should note sediment/debris accumulation or vegetation growth that may block or partially block the hydraulic opening. Inspectors should also note newly paved areas or developments that could increase the amount of runoff into the stream and increase high-water elevations.

Figure 4:7-22: Bridge with Flooded Approaches
### Functional Classification

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Bridge not over a waterway</td>
</tr>
<tr>
<td>9</td>
<td>Bridge deck and roadway approaches above flood water elevations (high water); chance of overtopping is remote</td>
</tr>
<tr>
<td>8</td>
<td>Bridge deck above roadway approaches; slight chance of overtopping roadway approaches</td>
</tr>
<tr>
<td>6</td>
<td>Slight chance of overtopping bridge deck and roadway approaches</td>
</tr>
<tr>
<td>4</td>
<td>Bridge deck above roadway approaches; occasional overtopping of roadway approaches with insignificant traffic delays</td>
</tr>
<tr>
<td>3</td>
<td>Bridge deck above roadway approaches; occasional overtopping of roadway approaches with significant traffic delays</td>
</tr>
<tr>
<td>2</td>
<td>Occasional overtopping of the bridge deck and roadway approaches with significant traffic delays</td>
</tr>
<tr>
<td>2</td>
<td>Frequent overtopping of the bridge deck and roadway approaches with significant traffic delays</td>
</tr>
<tr>
<td>2</td>
<td>Occasional or frequent overtopping of the bridge deck and roadway approaches with severe traffic delays</td>
</tr>
<tr>
<td>0</td>
<td>Bridge is closed</td>
</tr>
</tbody>
</table>

Figure 4:7-23: Item 71, Waterway Adequacy Appraisal Ratings

In rating waterway adequacy, the following are used to describe the likelihood of overtopping:

15) Remote – greater than 100 years
16) Slight – 11 to 100 years
17) Occasional – three to 10 years
18) Frequent – less than three years

In rating waterway adequacy, the following are used to describe the traffic delay:

19) Insignificant – minor inconvenience; highway passable in a matter of hours
20) Significant – traffic delays of up to several days
21) Severe – long-term delays to traffic with resulting hardship
Subsection 7.3.2  Additional Waterway Adequacy Items

State-owned bridges must be rated for the following items, in addition to Item 71. Each item shall be rated as described.

ITEM 71.1X – OVERTOPPING POSSIBILITIES

Enter the possibility of overtopping in accordance with the definitions below. Provide comments specific to this item.

1  Remote – greater than 100 years
2  Slight – 11 to 100 years
3  Occasional – three to 10 years
4  Frequent – less than three years

ITEM 71.2X – OVERTOPPING TRAFFIC DELAYS

Enter the overall significance of traffic delays caused by overtopping in accordance with the definitions below. Provide comments specific to this item.

1  Insignificant – minor inconvenience; highway passable in a matter of hours
2  Significant – traffic delays of up to several days
3  Severe – long-term delays to traffic with resulting hardship
SECTION 7.4 SCOUR

Subsection 7.4.1 Introduction

Scour is the general or localized erosion of the streambed or bank material due to flowing water. Scour often occurs around obstructions in waterways, such as piers and abutments, or near debris. A scour critical bridge is a bridge with a foundation element that has been determined to be unstable due to observed scour at the bridge site, or due to the scour potential determined from a scour evaluation. Designed scour countermeasures are actions taken to correct an existing or potential scour problem. They have been evaluated by a hydraulic engineer for a specific bridge and location. Designed scour countermeasures may include the placement of riprap, installation of armoring along an embankment, or other means to reduce the likelihood of scour.

Subsection 7.4.2 Scour Evaluation Study

If a bridge is over water or has elements that could be submerged during a flood, the bridge needs to be evaluated for susceptibility to scour and to determine if countermeasures are required to ensure the stability of the structure. A Scour Evaluation Study is performed by the Division of Production for state-owned bridges, and by the Inspection Consultant for county or local bridges. A Scour Evaluation Study is performed for all new bridges, for bridges rehabilitated using Federal Aid funding, or if a bridge is being evaluated for scour countermeasures. The input from the inspection team is instrumental to the Scour Evaluation Study team in recommending a rating for NBI Item 113. Based on the recommendations in the Scour Evaluation Study and the input from the inspection team, the State Program Manager determines the rating for Item 113 for state bridges, and the Inspection Consultant determines the rating for toll road, county, or local bridges.

A Scour Evaluation Study considers the hydraulic, geotechnical, and structural characteristics of the bridge and the site where it is located. Details for conducting a Scour Evaluation Study are included in the FHWA Technical Advisory – T5140.23, Evaluating Scour at Bridges. The anticipated depth of scour is computed as a part of this study. The following data is considered in this evaluation:

1) Existing and historic site conditions regarding the streambed, scour, and channel stability
2) Soil borings or other data indicating the soil composition at and below the elevation of the streambed
3) Stream discharge, slope, flow velocities, and the location and depth of backwaters
4) The location, type, and skew of substructure units
5) The angle of attack
6) The flood history
7) Existing scour countermeasures
Subsection 7.4.3  Scour Inspection

Scour can fail otherwise sound structures, so it is critical that bridges are inspected for scour during Initial Inspections, Routine Inspections, and as called for in the Plan of Action for any scour critical bridge. Underwater Inspections are required if it is not possible perform this inspection as a part of the Inventory and Routine Inspections. If probing indicates a changed condition, an In-Depth Channel Bottom Survey should be performed. If the inspection team concludes that the calculated scour depth identified in the Scour Evaluation Study is not consistent with the site conditions, they should recommend that the bridge be re-evaluated.

Probing the bridge substructure elements in water will provide information on local scouring or exposure of the foundation. Signs of scour include an exposed top or side of the footing. Unless the footing is embedded in the exposed bedrock, it is rare that the original design would call for the footing to be exposed. Also, excessively loose or unconsolidated sediment in the streambed can suggest an area of scour. When scour is found, the inspector should attempt to angle the probe to allow probing under the foundation. The conditions noted should be recorded and a recommended cycle for re-inspection established, based on the observed conditions, the likelihood of scour occurrence, and the criticality of the bridge for continued service.

Inspectors need to recognize and understand the relationships between the bridge, the stream, and the floodplain. Before beginning the inspection of a bridge for scour, the inspection team should review the existing plans and previous inspection reports. Items to review include:

1) Previous scour evaluations to determine if the bridge is scour critical.
2) Any scour Plan of Action previously developed for the bridge.
3) Previous streambed cross sections.
4) Aerial photographs or sketches that indicate the past position of the streambed.
5) Bridge foundations shown on the plans (if any), including pile tip elevations.
6) Sub-surface soil condition reports.
7) Any special items to be checked during the inspection.
8) All equipment needed to obtain streambed cross sections.
9) Scour Committee reports for state-owned bridges.
   1) The Scour Inspection should including the following:
10) Probe around each substructure unit in water for scour and undermining.
11) Record the location, length, width, and depth of any scour holes.
12) Check for changes in the streambed elevation.
13) Note the type of bed material.
14) Check for changes in the streambed cross section or alignment. Note if the streambed has shifted to a different location. This is especially important for multi-span bridges.
15) Check for the rotational movement or settlement of the substructure units.
16) Check for any damage to any scour countermeasures such as the subsidence of armoring or loss of protection.
17) Note if the bridge is narrower than the width of the stream or reservoir.
18) Note any erosion of the embankment.
19) Note drift or debris on the upstream side of the piers or abutments.
20) Note if the embankments cross the floodplain or restrict water flow during periods of high water.
21) Note aggressive stream characteristics such as high velocity, steep slope, or deep flow.
22) Note the angle of attack.
23) Note the condition of any substructure unit protection or countermeasures.

Figure 4:7-25: Flooded Bridge

Subsection 7.4.4  NBI Rating of Scour

The NBI coding for Item 113 is shown in Figure 4:7-26. A bridge is considered scour critical if the foundations are determined to be unstable due to observed scour at the bridge site, or if the bridge has calculated or assessed scour potential. Item 113 is rated
4 if scour has been observed in the field and the foundation is stable, but action is required to protect exposed foundations. Item 113 is rated 3 if the bridge has assessed or calculated scour potential. Item 113 is rated 2 if the field review shows extensive scour has occurred and the foundation is not stable. Item 113 is rated 1 if the field review shows extensive scour has occurred and failure of piers/abutments is imminent. Item 113 is rated 0 if the bridge has failed. When the scour rating is 2 or less, the foundation rating, Item 60, should be 2 or less.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>The bridge is not over a waterway.</td>
</tr>
<tr>
<td>U</td>
<td>This is a bridge with an unknown foundation that has not been evaluated for scour. Until the risk can be determined, a Plan of Action should be developed and implemented to reduce the risk to users from a bridge failure during and immediately after flood events. See Section 7.7.</td>
</tr>
<tr>
<td>9</td>
<td>The bridge foundations (including piles) on dry land are well above flood water elevations.</td>
</tr>
<tr>
<td>8</td>
<td>The bridge foundations are determined to be stable for the assessed or calculated scour condition. Scour is determined to be above the top of footing (see example A in Figure 4:7-27) by assessment (i.e., bridge foundations are on rock formations that have been determined to resist scour within the service life of the bridge), by calculation, or by installation of properly designed countermeasures.</td>
</tr>
<tr>
<td>7</td>
<td>Designed countermeasures have been installed to mitigate an existing problem with scour and to reduce the risk of bridge failure during a flood event. Instructions contained in a Plan of Action and have been implemented to reduce risk to users from a bridge failure during or immediately after a flood event.</td>
</tr>
<tr>
<td>6</td>
<td>Scour calculation/evaluation has not been made. (Use this only where a bridge has not received an initial inspection.)</td>
</tr>
<tr>
<td>5</td>
<td>The bridge foundations are determined to be stable for assessed or calculated scour condition. Scour is determined to be within the limits of footing or piles (see Example B in Figure 4:7-27) by assessment (i.e., bridge foundations are on rock formations that have been determined to resist scour within the service life of the bridge), by calculation, or by installation of properly designed countermeasures.</td>
</tr>
<tr>
<td>4</td>
<td>The bridge foundations are determined to be stable for assessed or calculated scour conditions. The field review indicates action is required to protect exposed foundations.</td>
</tr>
</tbody>
</table>
| 3    | The bridge is scour critical and the bridge foundations are determined to be unstable for assessed or calculated scour conditions:  
  • Scour within limits of footing or piles (see Example B in Figure 4:7-27)  
  • Scour below spread-footing base or pile tips (see Example C in Figure 4:7-27) |
| 2    | The bridge is scour critical. The field review indicates that extensive scour has occurred at the bridge foundations. The foundations are determined to be unstable by:  
  • A comparison of calculated scour and observed scour during the bridge inspection, or  
  • An engineering evaluation of the observed scour condition reported by the bridge inspector in Item 60. |
| 1    | The bridge is scour critical. The field review indicates that failure of the piers/abutments is imminent. The bridge is closed to traffic. Failure is imminent based on:  
  • A comparison of calculated scour and observed scour during the bridge inspection, or  
  • An engineering evaluation of the observed scour condition reported by the bridge inspector in Item 60. |
| 0    | The bridge is scour critical. The bridge has failed and is closed to traffic. |

Figure 4:7-26: NBI Scour Ratings
Examples of calculated scour depth and the actions needed for different cases are shown in Figure 4:7-27.

### Figure 4:7-27: Actions Needed After Calculating Scour Depth

<table>
<thead>
<tr>
<th>EXAMPLES:</th>
<th>CALCULATED SCOUR DEPTH</th>
<th>ACTION NEEDED</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Above top of footing</td>
<td><img src="image" alt="Diagram" /></td>
<td>None - indicate rating of 8 for this item</td>
</tr>
<tr>
<td>B. Within limits of footing or piles</td>
<td><img src="image" alt="Diagram" /></td>
<td>Conduct foundation structural analysis</td>
</tr>
<tr>
<td>C. Below pile tips or spread-footing base</td>
<td><img src="image" alt="Diagram" /></td>
<td>Provide for monitoring and scour countermeasures as necessary</td>
</tr>
</tbody>
</table>

- Spread Footing (not founded in rock)
- Pile Footing

**Spread Footing (Not Founded in Rock)**

**Pile Footing**


### Subsection 7.4.5 Scour Plan of Action

For every bridge identified as scour critical (a rating of 3 or less for Item 113), a Plan of
Action must be developed. It must include:

1) General Information about the bridge, including the following:
   a) County name
   b) County number
   c) INDOT district number
   d) Bridge number
   e) NBI number
   f) Facility carried
   g) Feature intersected
   h) Year constructed
   i) Whether the bridge serves a designated emergency route
   j) Average daily traffic
   k) Year of average daily traffic
   l) Daily truck percent
   m) Date of the most recent cross section
   n) A copy of the most recent channel cross section with comments as needed
   o) Soil information

2) Information about the Plan of Action, including the following:
   a) Date the Plan of Action was approved
   b) Date the Plan of Action was updated
   c) Recommended update frequency for the Plan of Action
   d) Author of the Plan of Action
   e) Person responsible for maintaining the Plan of Action
   f) Any concurrences on the Plan of Action

3) A summary of the scour status of the bridge, including the following:
   a) Official scour rating for the bridge (Item 113A) with notes as needed
   b) Proposed scour rating for the bridge (Item 113B) with notes as needed
   c) Substructure rating for the bridge (Item 60) with notes as needed
   d) Substructure rating for each individual substructure unit in the water
   e) Channel condition rating (Item 61) with notes as needed on the channel condition and material
   f) Condition of the culvert, if applicable (Item 62), with notes as needed
g) Waterway adequacy rating (item 71) with notes as needed
h) Comments on the scour history of the bridge
i) Comments on the flood history

4) Information on the monitoring plan, including the following:
   a) Reason for any monitoring program
   b) What needs to be monitored
   c) Triggers that initiate monitoring such as flood stage, inches of rain in a designated time period, etc.
   d) Person or agency that will monitor the bridge
   e) Any monitoring preparations such as Q100 flow lines marked on a pier
   f) Specific signs that would indicate a problem, such as sagging superstructure
   g) Monitoring termination criteria
   h) Comments on the monitoring method
   i) Any monitoring history
   j) Bridge owner contact information

5) Information on any countermeasures, including the following:
   a) Existence of any countermeasures
   b) Rating of any countermeasures
   c) Observations about the countermeasures
   d) Recommendation on what countermeasures are needed

6) Emergency traffic information, including the following:
   a) Closure plan
   b) Detour route
   c) A note that only an approved Inspection Team Leader can reopen the bridge

7) Recommendations, including the following:
   a) Recommendations for Routine Inspections
   b) Recommendations for Underwater Inspections
   c) Countermeasure recommendations

Attachments to the Plan of Action may include boring logs, bridge elevation drawings, a plan showing the locations of scour holes, drift, or debris. It may also include supporting documentation, calculations, and photos.

Major river bridges or other unique bridges may require more extensive Plan of Action documentation. The Plan of Action must be maintained in the Central Database. A copy
must also be available for use during field inspections.

Subsection 7.4.6 Scour Plan of Action for Bridges with Unknown Foundations

If a bridge with an unknown foundation has been coded as scour critical in accordance with the field observations or the assessment process described in Section 7.5, a Plan of Action needs to be developed as described in Subsection 7.4.5 above.

If a bridge with an unknown foundation remains coded U for Item 113, a Plan of Action must be developed based on a risk assessment that considers safety to the traveling public and the consequences of the loss of service of the structure. This Plan of Action may be less detailed than a Plan of Action for a scour critical bridge, but it must protect the users during and after a flood event and provide a proactive plan for addressing the bridge scour concerns in the future.

For a bridge considered at low risk, as discussed in Section 7.5, the Plan of Action will generally require monitoring bridges for scour during routine inspections and after triggering events. If scour or a rainfall event has been observed in excess of predetermined events or limits, the bridge may need to be considered for an in-depth foundation investigation.

For a bridge considered at moderate risk, as discussed in Section 7.5, the Plan of Action will be developed in accordance with an engineering evaluation of the risk and the level of certainty of the information available for that bridge. If scour or a rainfall event has been observed in excess of predetermined events or limits, the bridge should be considered for an in-depth foundation investigation.

For a bridge considered at high risk, as discussed in Section 7.5, a Plan of Action similar to that developed for a scour critical bridge must be developed. This Plan of Action will require more frequent monitoring than bridges considered low or moderate risk. If any significant changes in the streambed occur, the inspection team should recommend an in-depth foundation investigation, installation of designed countermeasures, or the timely design and installation of a new bridge.
Figure 4:7-28: Flood Event
SECTION 7.5 UNKNOWN FOUNDATIONS

Subsection 7.5.1 Confirm Coding

Identifying scour critical bridges allows for the efficient allocation of monitoring time and money to install countermeasures or replace bridges. The scour evaluation team needs to check all available information for any bridge coded U or 6 to ensure that the foundation is actually unknown. A code designation of 6 is only used after a new bridge has been identified and before the initial inspection is performed.

If the foundation has been completely and confidently identified, a Scour Evaluation Study should be made in accordance with Hydraulic Engineering Center (HEC) 18. The completion of this evaluation can be made in order of the priority, determined by the importance of the road, as follows:

1) Principal Arterial – Interstate
2) Principal Arterial – Other Freeways or Expressways
3) Other Principal Arterial
4) Minor Arterial
5) Major Collector
6) Local Road

Subsection 7.5.2 Classifying Scour Risk for Bridges with Unknown Foundations

If the type, location, and depth of the foundation cannot be completely and confidently identified, the scour evaluation team should classify the bridge based on risk of failure and impact to users as high-, moderate-, or low-risk.

Factors that should be considered in this classification include the following:

1) Functional classification of the inventory route (Item 26)
2) Designated level of service (Item 5C)
3) Detour length (Item 19)
4) Year built (Item 27)
5) Average daily traffic (Item 29)
6) Average daily truck traffic (Item 109)
7) Navigational clearances (Item 39 and 40)
8) Condition ratings (Items 58, 59, 60, 61, and 62)
9) Waterway adequacy (Item 71)
10) Strategic Highway Network (STRAHNET) highway designation (Item 100)
11) Designated national network (Item 110)
12) Aggravating stream characteristics such as high velocity, steep slope, or deep flow
13) Evidence of an actively degrading channel
14) Evidence of embankment movement or settlement
15) Type of bed material
16) The angle of attack/alignment of channel
17) Significant overbank or floodplain flow (floodplain greater than 150 feet wide)
18) Possibility of bridge overtopping
19) Evidence of scour and/or degradation
20) Evidence of structural damage due to scour, such as substructure movement or settlement
21) Condition of any abutment and/or pier protection
22) Condition and functioning of any existing countermeasures
23) Any history of excessive drift or debris
24) The size of the drainage area

In Indiana, a bridge with an unknown foundation can be considered low-risk without further study only if it meets all of the following criteria:
1) The average daily traffic (ADT) is less than 4000.
2) The bridge is not on a marked state highway.
3) The inventory route is not a STRAHNET route.
4) The bridge has no history of scour-related problems following a 100-year flood event.
5) The bridge has no history of significant debris buildup.
6) The substructure, Item 60, is rated 5 or higher.
7) The channel and channel protection, Item 61, is rated 7 or higher.
8) The waterway adequacy, Item 71, is rated 6 or higher.
9) The angle of attack is less than 20 degrees.

In Indiana, a bridge with an unknown foundation is considered high-risk if so designated by the District Bridge Engineer or the Inspection Consultant in consultation with the Inspection Team Leader, or if it meets any one of the following criteria:
1) The ADT is greater than 25,000.
2) The substructure, Item 60, is rated 3 or less.
3) The channel and channel protection rating for Item 61 is 4 or less.
4) The waterway adequacy rating for Item 71 is 4 or less.
5) The inventory route is a STRAHNET route.

6) The angle of attack is greater than 40 degrees.

7) Scour greater than 4-feet deep has been documented at the bridge site.

Bridges with unknown foundations not meeting the criteria for low-risk, and not classified as high-risk, will be classified as moderate-risk.

**Subsection 7.5.3 Unknown Foundations Classified As High-Risk**

If a bridge with an unknown foundation is considered high-risk, the scour evaluation team should positively identify the type, location, and depth of the foundation with appropriate methods of discovery such as nondestructive testing (NDT) or invasive techniques such as test pits. The scour evaluation study should then be completed and Item 113 re-coded. A Plan of Action for the bridge must be prepared and implemented until the scour evaluation study is completed.

**Subsection 7.5.4 Unknown Foundations Classified As Moderate-Risk**

If the available information, including inspection reports, scour evaluation reports, and plans, do not allow the scour evaluation team to confidently identify the foundation characteristics, the scour evaluation team should assume foundation characteristics using inference methods. Inferences and assumptions must be justified within an acceptable degree of engineering confidence. To support these assumptions, the study should include the following:

1) Research common practices for the time period and type of bridge, including:

2) Review any historical technical inventory of project plans.

3) Review any standard sheets.

4) Review any construction specifications.

5) Review any design guidance.

6) Review information available for nearby bridges of similar type and age with known foundations.

7) Review any geologic data available from the site or from nearby bridge sites.

If the scour evaluation team is confident that the information gathered is reasonable, considering the risk characteristics of the bridge, the team should conduct the scour evaluation using the inferred information and re-code Item 113. An Inspection Team Leader, licensed in the state of Indiana, must certify the re-coding of any bridge previously identified as U to any coding other than scour critical. If the information gathered in not sufficient, positive discovery methods should be used to identify the bridge foundation, or a Plan of Action should be developed and implemented for the U-coded bridge.
Subsection 7.5.5  Unknown Foundations Categorized As Low-Risk

If the available information, including inspection reports, scour evaluation reports, and plans, do not allow the scour evaluation team to confidently identify the foundation, they should assume foundation characteristics using inference methods as described above. If the information inferred is adequate to assess scour vulnerability, a scour evaluation should be completed and Item 113 re-coded. An Inspection Team Leader, licensed in the state of Indiana, must certify the re-coding of any bridge previously identified as U to any coding other than scour critical. If the information gathered is not adequate, a Plan of Action should be developed and implemented for the U-coded bridge.
CHAPTER 8  BATS AND SWALLOWS

SECTION 8.1  INTRODUCTION

Some species of bats are listed as endangered under federal or state law, and cliff swallows are protected under the Migratory Bird Treaty Act. Inspectors must perform a preliminary screening for bats and cliff swallows as a part of each inspection for state-owned bridges.

Figure 4:8-1: Cliff Swallow Nests

Figure 4:8-2: Cliff Swallow Colony
SECTION 8.2  HABITAT IDENTIFICATION

Cliff and barn swallows often nest under highway bridges on concrete walls or beams, typically near large waterways or reservoirs. Cliff swallow nests have a distinctive rounded top, as shown above in Figures 4:8-1 and 4:8-2. Cliff swallows are a colony nesting bird and there may be several to hundreds under one bridge.

Barn swallows do not nest in colonies. Their nests are generally found alone and the shape is indistinct, as shown in Figure 4:8-3. Barn swallows are not tracked by the Indiana State Department of Natural Resources, but are discussed here to highlight the differences between cliff swallows and barn swallows.

Bats are more likely to be found on concrete or wood bridges than on steel bridges, and are generally located near a large river or wide floodplain. The preliminary screening for bats should include the following:

1) Take care not to touch any bats or expose yourself to danger. If bitten, call the Department of Health at 317-233-1325 and record the incident immediately. Few bats have rabies; however, it is a deadly virus. If bitten by a bat, you will need rabies post-exposure shots.

2) Look for bats flying or roosting (hanging) and note the approximate number of bats.

3) Note any dead or injured bats.

4) Listen for high-pitched squeaking or chirping and identify the location of such sounds, preferably with a sketch, for later examination by bat biologists.

5) Note bat droppings and their location. Bat droppings are small and mouse-like, but less regular, and are usually brown or black in color. Older droppings may be gray. Check under likely roosting spots such as cracks, cave-like areas, and expansion joints.

6) Note any pungent urine smell.

7) Look for four- to six-inch wide horizontal, dark stains located on supports beams and walls below the bridge deck. The stains often appear wet.

8) Closely check cracks, which are often used as a foothold in roosting.

9) Closely check expansion joints and areas providing cave-like conditions.
Figure 4:8-3: Single Barn Swallow Nest

Figure 4:8-4: Bat Droppings
Figure 4:8-5: Bats Roosting Along Crack and Associated Staining

Figure 4:8-6: Bat Guano on Riprap
Figure 4:8-7: Bat
SECTION 8.3  CODING

The presence of cliff swallow nests and the approximate number of nests found on a bridge must be noted in the Central Database. Add photos to the bridge file.

Inspectors must note the presence of bats or possible nesting sites in the Central Database. Estimate of the number of bats if possible. Add photos to the bridge file.
SECTION 9.1 INTRODUCTION

In Indiana, an underfill structure is defined as a structure where vehicles do not drive directly on a structural deck set on superstructure elements. Closed-spandrel arch bridges are considered underfill structures only if the level of soil or fill is higher than the level of the copings or headwall/spandrel walls. Many states call these structures culverts or tunnels. When underfill structures span more than 20 feet, they are classified as bridges and documented as culverts. Underfill structures spanning 20 feet or less are considered small structures.

Underfill structures do not have a roadway deck or bridge joints at the end of the bridge. They are usually covered by roadway fill material, typically called overburden, or embankment. The roadway rests on the fill material. Often this fill extends laterally a significant distance from the edge of the pavement. This area can support vegetation.

Underfill structures are designed to carry the soil dead load above the structure, as well as the live loads due to traffic above. Above certain fill heights, live loads will arch over the structure and only the soil dead loads will be carried by the structure. An underfill structure’s strength is achieved through its own material properties and confining lateral pressures from the surrounding soil.

Figure 4:9-2 shows some examples of typical underfill structures. If you are unsure if a structure should be designated as an underfill structure, contact the State Program Manager for clarification.
Figure 4.9-47: Typical Underfill Structures
SECTION 9.2 TYPES OF UNDERFILL STRUCTURES

Underfill structures are constructed from a wide variety of materials, including concrete, steel, and aluminum. They may be constructed of stone, masonry, timber, or plastic. This section discusses the typical shapes of these structures, the structural categories, and the end treatments that the inspector may encounter.

Subsection 9.2.1 Underfill Structure Shapes

The underfill structure shape chosen for a location may or may not be dependent upon hydraulic performance requirements. Other factors that may affect the shape chosen are structural requirements, potential for clogging by debris, vertical clearance, and the need for a natural stream bottom. Typical underfill structure shapes include the following:

Circular: This is the most common underfill structure shape. Although hydraulically and structurally efficient, it can reduce the width of a stream and is more prone to clogging than other shapes. Soil pressures around circular-shaped underfill structures are directed towards the middle of the shape and are fairly uniform all around.

Pipe Arch: This shape is used when the distance from the stream bottom to roadway is limited. It is arched on top and flattened on the bottom. The flattened bottom allows a wider stream to flow through. As with circular underfill structures, pipe arch structures are prone to clogging. Since they closely approximate a true arch, soil pressures on the underside are fairly low, with high reaction pressures occurring at the bottom corners. They are not as structurally efficient as a circular shape.

Elliptical: Elliptical shapes have the same advantages and disadvantages as pipe arch underfill structures. They may be oriented horizontally or vertically.

Arch: Arches are open shapes used when limited obstruction to stream flow is required, and where the natural stream bottom is generally resistant to scour. They offer less obstruction to stream flow than pipe arches. The spring lines of arches bear on footing foundations, and riprap is commonly used to protect them from erosion if the stream bottom is not resistant to scour. Soil pressures on the sides of an arch structure try to push the sides towards the center of the stream, resulting in the top of the arch being pushed up. Soil dead loads above the top of the arch help restrain this “peaking” tendency.

Tied Arch: These are similar to arch underfill structures, but they have a floor covering the natural streambed and a tie device embedded in the floor to keep the walls together.
Box: These are square or rectangular-shaped structures. They are commonly chosen because they are adaptable for many site conditions and they can be used when the distance from the stream bottom to roadway is limited. Box underfill structures always have a floor (natural streambed is covered). They are not as structurally efficient as other shapes.

Frame: These are similar to box underfill structures, but frames do not have a floor, so the natural streambed is exposed. The walls of these frames bear on footing foundations.

Multiple Barrel: Multiple barrel or cell underfill structures are simply a series of pipes, arches, or boxes placed side by side. Their use is common when the distance from the stream bottom to the roadway is limited. Their major disadvantage is that waterway debris is easily snagged by the cell walls or soil between the openings. Refer to Figures 4:9-3 through 4:9-5 for views of multiple barrel underfill structures.

Tunnels: A tunnel is a type of underfill structure that carries vehicle, pedestrian, or rail traffic. See Figure 4:9-6.
Figure 4:9-49: Two-Barrel Corrugated Steel Underfill Structure

Figure 4:9-50: Five-Barrel Corrugated Steel Underfill Structure
Subsection 9.2.2 Structural Categories

Underfill structures can be structurally flexible or rigid. It is important for an inspector to understand the structural behavior of an underfill structure so that a proper assessment can be made as to the cause of any damage found. Structural behavior is dependent upon the material from which an underfill structure is built.

(a) FLEXIBLE UNDERFILL STRUCTURES

Underfill structures constructed of corrugated metal are flexible, and can be easily deformed under load if not properly installed. Because the thinness of the corrugated metal plates leaves these structures with little bending strength of their own, they must rely on the surrounding soil/backfill material for support and shape retention.

A metal pipe with no lateral soil support will “squash” or flatten under vertical loads. The top of the pipe will deflect downward, and the sides of the pipe will bulge outward. Properly compacted soil surrounding the pipe will restrain the sides from bulging. This keeps the pipe ring in compression, and allows the structure to support vertical loads with acceptable deflections by way of arching action.
(b) RIGID UNDERFILL STRUCTURES

Cast-in-place concrete, precast concrete, and masonry underfill structures are considered to be rigid. The construction material is stiff enough to resist bending and to support vertical loads independent of the surrounding soil. As such, tension and compression stresses due to bending are created in the structure. When viewed from the inside, a rigid underfill structure will experience tensile stresses on the top and bottom surfaces, while compressive stresses will be generated on the sides. These stresses will be opposite on the soil side. Rigid underfill structures do not appreciably deflect before they crack or fracture.

Subsection 9.2.3 End Treatments

Structures at the ends of underfill structure openings are called end treatments. End treatments are used to control erosion, support backfill, improve hydraulic efficiency, and provide additional stability to the underfill structure ends. The most common types of end treatments include the following:

Projection: A simple barrel extension beyond the embankment. No additional support is used.

Pipe End Section: Similar to a projection, a pipe end section is simply a length of underfill structure pipe added to the end of the underfill structure barrel. End sections often have a small, monolithic apron.

Mitered End: The end of the underfill structure is cut to match the slope of the embankment. The cut starts at the top of the underfill structure and slopes down towards the bottom.

Skewed End: On underfill structures skewed to the roadway, their ends may be cut parallel to the roadway.

Headwalls/Wingwalls: Headwalls are vertical walls surrounding the end of the underfill structure. They are used in conjunction with wingwalls to retain fill, prevent erosion, and improve the hydraulic capacity of the underfill structure.

Aprons: These devices are used in the streambed to reduce or prevent scour and erosion at the inlets and outlets of underfill structures. These usually have a buried end which extends down into the channel bottom approximately 18 inches to prevent undercutting. They are typically constructed with concrete or riprap.
Figure 4:9-52: Mitered End Treatment

Figure 4:9-53: Headwall and Wingwalls
Prior to inspecting an underfill structure, the inspector should review all available information about the structure. Inspectors should check to see if a soil analysis was conducted prior to building an underfill structure. Structures built over compactable soils can settle under the roadway, leaving a sag along the barrel length of the structure. An initial review will help establish equipment needs, inspection procedures, and flag areas of existing distress. Most inspections will require rubber boots or hip waders and a flashlight. A range pole/probing rod should be used to check for scour or deterioration below the water level.

Many underfill structures are large enough that the entire length can be inspected from the inside. Smaller underfill structures that cannot safely or practically be entered should be examined by looking through the opening from both ends. Locations along sectional underfill structures may be conveniently referred to by using structure joints as station numbers from one end of the pipe. Defect positions along the circumference of the barrel should be referenced like hours on a clock.

The structural inspection of any underfill structure will include an inspection of the structure itself, the roadway over the structure, plus the wingwalls, curbs, sidewalks, and railings, if these elements exist. An NBI condition rating must be assigned to the underfill structure, as well as the channel, channel protection, and waterway adequacy. A rating must be assigned for the embankment, roadway approach, and approach roadway alignment. An NBI appraisal rating must also be assigned for the railing, approach guardrail, guardrail transitions, and guardrail end treatments if these items exist.

Inspectors should evaluate underfill structures for possible re-lining work if significant defects are found. This repair work is not an appropriate solution for all defects, but could add many years of service to some structures.

Subsection 9.3.1 Underfill Structure Inspection Hazards

There are a number of hazards that must be considered both in preparations for, and during, an underfill structure inspection.

Long underfill structures, or those with blocked ends, may have inadequate oxygen levels, or high concentrations of toxic or explosive gasses. Three people must perform the inspection in these situations in accordance with the confined space policy defined in Part 1, Chapter 4. Gas monitors must be worn and continuous ventilation may be required throughout the inspection to provide a safe working environment. Lifeline ropes clipped to the inspectors must be used so that the monitor can pull a disabled person out of the pipe.

Soft muck and scour holes may be present within the streambed inside of an underfill structure. High water flow rates and slippery bottoms or floors can knock an inspector off of his/her feet. Probing rods, life vests, and hard hats should always be used while wading through these hazardous conditions.

Wading should not be attempted unless the water level allows sufficient head room. If
wading is not possible, Underwater Inspection methods are required to properly perform the inspection. Refer to Part 1, Chapter 3 for Underwater Inspection equipment and personnel requirements.

Quicksand is produced when water flows upward through sand. When the flow is strong enough, sand particles are lifted up out of the streambed and kept suspended by the turbulent nature of the upward rising water. A similar situation may be found at the outlet of an underfill structure conveying large quantities of water. The falling water creates a scour hole and constant turbulence to keep the streambed sand particles suspended. An inspector who steps into the scour hole will actually float higher in the sand/water mixture than in pure water and can generally swim away from the scour hole.

Hazardous chemicals may be present in the stream water itself. A fire or explosion may result from careless behavior, such as smoking, in these conditions.

Debris accumulation and low water flow rates within underfill structures may provide ideal shelter for animals. The inspector should be aware that snakes, rodents, or dead animals may be present.

Tunnels should be inspected when traffic is at a minimum. It may be necessary to close lanes or close the tunnel. Coordination with the tunnel and roadway owners is critical.

**Subsection 9.3.2  Types of Underfill Structure Distress**

There are four general types of distress that any underfill structure can experience. Figures 4:9-9 through 4:9-11 show some typical types of material distress. High earth loads, water velocities, soil corrosiveness, and age can produce the following types of distress:

**Shear or Bending Failures:** High embankments impose high loads on all sides and can cause shear or bending failures. These failures may result in excessive global flattening, sheared-off bolts, or localized dents/bulges in steel underfill structures. Concrete underfill structures will exhibit longitudinal cracking, concrete crushing, or excessive deflections.

**Settlement:** Foundation settlement may be seen as a sag or rise in steel underfill structures. Differential vertical or lateral displacements at construction joints and pipe segment joints, or pipe segment joints that have opened up, suggest settlement of concrete underfill structures. Lateral movement of concrete box sections may also be observed.
Scour, Undermining, and Piping: High-water velocities within long, slender openings can result in scouring and undermining of the underfill structure ends. Scouring or undermining may also occur along the footings when the underfill structure has no bottom. Undermining can lead to a loss of bearing and subsequent structure settlement. Piping is the unintended flow of water around the outside of an underfill structure. It can begin where undermining of the end treatment or barrel allows water to flow. It may also occur at interior joints that have opened up due to soil settlements. Water inside of the underfill structure may flow out through the open joints. When this occurs, water flow can erode the surrounding soil, creating an artificial pipe. Piping can become a serious problem when an underfill structure loses its lateral soil support.

General Deterioration: Factors such as weathering, soil corrosiveness, abrasion, and chemical exposure cause deterioration of any construction material over time.
Figure 4:9-55: Masonry Headwall Separating From the Barrel

Figure 4:9-56: Through Thickness Section Loss at Water Line of Wall Separating Two Cells
Figure 4:9-57: Precast Concrete Underfill Structure
SECTION 9.4 STEEL UNDERFILL STRUCTURES

Steel underfill structures are usually constructed of corrugated, galvanized steel. Some Indiana counties use old steel railroad tank cars for underfill structures. Several types of steel structures are used, including corrugated metal pipes, structural steel plate pipes, corrugated steel boxes, and long-span corrugated steel structures.

Corrugated metal pipe underfill structures are either circular or pipe arch in shape and are factory-made into a complete, closed section. Pipe seams are either riveted, spot-welded, bolted, lock-seamed, or continuously welded. Corrugation patterns may be circumferential or spiral, and diameters up to 12 feet are readily available. These pipes are often protected with a galvanizing or bituminous coating.

Structural plate, steel pipe underfill structures are field assembled and constructed with multiple pre-curved corrugated plates. The field-assembled plate sections are fastened together with bolts to form a continuous pipe. Fastened plate edges oriented along the barrel length are called seams, while plate edges transverse to the barrel are called joints. Circular, pipe arch, elliptical, and arch underpass shapes are commonly found with spans up to 26 feet. They are galvanized for corrosion protection.

Corrugated steel box underfill structures approximate a rectangular shape, though their corners are rounded, sides tilted slightly, and tops slightly curved. They are reinforced in areas of maximum bending, and are available in spans up to about 20 feet.

Long-span corrugated steel structures are similar to structural plate steel pipes, but long-span underfill structures require longitudinal and circumferential stiffening members due to their great lengths.

The primary concern in inspecting steel underfill structures is the maintenance of the structure shape. Barrel misalignment, joint and seam condition, localized damage, and corrosion must also be checked.

Because steel underfill structures depend upon well-compacted soil to help retain their shape, excessive flattening or widening suggests a soil failure. As a minimum, the height and widest opening should be measured at both ends. If size and water flow permit, measurements in the middle of the barrel and at the quarter points should also be recorded. Bolted joints are excellent places to take measurements because they can be easily found for comparison measurements on subsequent inspections. Measurements should always be taken at the inside crest of the corrugations. Critical measurements to be taken during an inspection for the most common barrel shapes are shown below in Figures 4:9-14 through 4:9-16. For shapes not provided, refer to the Bridge Inspector's Reference Manual (BIRM).
Structural inspection of steel underfill structures should include the following items:

1) Measure the height and width of the barrel at the ends, middle, and quarter points. These measurements should be compared to the original dimensions shown on the design drawings and previous inspections, if available. Excessive flattening suggests a soil failure. See Figures 4:9-14, 4:9-15, and 4:9-16 below for the required measurements for round steel pipe structures, structural plate pipe arches, and structural plate arches.

2) Measure the corrugation and thickness of the cross section.

3) Indicate on the report the extent of any flattening found. Include the affected length along the barrel and the location of the distress.

4) Examine the roadway above for any dips, cracking, settlement, or patching that would suggest a failing structure below.

5) Check for horizontal misalignments by sighting down the barrel length.

6) Check for vertical misalignments sighting down the barrel length. Note the presence of localized deep water or sediment accumulation at low spots within the barrel.

7) Look for localized damage in the form of dented, flattened, or bulged areas. Bulged areas on the bottom of a round barrel suggest settlement over a local hard spot. Bulged areas on the bottom of an arch pipe suggest the corners have settled. Small areas of localized damage are usually not critical. Localized damage may jeopardize the barrel’s ability to carry its ring compression loads.

8) Look for corrugation misalignments and “cusped” seams along the fastener lines. Cusped seams are separations in the plate lap caused by loose fasteners. This results in a discontinuity of the barrel curvature that can allow moisture and backfill inside.

9) Examine all seams and joints for plate separation. Measure any separations found. A small rod or flat rule should be used to probe through any separation to check for voids in the backfill.

10) Check for cracking at the bolt holes. These are usually caused by excessive barrel strains due to deflections.

11) Check for loose bolts by tapping lightly with a hammer.

12) Check the entire barrel for the extent and severity of corrosion. The heaviest corrosion will normally appear near the water surface. Sharp blows with a hammer are the accepted method for the inspector to evaluate the general integrity of the steel.

13) Look for signs of abrasion along the barrel. Abrasion can accelerate the corrosion process by scraping away the metal’s protective coating.

14) Examine the inlet and outlet of the barrel for signs of scour or undermining underneath a closed pipe. This could lead to piping.
15) Examine for scour or footing undermining along the length of arch underfill structures. Undermining may allow the concrete footing to rotate, failing the arch.

16) Examine end treatments and wingwalls for damage, deterioration, debris accumulation, streambed scour, undermining, settlement, tipping, and embankment erosion. These deficiencies can cause hydraulic inefficiencies and roadway settlements.

17) Check for excessive joint openings between headwalls, wingwalls, and aprons.

Figure 4:9-58: Tearing at Connection
1. MINIMUM MEASUREMENTS REQUIRED:
   HORIZONTAL DIAMETER = AC

2. IF FLATTENING OBSERVED MEASURE:
   CHORD AND MID ORDINATE OF FLATTENED AREA

3. IF HORIZONTAL DIAMETER EXCEEDS DESIGN BY MORE THAN 10% MEASURE:
   VERTICAL DIAMETER = BD

Figure 4:9-59: Critical Measurements for Round Steel Pipe Underfill Structures
Figure 4:9-60: Critical Measurements for Steel Pipe Arch Underfill Structures

1. MINIMUM REQUIRED MEASUREMENTS - AC, BD
   SPAN = AC
   RISE = BD

2. IF AC EXCEEDS DESIGN BY 3% OR MORE, MEASURE
   BF, ED, AND HORIZONTAL SPAN OF TOP ARC
Figure 4:9-61: Critical Measurements for Steel Plate Arch Underfill Structures

1. MINIMUM REQUIRED MEASUREMENTS:
   SPAN = AD + DC
   RISE = BD

2. MINIMUM REQUIRED ELEVATIONS - B

3. IF BD GREATER THAN DESIGN BY 5% OR MORE, CHECK SIDE CURVATURE

4. IF AD AND DC ARE NOT EQUAL, CHECK SIDE CURVATURE

5. IF BD LESS THAN DESIGN BY 5% OR MORE, CHECK TOP CURVATURE
Concrete underfill structures may be cast-in-place or precast. Cast-in-place concrete structures are typically box-shaped, arch-shaped, or three-sided concrete frames with separated footings. Cast-in-place underfill structures can be designed to fit the specific needs of a site.

Precast underfill structures are available in several standard shapes, including circular, box, elliptical, pipe arch, and arch. Sizes up to 12-feet wide are commonly available for closed shapes. Most modern concrete bridge sized precast structures are frames often called three-sided structures. Most frames and some arches are set on concrete footings, some with driven piles and others set in bedrock.

Proper bedding compaction and preparation during construction is critical if precast closed sections are to perform well in service. Properly prepared bedding material (usually crushed stone) under the sections will evenly support them. Voids within the bedding will force the rigid pipe sections to span over these soft spots, often resulting in transverse cracks. Voids under the mid-length of a section will lead to cracks on the bottom half of the pipe at mid-length. Voids under the ends of a section will lead to cracks on the top half of the pipe.

Improper compaction of fill material on the sides may lead to longitudinal cracks. Without proper soil side support, the structure will want to flatten under vertical loads. Because concrete is a rigid material, it will not flex, and longitudinal cracks along the top, bottom, and sides will result.

Barrel misalignment, joint condition, and localized wall damage are areas of concern during any concrete underfill structure inspection. Rigid underfill structures develop longitudinal or transverse cracks as a result of overloading or differential settlement. Rigid underfill structures do not significantly deform unless loaded to failure. Cracks can also result from improper shipment or placement during construction. The initial inspection should check for these defects.

Structural inspections of concrete underfill structures should include the following items:

1) Examine the roadway above for any dips, cracking, settlement, or patching that would suggest a failing structure below.

2) Check for horizontal misalignments by sighting down the barrel length.

3) Check for vertical misalignments by sighting down the barrel length and noting the presence of localized deep water or sediment accumulation at low spots within the underfill structure.

4) Look for open joints. Open joints may allow water infiltration into the underfill structure, possibly allowing the backfill material to enter as well. This can lead to roadway settlement above and debris accumulation within the barrel. Open joints that allow water to flow out of the barrel (exfiltration) may cause soil erosion. This can also lead to structure and roadway settlements.
5) Look for cracks, delaminations, or spalls at expansion joints or precast section joints. This type of deterioration suggests improperly functioning joints, possibly due to settlement.

6) Look for longitudinal cracks along the barrel or cell length. These may be caused by excessive overloads, improper fill compaction of barrel sections, or lateral differential settlements of box sections. Medium to wide crack widths should be measured and recorded.

7) Examine box tops when these elements double as the riding surface of traffic above. Longitudinal cracks in the box top may be caused by traffic overloads.

8) Look for transverse cracks. These may be caused by differential settlements along the barrel length, often the result of improper bedding material preparation.

9) Check the entire barrel or cell for delaminations, spalls, exposed reinforcing steel, cracking, and leaching. Note the location of such defects.

10) Examine the inlet and outlet of the barrel for signs of scour or undermining underneath a closed pipe. This could lead to piping.

11) Check for scour or footing undermining along the length of underfill structures with footings. Undermining may allow the concrete footing to rotate, causing structural failure.

12) Look for signs of abrasion along the length of the barrel.

13) Examine any anchor bolt conditions at the spring line of precast underfill structures.

14) Examine end treatments and wingwalls for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies and roadway settlements.

15) Check for excessive joint openings between headwalls, wingwalls, and aprons.

16) For tunnels, ensure that the drainage system is operating properly. Poor drainage can lead to ponding or flooding in the tunnel.

17) For tunnels, the inspector should evaluate the condition of any lighting inside the tunnel and note any damaged or nonfunctioning lights. All conduit and junction boxes should be inspected for damage, corrosion, loose mounting brackets, and missing covers.

18) Tunnel ventilation systems should be assessed. Check for intact vent cover grates, working blowers, working filtration systems, if applicable, adequate air exchange, and the presence of fumes or smoke.
Figure 4:9-62: Probing Concrete Underfill Structure
SECTION 9.6 OTHER UNDERFILL STRUCTURES

Subsection 9.6.1 Stone and Masonry Underfill Structures

Masonry underfill structures are rarely constructed today, but they can still be found in-service. They are built of stone or brick formed into arch or box shapes. Joints between the masonry units may be mortared, set in concrete, or set in place with no mortar. Masonry is still used sometimes to construct headwalls for underfill structures of other material types for aesthetic reasons. Material deterioration is the primary concern of any masonry underfill structure. Figure 4:9-18 depicts typical deterioration for masonry structures. In addition, signs of soil distress or overloading may show up as wall or arch bulging. For masonry tunnels, follow the inspection guidelines in Part 4, Chapter 4.

Figure 4:9-63: Masonry Underfill Structure with Severe Deterioration of Mortar Joints
Subsection 9.6.2 Aluminum Underfill Structures

Aluminum underfill structures are flexible and distress will appear primarily as shape distortions caused by soil failures or overloads. The shape and construction of aluminum underfill structures are similar to steel and they should be inspected in a manner similar to steel underfill structures, as described in Section 9.4.

Subsection 9.6.3 Plastic Underfill Structures

Plastic underfill structures are circular in shape and are only used for underfill diameters of five feet or less. They are normally made of high-density polyethylene and are considered flexible underfill structures. Distress will appear primarily as shape distortions caused by soil failures or overloads. Plastic structures can be placed side-by-side to achieve a span greater than 20 feet.

Subsection 9.6.4 Timber Underfill Structures

Timber underfill structures are usually in the shape of a box and are constructed of individual heavy timbers. They are not common because the dark and damp conditions within the box provide an ideal environment for fungi and parasites to thrive. Material deterioration is the primary concern of any timber underfill structure. In addition, signs of soil distress or overloading may show up as wall or ceiling bulging.

Subsection 9.6.5 Inspection of Other Underfill Structures

Structural inspections of other underfill structures should include the following items:

1) Examine the roadway above for any dips, cracking, settlement, or patching that would suggest a failing structure below.

2) Check for horizontal misalignments by sighting down the barrel length.

3) Check for vertical misalignments by sighting down the barrel length. Note the presence of localized deep water or sediment accumulation at low spots within the barrel.

4) Look for any wall, arch, or ceiling bulges. The location and size of such distress should be recorded.

5) Examine the inlet and outlet for signs of scour or undermining underneath masonry underfill structures with a floor, and plastic underfill structures.

6) Examine for scour or footing undermining along the length of underfill structures without floors. Undermining may allow the footing to rotate, failing the structure.

7) Look for signs of abrasion along the length of the barrel.

8) Examine end treatments for damage, deterioration, debris accumulation, streambed scour, undermining, and embankment erosion. These deficiencies can cause hydraulic inefficiencies and roadway settlements.

9) Check for excessive joint openings between headwalls, wingwalls, and aprons.
10) Look for cracked, crushed, or missing masonry units or mortar.

11) Look for signs of excessive masonry weathering.

12) Measure the height and width of plastic underfill structures at the ends, middle, and at 25-foot intervals in between. These measurements should be compared to the original dimensions shown on the design drawings, if available. Excessive flattening suggests a soil failure.

13) Indicate the extent of any flattening found. Include the affected length along the barrel, and location of the distress.

14) Look for localized damage in the form of dented, flattened, or bulged areas. Bulged areas on the bottom of a round barrel suggest settlement over a local hard spot.

15) Check the joints for separation and backfill infiltration.

16) Look for cracked or split timbers. These may be the result of a structural overload.

17) Look for signs of timber decay due to fungi or parasites.

18) Check for broken or missing timbers. These may allow backfill material to enter, causing roadway settlement above.

19) Examine exposed fasteners for deterioration.
SECTION 9.7 NBI UNDERFILL/CULVERT RATINGS

The culvert/underfill structure condition rating assesses the current condition of the structure as compared to its original, as-built condition. Postings or original design capacities less than current legal loads will not influence the rating. Because only a single number is used to rate the structure, the rating must characterize its overall general condition. The rating should not be used to describe local areas of deterioration, but widespread deterioration would influence the rating. Temporary supports do not improve the condition of the construction material or influence the rating.

The general Federal Highway Administration (FHWA) condition ratings are listed below, followed by supplemental rating guidelines to assist the inspector in properly assigning condition ratings for the most commonly used materials. Reference the BIRM for supplemental rating guidelines for less common structures and materials.

<table>
<thead>
<tr>
<th>Code (Rating)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NOT APPLICABLE</td>
</tr>
<tr>
<td></td>
<td>Supplemental Rating Guidelines: Use if structure is not an underfill structure.</td>
</tr>
<tr>
<td>9</td>
<td>EXCELLENT CONDITION</td>
</tr>
<tr>
<td>8</td>
<td>VERY GOOD CONDITION – No problems noted.</td>
</tr>
<tr>
<td></td>
<td>Supplemental Rating Guidelines: No noticeable or noteworthy deficiencies. Insignificant scrape marks caused by drift.</td>
</tr>
<tr>
<td></td>
<td>Steel and Aluminum Structures – Superficial corrosion with no pitting may be present. Minor construction defects may be present and the protective coating for steel structures is intact. Smooth curvature in the barrel is evident and horizontal shape measurements are within 10 percent of design for round pipes and three percent for pipe arches. The rise in structural plate arches is within three percent of the design. Seams and joints are tight with no openings and no erosion is present at the footings.</td>
</tr>
<tr>
<td></td>
<td>Concrete Structures – No settlement or misalignment is present. Joints are tight with no defects apparent. No cracking, spalling, or scaling is present and the surface is in good condition.</td>
</tr>
<tr>
<td></td>
<td>Stone and Masonry Structures – No settlement or misalignment is present. The mortar is tight with no defects apparent. No cracking, missing, or dislocated masonry is present and the surface is in good condition. The invert shows no signs of scour.</td>
</tr>
<tr>
<td>7</td>
<td>GOOD CONDITION – Some minor problems.</td>
</tr>
<tr>
<td></td>
<td>Supplemental Rating Guidelines: Insignificant damage caused by drift with no misalignment may be present. Local minor scouring near the cut-off wall, wingwalls, or pipes may also be present.</td>
</tr>
</tbody>
</table>
|               | Steel and Aluminum Structures – Smooth symmetrical curvature with superficial corrosion and no pitting or slight pitting may be present. Local section loss of less than 10 percent may be present. The protective coating is ineffective for steel structures. The top half of the pipe is smooth. Minor flattening of the bottom may exist for round pipe, and the bottom half is flattened, but still curved for pipe arches. Horizontal shape measurements are within 10 percent of the design for round pipes, and within three percent to five percent greater than design for pipe arches. Structural plate arches have a smooth and
symmetrical shape with slight flattening of the top or sides in one section, and the rise is within three percent to four percent of the design. The footings have minor erosion, causing minor differential settlement and minor cracking in the footing.

**Concrete Structures** – Shrinkage cracks, light scaling, and insignificant spalling which does not expose reinforcing steel may be present with no settlement. Misalignment is less than one inch at joints and joints have up to 1/2-inch openings with possible infiltration/exfiltration. Joint material is deteriorated at up to five percent of the joints. Hairline cracking may be present at isolated locations, and slight spalling or scaling is present on the invert.

**Stone and Masonry Structures** – No settlement with misalignment of less than one inch at the joints is present. Shallow mortar deterioration at up to five percent of the underfill structure is present. Surface deterioration of masonry at isolated locations may be present with minor scour at the invert.

6 **SATISFACTORY CONDITION** – Structural elements show some minor deterioration.

**Supplemental Rating Guidelines:** There is local minor scouring at the cut-off wall, wingwalls, or pipes.

**Steel and Aluminum Structures** – A smooth curvature, but nonsymmetrical shape, is present with local section loss up to 25 percent. The top half of the pipe has a smooth curvature, but the bottom half has flattened significantly for round pipes, or has flattened for pipe arches. Horizontal shape measurements are within 10 percent of the design for round pipes, and five percent greater than the design for pipe arches. Structural plate arches have a smooth, but nonsymmetrical shape with slight flattening of the top and sides throughout, and the rise is within four percent to five percent of the design. Hairline cracking at the bolt holes in one or more seams, one inch or less openings, and evidence of minor backfill infiltration at the joints and seams may be present. Footings have moderate cracking and differential settlement due to moderate erosion.

**Concrete Structures** – Deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spills on concrete walls and slabs maybe present up to one inch of misalignment and settlement at isolated locations. Joint material is generally deteriorated with minor cracking or spalling at joints. Joints have one inch of maximum separations with possible infiltration or exfiltration. Cracks are less than 1/8-inch wide, some with minor delaminations or spalling. The invert and the bottom of top slab have scaling less than 1/4-inch deep, or small spills are present. Minor scour near footings may be present.

**Stone and Masonry Structures** – Deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spills on masonry walls may be present. There is up to one-inch of misalignment and settlement. Shallow mortar deterioration over no more than 20 percent of the structure, missing mortar at isolated locations, possible infiltration or exfiltration, and minor cracking may be present. Minor cracking of masonry units and minor scour near the footings may also be present.

5 **FAIR CONDITION** – All primary structural elements are sound, but may have minor section loss, cracking, or spalling.

**Supplemental Rating Guidelines** – Minor settlement or misalignment may be present with noticeable scouring or erosion at cut-off walls, wingwalls, or pipes.
Steel and Aluminum Structures – Metal underfill structures have significant distortion and deflection in one section with significant corrosion or deep pitting. Moderate thinning with global section loss of less than 10 percent and/or local section loss of less than 50 percent may be present. Significant distortion at isolated locations in the top half and extreme flattening of the invert for round pipe, or slight reverse curvature in one location for pipe arches, may also be present. Horizontal shape measurements are between 10 percent and 15 percent greater than the design for round pipe, or within five percent to seven percent for pipe arches. For structural plate arches, there is significant distortion and deflection in one section, the sides are beginning to flatten, the shape is nonsymmetrical, and the rise is within five percent to seven percent of the design. Moderate cracking at the bolt holes in one seam near the bottom of pipe and slight deflection of the pipe caused by backfill infiltration through joints and seams may be present.

Concrete Structures – Moderate to major deterioration or disintegration, extensive cracking and moderate leaching, or spalls on concrete walls and slabs may be present. Up to two inches of misalignment and settlement throughout the pipe with possible piping may also be present. Joints are open and allowing backfill to infiltrate. Significant cracking or joint spalling is evident, and crack widths greater than 1/8 inch with moderate delamination and moderate spalling, exposing reinforcing steel at up to five percent of the structure, may be present. Large areas of the invert may have surface scaling or spalls greater than ¼-inch deep. Moderate scour along the footing may exist and protective measures may be required to prevent undermining.

Stone and Masonry Structures – Moderate to major deterioration or disintegration, extensive cracking and leaching, or spalls on masonry walls with up to two inches of misalignment or settlement may be present. The mortar is deteriorated at up to 50 percent of the structure with loose or missing mortar at up to five percent of the structure. Infiltration staining is apparent. Minor cracking and slight dislocation of masonry units, large areas of surface scaling, and moderate scour along the footing may exist. Protective measures may be required to prevent undermining.

4 POOR CONDITION – Advanced section loss, deterioration, or spalling may be present.

Supplemental Rating Guidelines: Considerable settlement or misalignment and considerable scouring or erosion at cut-off walls, wingwalls, or pipes may be present.

Steel and Aluminum Structures – Significant distortion and deflection throughout and extensive corrosion or deep pitting with pronounced thinning may be present. Some deflection or penetration exists when struck with a pick hammer. Global section loss of up to 20 percent and local section loss of up to 75 percent may exist. Round pipes have significant distortion throughout the length of the pipe, and the lower third may be kinked. Pipe arches have significant distortion along the top of the arch, and the bottom has reverse curvature. Horizontal shape measurements are between 10 percent to 15 percent greater than the design for round pipe, and more than seven percent greater for pipe arches. For structural plate arches, there is significant distortion and deflection throughout, the sides are flattened with a radius of no more than 100 percent greater than the design, and the rise is within seven percent to eight percent of the design. Cracking at the bolt holes on one seam near the bottom of pipe, with up to two-inch crack propagation on each side of the bolt holes may exist. Deflection caused by backfill infiltration through open joints and seams may be present with footings that are rotated due to erosion and undercutting. Settlement has caused damage to the arch. Significant undercutting and extreme differential settlement of the footing, causing major cracking in the footing, may be present.

Concrete Structures – Large spalls with exposed reinforcement, heavy scaling, wide
cracks, considerable efflorescence, or opened construction joints permitting loss of backfill may be present. Up to three inches of misalignment and settlement of the pipe, with evidence of piping, may also exist. The end sections of precast pipes are dislocated and about to drop off. Up to two inches of differential movement and separation at the joints with significant infiltration and exfiltration may be present. Extensive cracking with crack widths greater than 1/8 inch and with efflorescence and spalling at up to 10 percent of the underfill structure may be present. At up to five percent of the underfill structure, spalls with exposed and corroded reinforcing steel with no more than 10 percent section loss may exist. The invert has extensive surface scaling greater than 1/2-inch deep. Scour along footings with slight undermining may exist and protection is required to prevent further undermining.

Stone and Masonry Structures – Large spalls, heavy scaling, wide cracks, considerable efflorescence, or opened construction joints permitting loss of backfill may exist. Up to three inches of misalignment and settlement may be present. The mortar is severely deteriorated over no more than 75 percent of the underfill structure. Loss of mortar, infiltration, and exfiltration between masonry and stone units, along with the displacement of individual units, may exist. Scour along the footings with slight undermining may be present. Protection is required to prevent further undermining.

3 SERIOUS CONDITION – Loss of section, deterioration, or spalling has seriously affected the primary structural components. Local failures are possible.

Supplemental Rating Guidelines: Any condition described in Condition Rating 4 that is excessive in scope, along with severe movement or differential settlement of the segments and loss of fill may be present. Holes may exist in walls or slabs. Integral wingwalls are nearly severed from the structure. Severe scour or erosion at cut-off walls, wingwalls, or pipes may exist.

Steel and Aluminum Structures – Extreme distortion and deflection in one section, extensive corrosion, or deep pitting with scattered perforations may exist, with global section loss up to 30 percent and local section loss up to 100 percent. Round pipes have extreme deflection at isolated locations, flattening of crown, and a crown radius of 20 to 30 feet. Pipe arches have extreme deflection in the top arch in one section, and the bottom has reverse curvature throughout. Horizontal shape measurements are more than 115 percent of the design for circular pipes, and more than 117 percent of the design for pipe arches. For structural plate arches, there is extreme distortion and deflection in one section, the sides are virtually flat, the shape is extremely nonsymmetrical, and the rise is within eight percent to 10 percent of the design. Up to three-inch long cracks on either side of the bolt holes on one or more seams may be present. Footings are rotated, severely undercut, and have major cracking and spalling.

Concrete Structures – Shear cracks may be present. Up to four inches of ponding water due to sagging and misalignment of the structure may be present. The end section of precast pipes has dropped off. Up to three-inch joint openings and differential movement, along with dislocated joints in several locations, exposing fill material, may exist. Infiltration or exfiltration, causing misalignment of pipe and depressions or settlement in the roadway, may be present. Extensive cracking throughout no more than 30 percent of the structure may accompany spalling with exposed reinforcement that has 10 percent section loss throughout no more than 10 percent of the structure. Scaling has exposed reinforcing steel in the bottom of the top slab or invert. Severe footing undermining with differential settlement, causing minor cracking or spalling in footing and walls, may be present.
Stone and Masonry Structures – Up to four inches of ponding water due to sagging and misalignment of the pipe may be present. Missing mortar with infiltration or exfiltration, causing misalignment of the structure and depressions or settlement in the roadway throughout no more than 10 percent of the structure, may also exist. Individual masonry units in the lower part of the structure are missing or crushed. Severe footing undermining with differential settlement, causing minor cracking or spalling in footing and minor distress in walls, may be present.

2 CRITICAL CONDITION – Advanced deterioration of primary structural elements exists. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.

Supplemental Rating Guidelines: The structure is not functioning due to misalignments. Integral wingwalls have collapsed and there is severe settlement of the roadway due to loss of fill. Sections of the structure may have failed and can no longer support embankment. Complete undermining at cut-off walls and pipes may exist. Corrective action is required to maintain traffic.

Steel and Aluminum Structures – Extreme distortion and deflection throughout, along with extensive perforations due to corrosion on up to five percent of the structure, may be present. Round pipes have extreme deflection and distortion throughout the pipe, flattening of the crown, and a crown radius over 30 feet. Pipe arches have extreme deflection along the top of the pipe. Horizontal shape measurements are more than 120 percent of the design for circular pipes, and more than 107 percent of the design for pipe arches. For structural plate arches, there is extreme distortion and deflection throughout, the sides are flattened, the shape is extremely nonsymmetrical, and the rise is not within 10 percent of the design. Seams are cracked from bolt to bolt with significant amounts of backfill infiltration. Severe differential settlement of the footing has caused distortion and kinking of the arch.

Concrete Structures – Severe cracks with more than two inches of differential movement, along with exposed reinforcement with more than 20 percent section loss throughout at least 20 percent of the structure may be present. The top slab or invert concrete is completely deteriorated over more than three percent of the structure. Severe footing undermining with significant differential settlement, causing severe cracks in the footing and distress in the walls, may be present.

Stone and Masonry Structures – Individual masonry units in the top of the structure are missing or crushed. Severe footing undermining with significant differential settlement, causing severe cracks in the footing and distress in walls, may be present.

1 “IMMINENT” FAILURE CONDITION – Major deterioration or section loss is present in critical structural components, or obvious vertical or horizontal movement is affecting the structural stability. The bridge is closed to traffic, but corrective action may put it back in light service.

Supplemental Rating Guidelines: The road is closed to traffic.

Steel and Aluminum Structures – The invert is completely deteriorated. Round pipes are partially collapsed with the crown in reverse curvature. Pipe and plate arches are partially collapsed. Seams have failed.

Concrete Structures – The structure is partially collapsed. Severe footing undermining is present.

Stone and Masonry Structures – The structure is partially collapsed. Severe footing undermining is present.
0  FAILED CONDITION – The bridge is out-of-service due to a partial or complete collapse. Replacement is necessary.

To establish a rating, identify phrases within the guidelines that describe a rating more severe than what actually exists. The correct rating number will be one number higher than the one describing the more severe condition.

For example, suppose a steel underfill structure has surface corrosion at the invert and waterline, plus random joint bolts that have minor to moderate corrosion. The seams are tight. The structure is an eight-foot-wide arch pipe, with a measured horizontal dimension of eight feet, four inches (4.2 percent greater than the design value). Condition Rating 7 indicates that there is moderate rust or pitting, and the horizontal dimension of the structure is between three percent to five percent of the design value. There may be minor openings at the seams. Condition Rating 6 indicates that there is fairly heavy rust with minor pitting and slight thinning. There may be evidence of backfill infiltration at the seams, and the horizontal dimension of the structure is greater than five percent of the design value. Using the method described above, Condition Rating 6 describes a situation more severe than what actually exists. Therefore, a rating of 7 would be appropriate.

Ratings of 9 to 7 apply to structures in good condition, 6 to 5 suggest fair condition, 4 to 3 suggest poor condition, 2 suggests poor/critical condition, and 1 to 0 suggest critical condition.
SECTION 9.8 ADDITIONAL UNDERFILL/CULVERT RATINGS

Subsection 9.8.1 Condition Ratings

Additional items to be rated for the Central Database are listed below. Some items are shown below in Figure 4:9-19. Each item shall be rated as a stand-alone item, assessing its condition independently, and not how it might relate to Item 62, the NBI culvert condition rating. Each item shall be rated as follows unless noted:

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor problems
6  Satisfactory Condition – structural elements show some minor deterioration
5  Fair Condition – minor section loss, cracking, or spalling
4  Poor Condition – advanced section loss, deterioration, or spalling
3  Serious Condition – loss of section, deterioration, or spalling has seriously affected components
2  Critical Condition – advanced deterioration of primary elements
1  Imminent Failure Condition – roadway closed to traffic
0  Failed Condition – beyond corrective action
ITEM 62.01 – BARREL

The barrel is the main body of the structure and consists of the portion of the structure that is under the fill. Typically, the barrel is the largest portion of the structure and the barrel rating will be the same as the overall rating, unless the ends of the structure are in much worse condition. The overall rating should never be higher than the barrel rating. The barrel rating should be selected using the relevant rating guidelines in Subsection 9.7.1.
ITEM 62.02 – ALIGNMENT

The alignment rating considers both the horizontal and vertical deflection of the structure. The rating should be selected using the relevant guidelines from Subsection 9.7.1.

ITEM 62.03 – STEEL

Rate the condition of the steel in steel barrels using the relevant guidelines from Subsection 9.7.1. The rating of the steel may be different than the barrel rating since the structure is flexible and the barrel rating may be governed by the alignment.

ITEM 62.04 – BOLTS

The longitudinal seams and transverse joints of some steel structures are bolted together with high-strength bolts in two rows: one row in the crests, and one row in the valleys of the corrugations. Check the tightness of the bolts by tapping lightly to detect movement. Check for corrosion, which can cause section loss and increased stress in the bolts.

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor problems
6  Satisfactory Condition – one percent of bolts are loose, missing, or corroded with section loss
5  Fair Condition – three percent of bolts are loose, missing, or corroded with section loss
4  Poor Condition – five percent of bolts are loose, missing, or corroded with section loss
3  Serious Condition – 10 percent of bolts are loose, missing, or corroded with section loss
2  Critical Condition – 15 percent of bolts are loose, missing, or corroded with section loss
1  Imminent Failure Condition – 20 percent of bolts are loose, missing, or corroded with section loss
0  Failed Condition – beyond corrective action
ITEM 62.05 – CONCRETE

Rate the condition of the concrete in structures with concrete barrels. The rating should be selected using the relevant guidelines in Subsection 9.7.1. The rating will usually match the rating for the barrel, unless the barrel rating is governed by the alignment.

Figure 4:9-65: Spalling Concrete on Underfill Structure

ITEM 62.06 – STONE

This item is only applicable to structures with stone barrels. The rating should be selected using the guidelines in Subsection 9.7.1 related to the deterioration of the stone barrel. The rating will usually match the rating for the barrel, unless the barrel rating is governed by the alignment.

ITEM 62.07 – HEADWALL

A headwall is a structural wall, usually made of concrete, at the inlet and outlet of an underfill structure to protect the embankment slopes, anchor the structure, and prevent undermining.

ITEM 62.08 – APRONS

Aprons are used in the streambed to reduce or prevent scour and erosion at each end of the structure. Aprons may consist of a concrete slab, grouted or ungrouted riprap, or other material, and usually include a cut-off wall to protect against undermining.

ITEM 62.09 – EROSION/SCOUR/UNDERMINING
Erosion generally refers to the loss of bank material and a lateral movement of the channel. Scour is related to a lowering of the streambed material by flowing water. Scour is classified into two types: local and general scour. Local scour is usually caused by a specific flow obstruction that causes a constriction of flow and occurs primarily at the outlet. Note any channel cleaning up or downstream which may have lowered the profile. This lowering can work its way to the culvert and cause scour underneath the structure. General scour extends farther along the stream and is not localized around a particular obstruction. General scour can involve a gradual lowering of the streambed and can result in abrupt drops in the channel that move upstream in peak flow, called head cutting. Head cutting can be a serious problem if it occurs in the downstream channel, since it may threaten the structure as it moves upstream. Undermining occurs when the load-bearing soil under the structure is removed by scour or erosion, resulting in an unsupported portion of the structure. The rating should be selected using the relevant portions of the rating guidelines in Subsection 9.7.1.

ITEM 62.10 – CONSTRUCTION JOINTS

Construction joints are the joints between concrete pours, joints between precast or fabricated sections of pipe, or seams between steel plates. These can also describe a joint where a structure has been lengthened. The rating should be selected using the relevant portion of the guidelines in Subsection 9.7.1.

ITEM 62.11 – WINGWALLS

Wingwalls are retaining walls on each side of the inlet and outlet designed to protect and retain the embankment slopes and prevent undermining.

ITEM 62.18 – EMBANKMENT

Embankment is the soil above the structure under the roadway and on the slope. Cracking or dips in the roadway and erosion of the embankment may be indicators of structural or hydraulic problems. Refer to Part 4, Chapter 6 for additional information on the inspection of the roadway approach and embankment.

N  Not Applicable
9  Excellent Condition – new
8  Very Good Condition – no problems noted
7  Good Condition – some minor problems
6  Satisfactory Condition – cracking in isolated locations on roadway and slight erosion
5  Fair Condition – noticeable erosion of embankment; slight dips in roadway and cracking in 10 percent of pavement
4  Poor Condition – considerable erosion of embankment; noticeable dips in five percent of roadway and cracking in 20 percent of pavement
3  Serious Condition – severe erosion of embankment; large dips in 10
percent of roadway and cracking in pavement with one inch of differential movement

2 **Critical Condition** – extreme erosion of embankment; large and deep dips in 20 percent of roadway and cracking in pavement with three inches of differential movement

1 **Imminent Failure Condition** – roadway is closed to traffic due to erosion of embankment, dips in the roadway, and cracking in pavement

0 **Failed Condition** – beyond corrective action

**Subsection 9.8.2 Subjective Appraisal Items**

Subjective items to be rated for state-owned bridges are listed below. Each item shall be rated as a stand-alone item, assessing its condition independently and not how it might relate to Item 62, the NBIS condition rating. Each item shall be rated as follows unless noted:

N **Not Applicable**

9 **Excellent Condition** – new

8 **Very Good Condition** – no problems noted

7 **Good Condition** – some minor problems and insignificant impact damage from drift

6 **Satisfactory Condition** – minor impact damage with no effect on structure function

5 **Fair Condition** – moderate impact damage having a small effect on structure function

4 **Poor Condition** – major impact damage having a moderate effect on structure function

3 **Serious Condition** – severe impact damage having a major effect on underfill structure function, such as noticeable live load deflection, vibration, impact, or noise from roadway above

2 **Critical Condition** – impact damage preventing function of the structure, excessive live load deflection, vibration, impact, or noise from roadway above

1 **Imminent Failure Condition** – roadway is closed to traffic

0 **Failed Condition** – beyond corrective action
ITEM 59A.53 – DEFLECTIONS

Underfill structures do not typically deflect under live load from the roadway above, and live load deflection would be an indication of a serious problem. Unless there is live load deflection, the deflection rating should be the same as the alignment rating, Item 62.02.

ITEM 59A.54 – VIBRATIONS

Underfill structures are dampened by the overburden, so there should be no vibration. Vibration from live load on the roadway above is an indication of a serious problem.

ITEM 59A.55 – IMPACT

Rate any impact noticeable in the underfill structure from traffic on the roadway.

ITEM 59A.56 – NOISE

Underfill structures are dampened by the overburden, so there should be no traffic noise coming from the roadway. Noise from live load on the roadway above is an indication of a serious problem.

Subsection 9.8.3 Inventory Data

Inventory data to be collected for the Central Database is listed below. Each item shall be measured as follows unless noted:

ITEM 62.12 – DESCRIPTION OF CELLS/BOXES/PIPES

The description of the cells, boxes, or pipes should include the quantity of cells and the shape, orientation, and material for each cell.

ITEM 62.13 – FILL HEIGHT

The fill height is the depth of cover or overburden above the structure, as shown in Figure 4:9-21. The fill height is measured in feet, to the nearest tenth of a foot.
ITEM 62.14 – MINIMUM DISTANCE TO HEADWALL/COPING

Record the minimum distance from the headwall or coping to the edge of the roadway. The distance is measured perpendicular to the roadway and is in feet to the nearest tenth of a foot.

ITEM 62.15 – CULVERT BARREL LENGTH

The barrel length is the longitudinal length along the barrel, as shown in Figure 4:9-19. If there are multiple barrels with varying lengths, the barrel length of the longest cell should be used. The length is measured in feet to the nearest tenth of a foot.

ITEM 62.16 – CULVERT HEIGHT

The height is the clear distance from the bottom of the structure or the top of the footing, to the lowest point of the structure. The height is measured in feet to the nearest tenth of a foot.

ITEM 62.17 – CULVERT WIDTH

The culvert width is the width perpendicular to the length of the barrel, shown as NBI Item 49 in Figure 4:9-19. In the case of multiple pipes where the clear distance is less than half the smaller continuous opening, the width is equal to the distance between the outside walls of the outer most pipes, as shown in Figure 4:9-19. The width is measured in feet to the nearest tenth of a foot.

On structures perpendicular to the roadway, the barrel width will be the same as the span length. On skewed structures, these will not be the same.
Figure 4:9-67: Two-Celled, Reinforced Concrete Underfill Structure

Figure 4:9-68: Concrete Headwall Failure
Figure 4:9-69: Masonry Headwall Separating From Metal Barrel

Figure 4:9-70: Through Thickness Section Loss at Water Line of Wall Separating Two Cells
Figure 4:9-71: Barrel with Good Alignment

Figure 4:9-72: Surface Corrosion Near Water Line
Figure 4:9-73: Light to Moderate Bolt Corrosion

Figure 4:9-74: Severe Bulging
Figure 4:9-75: Severely Distorted Barrel

Figure 4:9-76: Joint Separation Between Pipe Segments
Figure 4:9-77: Masonry Culvert with Severe Deterioration of Mortar Joints
CHAPTER 10 STRUCTURES OVER ROADWAYS

SECTION 10.1 INTRODUCTION

This chapter discusses railway, pedestrian, and pipeline bridges over roadways. Although the inspecting agency does not own these bridges, their safety must be assessed and pertinent information must be inventoried.

The assessments discussed in this chapter are an additional safety check for the traveling public, and do not limit the ultimate responsibility of the structure owner to ensure a safe structure. Inspectors for state, toll road, county, or local agencies may perform the assessment of these structures through cooperative inspection efforts with the owner or through independent inspections. The level of effort for these structures will be owner and site-specific. Visual inspection using binoculars from the underside of the structure, as well as reviewing the owner’s latest inspection report, may satisfactorily confirm the safety of the structure.

The owner should be notified in writing if a safety condition exists. For safety deficiencies that present a hazard to the public, the inspector should implement the emergency notification procedure outlined in Part 1, Chapter 7 of this manual.

All inventory route information and associated under records required for Item 5 of the Bridge Reporting for Appraisal and Greater Inventory (BRAGI) Coding Guide must be collected for all structures over roadways. Safety assessments are currently required for all structures over state-owned and toll road routes and are recommended, at this time, for structures over local agency routes.
SECTION 10.2 RAILWAY BRIDGES

Although railway bridges have much larger vertical, live, impact, centrifugal, and longitudinal (braking) loads than roadway bridges, the inspection of a railway bridge is similar to that of a highway bridge. Refer to Part 4, Chapters 4 and 5 of this manual for a discussion on the superstructure and substructure inspection. This chapter will focus on the inspection and evaluation of problems which are unique to a railway bridge. Refer to Figure 4:10-1 and Figure 4:10-2 for views of a typical railway bridge.

Figure 4:10-78: Railroad Bridge Top View

Figure 4:10-79: Railroad Bridge Elevation View
Subsection 10.2.1 Railway Bridge Inspection Reporting

Private railroad companies own most of the railway bridges in Indiana. The type and extent of railway bridge inspections may vary from one company to another. The American Railway Engineering and Maintenance-of-Way Association (AREMA) recommends a 12-month annual inspection program be completed by the owners of all railway bridges. At times, because of poor condition or low-rating capacity, inspections may often be scheduled at three-, four-, or six-month intervals. The owner of the railway structure is responsible for the safety associated with the bridge. Any additional inspections by others which are related to the safety of the traveling public under the bridge should be considered supplemental bridge inspection data.

During a Supplemental Inspection, the inspector should report indications of failure in any portion of the structure and any conditions that could contribute to a future failure. Loose or corroded elements in danger of falling onto traffic lanes or pedestrians below should be noted. If possible, structures should be observed during the passage of a train so the effects of vibrations and deflections may be noted. All pertinent defects should be noted and recorded.

Subsection 10.2.2 Railway Bridge Approach Inspection

The railway track approach immediately adjacent to the abutment and backwall is one of the most important areas of a railway bridge. When the approach surface is uneven, large forces are applied to the backwall and bridge seat by passing trains. This can cause broken backwall ties, cracked and failed backwalls, or damaged bridge seats.

When inspecting railway bridges, the approaches should be observed for the following serious conditions:

1) The approach is excessively low, out of cross-level, or both.
2) Broken track and backwall ties are present in the approach area.
3) Mud in the track at the approach and backwall is present which suggests approach settlement.
4) Bent or broken rails are present.
5) Missing or broken track components, such as angle bars, bolts, or spikes are present.
SECTION 10.3   PEDESTRIAN BRIDGES

The inspection of a pedestrian bridge is similar to that of roadway bridges. Pedestrian bridges over roadways should be inspected at a 24-month maximum interval with interim inspections for problem areas.

Since pedestrian bridges will not encounter the same loadings that vehicle or railway bridges encounter, some pedestrian bridges are constructed with a nonredundant girder system. The inspector should pay extra attention to any nonredundant girder system to ensure excessive corrosion or cracking is not occurring. Fencing may make it difficult for the inspector to see critical areas clearly and access equipment may be necessary. Refer to Figure 4:10-3 for an elevation view of a pedestrian bridge.

Figure 4:10-80: Elevation View of Pedestrian Bridge
SECTION 10.4 PIPELINE BRIDGES

The inspection of a pipeline bridge is similar to that of the other bridges discussed in this manual. Pipeline bridges should be inspected at 24-month intervals with interim inspections for problem areas.

Pipeline bridges typically are owned by either a transport company that moves a bulk product, or a distribution company that sells the product. The company’s product normally consists of a fuel, such as gasoline, fuel oils, propane, or natural gas in either liquid or gas form.

The inspector should familiarize him/herself with the products carried in these pipelines and be aware of the signs of a leak, including hissing sounds and dripping liquids. Many of these products lack an easily recognized identifier. For example, bulk natural gas does not have the telltale odor added until it is processed by the distribution company. If a leak is detected, the inspector should immediately leave the site by foot, and then call 9-1-1. It is important to leave the site without introducing an ignition source, such as a cigarette or sparks created by starting a vehicle or using a cell phone. The inspector should also be familiar with safety procedures with respect to leaks involving these fuels. The inspection should not continue until the owner has contained the leak and given notice to proceed.

Pipelines and pipeline bridges should be inspected for material deterioration and any loose bolts or pieces of material that could fall on to the roadway below. In addition, the inspector should look for sags in the pipe or pipeline bridge and inspect any supporting cables and foundations. Refer to Figure 4:10-4 for an end view of a pipeline bridge.

Figure 4:10-81: End View of a Pipeline Bridge
Pipelines are most often connected to a bridge using a clamping system. Refer to Figure 4:10-5 for a view of a typical pipeline-to-bridge connection. This bridge uses U-bolts to hold the pipeline to the bridge. All connections should be inspected to ensure the pipeline is securely fastened. Any loose or missing connections should be noted in the inspection report.

Figure 4:10-82: Pipeline to Bridge Connection
CHAPTER 11 FATIGUE AND FRACTURE CRITICAL INSPECTIONS

SECTION 11.1 INTRODUCTION

An important aspect in inspecting and evaluating a steel bridge is to determine if the bridge has a potential for fatigue and/or sudden fracture. Fatigue and fracture may occur under loads or conditions below the original design requirements and result in an often sudden, brittle failure of a portion of, or the entire, bridge. These failures often occur in a relatively short period of time and the defects may spread rapidly prior to the failure. Fatigue details and damage occur in both redundant steel bridges, as well as fracture critical bridges.

Due to these potential conditions, it is imperative that bridges be identified as fracture critical in accordance with the NBIS and that the fracture critical elements are properly inspected. An extra degree of caution and detail must be exercised during the inspection of fracture critical bridges. Fatigue-prone details must be properly identified and thoroughly inspected. The potential for failure warrants the added level of effort and detail required for monitoring and reporting any potential defects throughout the life of the bridge. The detailed inspection reports also permit the owner of the bridge to make any necessary repairs before any major problems occur, and assist future inspectors at the bridge.

Figure 4:11-83: Girder Failure Due to Brittle Cracking at Intersecting Weld
Figure 4:11-84: Girder Failure Due to Brittle Cracking
SECTION 11.2  FATIGUE- AND FAILURE-PRONE DETAILS

One of the major causes for fracture failure is fatigue. Fatigue is defined as the tendency of a member to fail at a stress level below yield stress when subjected to cyclical loading. Fatigue cracks and damage can develop in steel bridges as a result of repeated loading. Fatigue cracks initiate from points of stress concentrations in structural members or details. Stress concentrations often result from:

- Material flaws.
- Connection details.
- Out-of-plane distortions.
- A change in a member cross section.

Most cracks in steel members occur in the tension zones, generally at a flaw or defect in the base material. Frequently, the crack is a result of fatigue occurring in the areas of stress concentrations mentioned above. Recognizing and understanding the behavior of connections and details are crucial if the inspector is to properly inspect steel bridges and fracture critical members, because connections and details are often the locations of the highest stress concentrations. It is the inspector’s responsibility to have adequate knowledge, resources, and the ability to clearly identify and inspect fatigue-prone details and material flaws. Numerous references are available that provide excellent guidance on fatigue-related issues. The Manual for Inspecting Bridges for Fatigue Damage Conditions (Yen, Huang, Lai & Fisher - 1990) and the Bridge Inspector’s Reference Manual (Publication No. FHWA NHI 03-001) (BIRM) are recommended references for fatigue inspections.

AASHTO bridge specifications have categorized the susceptibility of various steel bridge details to fatigue cracking. These details were categorized for beam or girder in-plane bending and axial loading of members or member components. See Appendix A, Fatigue Prone Details, for more detailed information. The progression of a Fracture Critical Inspection should be in the order of the susceptibility to fatigue crack propagation and fatigue life cycle, ordered from the highest susceptibility (E’) to the lowest (A). Of all the details, those of Categories D, E, and E’ are the most susceptible to fatigue crack growth. These details must be thoroughly examined at every inspection, and consideration must be given to fatigue-causing factors such as traffic counts and vehicular loadings.
Figure 4:11-85: Sheared-Off Diaphragm Bolts Due to Fatigue

Figure 4:11-86: Fatigue Crack Through the Line of a Connection Angle
Figure 4:11-87: Unarrested Fatigue Rivet Crack
SECTION 11.3 WELDS

Metal bridges, particularly those that are welded, can contain material flaws. Flaws can vary in size from undetectable, nonmetallic inclusions, to large cracks. Material flaws may exist as external flaws such as pits, or internal flaws such as nonmetallic inclusions or lamellar tears.

Flaws can also be introduced during fabrication, material handling, or erection. These flaws can include:

- Damage at the edges of drilled or punched holes.
- Gouges/notches from flame-cutting, grinding, or impacts.
- Sharp corners at coped or blocked details.
- Incomplete welding fusion.
- Slag inclusions.
- Porosities.
- Blow holes.
- Undercuts.
- Craters.
- Weld cracks.
- Back-up bars or tack welds left in place.
- Plug welds.
- Arc strikes.
- Nicks.
- Notches.
- Indentations.
- Tears.
- Chain marks.
- Pitting from corrosion.

Most weld cracks start at either the weld toe or the weld root. Cracks at the weld toe can generally be detected using visual nondestructive testing (NDT) methods such as dye penetrant. Cracks at the weld root, often caused by a weld defect, will not be visible until they have grown large enough to break the surface of the weld.
Figure 4:11-88: Fatigue Cracks in Weld Due to Out-of-Plane Distortion

Figure 4:11-89: Typical Weld Details

Figure 4:11-90: Rust Line at Weld Toe Indicating a Fatigue Crack
Figure 4:11-91: Fatigue Cracks in Weld After Rehabilitation

Figure 4:11-92: Fatigue Cracks in Weld Due to Stresses After Rehabilitation
SECTION 11.4  GUSSET PLATES

Gusset plates transfer loads from one member to another and should be inspected carefully for section loss. Corrosion of gusset plates can be difficult to quantify because of the limited access to these plates in tightly configured connections, or those where the members framing into the gusset plates are closely spaced.

Inspectors should identify the primary truss gusset plates where corrosion is evident, and visual inspections with traditional measurement devices (calipers, depth probe, tape measure, etc.) may not detect or adequately quantify section loss due to corrosion for the entire plate.

At these locations, inspectors should use an appropriate NDT technology to assess the gusset plate condition, quantifying the plate thickness. The measurement location and dimension from each inspection should be documented and retained in the bridge file. The measurement locations should be identifiable from readily reestablished reference points.

Ultrasonic testing methods for thickness measurement are recommended for this testing in combination with a visual inspection.
SECTION 11.5 OUT-OF-PLANE DISTORTION

Many fatigue cracks result from out-of-plane distortion across a small gap, usually a segment of a girder web. The problem of distortion-induced fatigue cracking has been observed in the following types of bridges:

- Trusses
- Suspension bridges (floor system)
- Two-girder bridges
- Multi-beam and multi-girder bridges
- Tied arch bridges
- Box girder bridges

![Figure 4:11-93: Out-of-Plane Bending at Floor Beam Connection Plate](image)

![Figure 4:11-94: Double Fatigue Cracks in Girder Web, Top of Connection Plate](image)

(Out-of-Place Bending)
SECTION 11.6  FATIGUE REPORTING

Adequate documentation is crucial in the monitoring of fatigue damage. Once fatigue damage is located, all similar fatigue details on the bridge should be re-evaluated and examined. The inspector should give strong consideration to reducing the inspection frequency due to the potential for rapid deterioration or failure. The FHWA suggests that approximately 95 percent of the fatigue life has been surpassed with the presence of a fatigue crack. Suitable documentation is mandated so the fatigue areas can be closely monitored across inspection cycles and by different inspectors. When a fatigue crack or suspected crack has been detected, the following relevant information should be recorded:

1) Date the crack was detected, confirmed, and re-examined
2) Relation of the crack to the areas of tension stresses
3) General location of the crack, such as “at panel point L4 of the west truss,” or “at the upper end of the connection plate of the L4 floor beam,” etc.
4) Detailed sketches of the location, orientation, length, and width of crack; extra care should be given to determine the location of the ends of the crack; limits of the crack should be clearly marked and dated on the member
5) Dimensions and details of the member containing the crack
6) Any noticeable conditions at the crack when vehicles traverse the bridge, such as opening and closing of the crack, visible distortion at the local area, etc.
7) Any configuration and geometrical conditions of the other members or components adjacent to, or near, the cracked member, which may have deviated from the expected, or which may have been altered after erection of the bridge
8) Condition of the corrosion, accumulation of dirt and debris, etc., at the general location of the crack
9) Weather conditions when the crack was discovered or inspected
10) Testing performed at the location of the crack or similar locations
Note the documentation shown in Figure 4:11-13.

The following is a list of some of the bridge superstructure types that have been identified as susceptible to fatigue cracking. However, other steel bridges are still at risk for failure and Fracture Critical Inspections are not limited to the structure types provided in this list. The bridges are listed in order, with the most susceptible first:

1) Suspended spans with two girders
2) Bar-chain suspension bridge with two eyebars per panel
3) Welded, tied arches with box-shaped tie girder
4) Simple span truss with two eyebars or single member between panel points
5) Simple-span, single-welded box girders with details such as termination of longitudinal stiffeners or gusset plate
6) Simple-span, two-girder bridges with welded partial-length cover plates on the bottom flange
7) Continuous-span, two-girder system with cantilever and suspension link arrangement and welded partial-length cover plates
8) Simple-span, two-girder system with lateral bracing connected to horizontal gusset plates which are attached to webs
9) Single-welded I-girder or box girder pier cap with bridge girders and stringers attached by welding
SECTION 11.7 THE FRACTURE CRITICAL INSPECTION

Proper identification, classification, inspection, and reporting of all fracture critical bridges and the subsequent members are crucial to the longevity of Indiana’s bridges and the safety of the public. Uniformity in reporting permits the inspectors to accurately and closely monitor any problems throughout the life of the structure. Detailed and accurate reporting also permits the bridge owner to maintain and repair the bridge before major problems evolve.

Subsection 11.7.1 Classification of Fracture Critical Members

The FHWA defines a fracture critical member as a steel member in tension, or with a tension element, whose failure would probably cause a portion of, or the entire, bridge to collapse. A fracture critical bridge is one that contains a fracture critical member. The FHWA presents two criteria for identifying a fracture critical bridge:

- Steel members must be in tension, or elements/fibers of the member must be in tension. These loading conditions may include tensile forces, shear, flexure, and torsion. Load analysis ratings may indicate some members experience a stress reversal (varies from tension to compression) under various loads. Such members are to be included under this criteria.

- There must be no load path redundancy of the bridge, in which no other structural elements are capable of carrying the load if a main load-carrying member fails. For a bridge to be defined as non-load path redundant, it must have two or less load paths.

Some typical bridges that may be considered fracture critical include, but are not limited to, these types:

- Truss bridges containing two main load-carrying members
- Through girder bridges
- Two-girder bridges
- Tied arch bridges
- Box girders
- Cable-stayed bridges
- Suspension bridges
- Steel rigid frame bridges
- Bridges containing steel cross-girders or steel pier caps
- Bridges with pin-and-hanger systems (will always be classified, at a minimum, as a special detail inspection, Item 92C)
- Movable bridges

See Appendix B for examples of fracture critical bridges, components, bending
diagrams, typical crack locations, and typical pin-and-hanger parts. Timber covered bridges (trusses) with steel vertical tension hangers are not coded as fracture critical (Item 92A). Unless a structural analysis indicates these are primary members, they are to be considered a secondary member (non-fracture critical).

Once a bridge is designated as fracture critical, each individual member and connection must be identified for the inspection. Any attachment connected to the tension area of a fracture critical member and having a length in the direction of the tension stress greater than four inches shall be considered part of the tension component and, therefore, shall be considered fracture critical. For definition purposes and uniformity in reporting, the portions of the fracture critical member within a minimum of 12 inches of the entire connection (gusset plates, connection plates, etc.) shall be considered a fracture critical connection, whereas the portion of the tension member beyond the 12-inch window shall be considered a fracture critical member. See Figures 4:11-14 through 4:11-16 for examples of this definition. The Inspection Team Leader shall use sound judgment to expand the minimum 12-inch criteria to include additional fatigue details, and also consider the scale of the bridge and associated members. Floor beam connections, lateral bracing connections, bearings, gusset plates, connection angles, pins, hangers, etc. are all typically considered as part of the fracture critical connection.

![Fracture Critical Truss Connection](image_url)
In the event that original design plans of a fracture critical bridge clearly indicate that a tension member is not fracture critical due to internal redundancies within the bridge, these members will still require a detailed Fracture Critical Inspection. These tension members may only be omitted from the Fracture Critical Inspection if permission is given by the owner and the State Program Manager prior to the inspection.
Subsection 11.7.2 Inspector Qualification

All Inspection Team Leaders for fracture critical bridges must:

1) Meet requirements in Part 1, Chapter 2

2) Possess adequate knowledge and understanding of how a fracture critical bridge functions, and where possible defects may occur;

3) Possess suitable knowledge of the function of the specific bridge undergoing the inspection and, subsequently, the more complex bridges will warrant more knowledgeable, experienced inspectors; knowledge includes the understanding and ability to perform testing or recommend advanced testing procedures at problem areas; must be current on issues with the type of bridges being inspected

4) Physical ability to provide a hands-on inspection of all fracture critical members and connections in the individual bridge, as defined in Section 11.2.5

For complex bridges that contain fracture critical members, additional requirements for the inspection of complex bridges are required as directed in Part 1, Chapter 2.

Subsection 11.7.3 Inspection Interval

Fracture Critical Inspections shall be performed at a regular interval not to exceed 24 months. If necessary, the inspection interval may be reduced. The inspection may be a supplemental inspection to the Routine Inspection. An entire bridge may require a 24-month Fracture Critical Inspection while several elements are identified for a six-month inspection cycle. The fracture critical Plan of Action must describe all fracture critical elements and their frequency of inspection that differ from the 24-month inspection cycle or the inspection cycle for the entire bridge.

Subsection 11.7.4 Inspection Preparation

The fracture critical Plan of Action must be developed and/or reviewed and updated prior to performing a Fracture Critical Inspection. The inspection Plan of Action plays a crucial role in assisting all current and future inspectors at the bridge. The Plan of Action serves as an important first step in performing a thorough and complete investigation of all fracture critical members, while identifying necessary means, methods, and equipment required to perform this inspection. The inspection Plan of Action is a required element for every fracture critical report. Although, these minimum requirements must be met for acceptance of the report by the Indiana Department of Transportation (INDOT), the inspecting agency may provide alternate inspection plan formats meeting internal guidelines, provided the criteria set forth in this chapter are met. A full sample report, including the inspection Plan of Action is included in Appendix C.

At a minimum, the inspection Plan of Action shall include the following:

1) Sketch(es) of the superstructure with locations of all fracture critical members and connections clearly identified; primary members that are not fracture critical should be clearly identified, as well
2) An elevation view for trusses with locations labeled by letters and numbers similar to the nomenclature indicated in Figure 4:11-17

3) Use a framing plan and elevation view for a through girder with detail locations labeled by letters and numbers similar to the nomenclature indicated in Figure 4:11-18

4) A north arrow

5) A general listing of all fracture critical members

6) A brief historical fact statement, such as a summary of repairs and rehabilitations or prior history of any problems

7) All inspection tools and access equipment required/used for the inspection

8) Traffic control requirements

9) Method used to measure the thickness of primary truss gusset plates and which gusset plates were measured using each method shall be clearly identified

10) Bridge cleaning requirements

11) Inspection frequency and identification of any fracture critical elements that require an inspection frequency different than the inspection frequency for the entire bridge

Other items that should be reviewed and made available to the inspector, if available, prior to the inspection include the following:

10) Existing bridge plans and any repair/rehabilitation plans

11) Historical data and maintenance history of the bridge

12) Prior load ratings or a preliminary load rating (invaluable in determining fracture critical members)

13) Prior inspection reports

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**TYPICAL ELEVATION SKETCH (TRUSS) AND NOMENCLATURE**

![Typical Elevation Sketch (Truss)](image)

Note: Alternate LO-L8 and U1-U7 is acceptable nomenclature

Fracture Critical Member

Non - Fracture Critical Member
Subsection 11.7.5 Field Inspection

The FHWA requires a hands-on inspection of all fracture critical members and/or components. Hands-on is defined as being within arm’s reach (two feet) of these components. INDOT firmly enforces the hands-on requirement during inspections due to the relatively small size and difficulty in locating cracks and adequately inspecting fatigue and other details. The hands-on inspection requirement warrants the utilization of ladders, man lifts, free climbing, and snooper vehicles to inspect all fracture critical components and members. Cracks and other deficiencies cannot be adequately located and inspected with the utilization of binoculars or outside of the inspector’s reach from the member.

Primary compression members, floor beams, and secondary members such as lateral bracing, portal bracing, etc. are not considered fracture critical. These items require inspection and reporting during the Routine Inspection cycle. However, special consideration should be given to ensure that all primary and secondary members are inspected during the Routine or Fracture Critical Inspection and that no members have been missed during the entire inspection cycle. At a minimum, the Inspection Team...
Leader should perform a brief walkthrough of all secondary and non-fracture critical primary members during the Fracture Critical Inspection as a simple means to ensure all members have been inspected. When expensive equipment such as a snooper vehicle or man lift is utilized during the Fracture Critical Inspection, the Inspection Team Leader should strongly consider and plan to utilize this equipment for the inspection of any difficult-to-inspect, non-fracture critical members or problem areas on the bridge.

Many fracture critical members and connections are often covered in dirt and debris. The dirt and debris can contribute to the deterioration of these members, and the dirtiest areas are often in the worst condition. INDOT requires all fracture critical members and components to be adequately cleaned and free of debris prior to the hands-on inspection. Typical areas that warrant cleaning are bearings and lower chords. Power washers, hand brooms, brushes, and shovels are effective tools to provide for an adequate inspection of members. The Inspection Team Leader may wish to coordinate with state or local maintenance crews to perform this work prior to the inspection; however, it is the responsibility of the inspector to ensure that all components are clearly visible and adequately cleaned. Special consideration must be given to the presence of lead-based paint during any bridge cleaning. This may prove harmful to the inspector and the environment if disturbed.

It is imperative that the inspector adequately identify and inspect each fracture critical member and fatigue detail. The FHWA suggests inspection for fatigue cracks in welded bridges should be performed at, but not limited to, the following locations:

For out-of-plane distortion in welded bridges, inspect the following locations:

1) Girder webs at floor beam and diaphragm connections
2) Ends of diaphragm connection plates in girder bridges
3) Box girder webs at diaphragms
4) Lateral bracing gusset plates on girder webs at floor beam connections
5) Floor beam and cantilever bracket connections to girders
6) Pin-connected hanger plates and fixed-pin plates

For main members in welded bridges, inspect the following locations:

1) Ends of welded cover plates
2) Groove welds in flange plates
3) Butt welds in longitudinal stiffeners
4) Web plates with cut-outs and filler welds
5) Intersecting groove welds
6) Welded repairs and reinforcement
7) Back-up bar splices
8) Stress risers
For connections and attachments in welded bridges, inspect the following locations:

1) Cut short flanges
2) Coped beam ends
3) Blocked flange plates
4) Welded rigid connections of cross-girders at bents
5) Welded flange attachments
6) Intersecting welds at gusset plates and diaphragms
In general, the locations where fatigue cracks develop in riveted and bolted bridges are similar to those in welded bridges. The FHWA suggests inspection for fatigue cracks in riveted or bolted bridges should be performed at, but not limited to, the following locations:

1) Rivets/bolts at end connections (check for cracking and prying)
2) End connection angle
3) Girder webs at floor beam connections
4) Floor beam connections to girders
5) Diaphragm connections to girders
6) Cantilever bracket connections to girders
7) Truss hangers
8) Eyebars (see Figures 4:11-19 and 4:11-20)
9) Tack welds
10) Rivet heads and bolts made of certain types and ages of steel on older bridges may have fatigue issues, especially if pack rust has developed between connection members; additional stress may be placed on the nut or rivet head at these locations.

The thickness of primary truss gusset plates should be measured as a part of a Fracture Critical Inspection. If the section cannot be adequately measured with traditional measurement devices, inspectors should use an appropriate NDT technology to assess the gusset plate condition and quantify the plate thickness.
Subsection 11.7.6 Field Inspection Reporting

Each bridge owner has unique requirements and preferences for bridge reporting. The guidelines listed in this section are the minimum reporting requirements for acceptance of a fracture critical report. Although these minimum requirements must be met for acceptance of the report by INDOT, the inspecting agency may provide alternate report formats meeting internal guidelines, as long as the criteria set forth in this chapter are met. An example inspection report has been provided in Appendix C. The following are minimum requirements for a Fracture Critical Inspection report:

1) Inspection Plan of Action
2) General statement discussing inspection procedures
3) Date, temperature, and weather conditions of the inspection
4) Time duration of the inspection
5) Inspection Team Leaders and Inspection Team Members present at the inspection
6) General summary of inspection results
7) Testing performed, and locations of these tests
8) Recommendations for repairs and maintenance, highlighting urgent repairs and listing programmed repairs
9) Photographs of every fracture critical member, connection, or component assigned a condition rating of 4 or less
10) Photographs of each fracture critical member at a frequency of not greater than 10 years (to be included in the bridge file)
11) Photographs of any cracks inspected or discovered

12) Recommended inspection interval

13) Documentation of inspection results for each individual member and/or component, including the following:
   a) Individual member rating
   b) Noted section loss
   c) AASHTO fatigue category
   d) Brief statement discussing the presence of cracks (or lack thereof)
   e) Adequate documentation of fatigue damage
   f) A table of showing the primary truss gusset plates, the thickness measurement taken, the location of each measurement, and the inspection procedure used to take each measurement

Figure 4:11-103: Inspector Performing Hands-On Inspection
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# APPENDIX A  FATIGUE-PRONE DETAILS

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<td><strong>Plain Member</strong></td>
<td>Base metal with rolled or cleaned surface. Flame-cut edges with American National Standards Institute (ANSI) smoothness of 1,000 or less.</td>
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<tr>
<td><strong>Built-Up Members</strong></td>
<td>Base metal and weld metal in members of built-up plates or shapes (without attachments) connected by continuous full penetration groove welds (with backing bars removed), or by continuous fillet welds parallel to the direction of applied stress.</td>
<td>T or Rev</td>
<td>B</td>
<td>3,4,5,7</td>
</tr>
<tr>
<td></td>
<td>Base metal and weld metal in members of built-up plates or shapes (without attachments) connected by continuous full-penetration groove welds with backing bars not removed, or by continuous partial penetration groove welds parallel to the direction of applied stress.</td>
<td>T or Rev</td>
<td>B'</td>
<td>3,4,5,7</td>
</tr>
<tr>
<td></td>
<td>Calculated flexural stress at the toe of transverse stiffener welds on girder webs or flanges.</td>
<td>T or Rev</td>
<td>C</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Base metal at ends of partial-length, welded cover plates with high-strength, bolted, slip-critical end connections (see Note³).</td>
<td>T or Rev</td>
<td>B</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Base metal at ends of partial-length, welded coverplates narrower than the flange having square or tapered ends, with or without welds across the ends, or wider than the flange without welds across the ends.</td>
<td>T or Rev</td>
<td>E</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>(a) Flange thickness ≤ 0.8 in</td>
<td>T or Rev</td>
<td>E</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>(b) Flange thickness &gt; 0.8 in</td>
<td>T or Rev</td>
<td>E'</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Base metal at ends of partial-length, welded cover plates wider than the flange without welds across the ends.</td>
<td>T or Rev</td>
<td>E'</td>
<td>7</td>
</tr>
<tr>
<td><strong>Groove-Welded Connections</strong></td>
<td>Base metal and weld metal in or adjacent to full-penetration groove weld splices of rolled or welded sections having similar profiles when welds are ground flush with grinding in the direction of applied stress and weld soundness established by nondestructive testing.</td>
<td>T or Rev</td>
<td>B</td>
<td>8,10</td>
</tr>
<tr>
<td></td>
<td>Base metal and weld metal in, or adjacent to, full-penetration groove weld splices with 2-foot radius transitions in width, when welds are ground flush with grinding in the direction of applied stress and weld soundness established by nondestructive testing.</td>
<td>T or Rev</td>
<td>B</td>
<td>13</td>
</tr>
</tbody>
</table>
Base metal and weld metal in, or adjacent to, full-penetration groove weld splices at transitions in width or thickness, with welds ground to provide slopes no steeper than 1 to 2-1/2 inches, with grinding in the direction of the applied stress, and weld soundness established by nondestructive testing:

(a) American Association of State and Highway Transportation Officials (AASHTO) M 270 Grades 100/100W (American Society for Testing and Materials [ASTM] A 709) base metal

(b) Other base metals

Base metal and weld metal in, or adjacent to, full-penetration groove weld splices, with or without transitions having slopes no greater than 1 to 2-1/2 inches, when the reinforcement is not removed and weld soundness is established by nondestructive testing.

<table>
<thead>
<tr>
<th>Groove-Welded Attachments—Longitudinally Loaded</th>
<th>Base metal adjacent to details attached by full- or partial-penetration groove welds when the detail length, L, in the direction of stress, is less than 2 inches.</th>
<th>T or Rev</th>
<th>C</th>
<th>6, 15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base metal adjacent to details attached by full- or partial-penetration groove welds when the detail length, L, in the direction of stress, is between 2 inches and 12 times the plate thickness, but less than 4 inches.</td>
<td>T or Rev</td>
<td>D</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Base metal adjacent to details attached by full- or partial-penetration groove welds when the detail length, L, in the direction of stress, is greater than 12 times the plate thickness or greater than 4 inches:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T or Rev</td>
<td>E</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T or Rev</td>
<td>E'</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Base metal adjacent to details attached by full- or partial-penetration groove welds with a transition radius, R, regardless of the detail length:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>--With the end welds ground smooth:</td>
<td>T or Rev</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>(a) Transition radius ≥ 24 in</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) 24 in. &gt; Transition radius ≥ 6 in</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) 6 in. &gt; Transition radius ≥ 2 in</td>
<td>D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) 2 in. &gt; Transition radius ≥ 0 in</td>
<td>E</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>For all transition radii without end welds ground smooth.</td>
<td>T or Rev</td>
<td>E</td>
<td>16</td>
</tr>
</tbody>
</table>
### Groove-Welded Attachments—Transversely Loaded

Detail base metal attached by full-penetration groove welds with a transition radius, R, regardless of the detail length and with weld soundness transverse to the direction of stress established by nondestructive testing:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Transition Radius</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>With equal plate thickness and reinforcement removed:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Transition radius ≥ 24 in</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td>(b) 24 in. &gt; Transition radius &gt; 6 in</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>(c) 6 in. &gt; Transition radius ≥ 2 in</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>(d) 2 in. &gt; Transition radius ≥ 0 in</td>
<td>E</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Transition Radius</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>With equal plate thickness and reinforcement not removed:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Transition radius ≥ 6 in</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>(b) 6 in. &gt; Transition radius ≥ 2 in</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>(c) 2 in. &gt; Transition radius ≥ 0 in</td>
<td>E</td>
<td></td>
</tr>
</tbody>
</table>

### Fillet-Welded Connections

Base metal at details connected with transversely loaded welds, with the welds perpendicular to the direction of stress:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Thickness</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Detail thickness ≤ 0.5 in</td>
<td>T or Rev</td>
<td>C</td>
</tr>
<tr>
<td>(b) Detail thickness &gt; 0.5 in</td>
<td>T or Rev</td>
<td>See Note²</td>
</tr>
</tbody>
</table>

Base metal at intermittent fillet welds. Shear stress on throat of fillet welds.

### Fillet-Welded Attachments—Longitudinally Loaded

Base metal adjacent to details by fillet welds with length, L, in the direction of stress, is less than 2 inches and stud-type shear connectors.

Base metal adjacent to details attached by fillet welds with length, L, in the direction of stress, between 2 inches and 12 times the plate thickness, but less than 4 inches.

Base metal adjacent to details attached by fillet welds with length, L, in the direction of stress, greater than 12 times the plate thickness, or greater than 4 inches:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Thickness</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Detail thickness &lt; 1.0 in</td>
<td>T or Rev</td>
<td>E</td>
</tr>
<tr>
<td>(b) Detail thickness ≥ 1.0 in</td>
<td>T or Rev</td>
<td>E'</td>
</tr>
</tbody>
</table>

Note: See Note² for more details.
### Base metal adjacent to details attached by fillet welds with a transition radius, R, regardless of the detail length:

--With the end welds ground smooth:

(a) Transition radius ≥ 2 in

(b) 2 in. > Transition radius ≥ 0 in

--For all transition radii without the end welds ground smooth.

<table>
<thead>
<tr>
<th>Condition</th>
<th>T or Rev</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>With the end welds ground smooth</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>(a) Transition radius ≥ 2 in</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>(b) 2 in. &gt; Transition radius ≥ 0 in</td>
<td>E</td>
<td></td>
</tr>
</tbody>
</table>

### Fillet-Welded Attachments—Transversely Loaded with the Weld in the Direction of Principal Stress

Detail base metal attached by fillet welds with a transition radius, R, regardless of the detail length (shear stress on the throat of fillet welds governed by Category F):

--With the end welds ground smooth

(a) Transition radius ≥ 2 in.

(b) 2 in. > Transition radius ≥ 0 in.

--For all transition radii without the end welds ground smooth.

<table>
<thead>
<tr>
<th>Condition</th>
<th>T or Rev</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>With the end welds ground smooth</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>(a) Transition radius ≥ 2 in</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>(b) 2 in. &gt; Transition radius ≥ 0 in</td>
<td>E</td>
<td></td>
</tr>
</tbody>
</table>

### Mechanically Fastened Connections

Base metal at gross section of high-strength, bolted, slip-resistant connections, except at axially loaded joints which induce out-of-plane bending in connecting materials.

Base metal at net section of high-strength bolted bearing-type connections.

Base metal at net section of riveted connections.

<table>
<thead>
<tr>
<th>Condition</th>
<th>T or Rev</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal at gross section of high-strength, bolted slip-resistant connections</td>
<td>T or Rev</td>
<td>B 21</td>
</tr>
<tr>
<td>Base metal at net section of high-strength bolted bearing-type connections</td>
<td>T or Rev</td>
<td>B 21</td>
</tr>
<tr>
<td>Base metal at net section of riveted connections</td>
<td>T or Rev</td>
<td>D 21</td>
</tr>
</tbody>
</table>

### Eyebar or Pin Plates

Base metal at the net section of eyebar head or pin plate.

Base metal in the shank of eyebars, or through the gross section of pin plates with:

(a) rolled or smoothly ground surfaces.

(b) flame-cut edges.

<table>
<thead>
<tr>
<th>Condition</th>
<th>T or Rev</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base metal at the net section of eyebar head or pin plate</td>
<td>T</td>
<td>E 23,24</td>
</tr>
<tr>
<td>Base metal in the shank of eyebars, or through the gross section of pin plates with: (a) rolled or smoothly ground surfaces.</td>
<td>T</td>
<td>A 23,24</td>
</tr>
<tr>
<td>(b) flame-cut edges.</td>
<td>T</td>
<td>B 23,24</td>
</tr>
</tbody>
</table>

---

**a** “T” signifies range in tensile stress only. “Rev” signifies a range of stress involving both tension and compression during a stress cycle.


**c** “Longitudinally Loaded” signifies direction of approved stress is parallel to the longitudinal axis of the weld. “Transversely Loaded” signifies direction of applied stress is perpendicular to the longitudinal axis of the weld.

**d** Transversely loaded partial penetration groove welds are prohibited.

**e** Allowable fatigue stress range on throat of fillet welds transversely loaded is a function of the effective throat and plate thickness. (See Frank and Fisher, *Journal of the Structural Division*, ASCE, Vo. 105, No. ST9, Sept. 1979.)

**f** Gusset plates attached to girder flange surfaces with only transverse fillet welds are prohibited.
SIMPLE SPAN TRUSS
BENDING IN TRUSS

SIMPLE SPAN
a.

CONTINUOUS SPANS
b.

CANTILEVER-SUSPENDED SPANS
BENDING IN GIRDERS

SIMPLE BEAM

CONTINUOUS SPANS

CANTILEVER - SUSPENDED SPANS
Cracks being pulled open by tensile forces.
Fatigue Categories A, B (on eyebar body), or E (on net section of eyebar head)
Fatigue Category A, B (on hanger plate body), or E (on net section of hanger or pin plate)
Fatigue Categories E and E’
Web Out-of-Plane Bending at Floor Beam Connection Plate
APPENDIX C: SAMPLE REPORTS

SAMPLE SPECIAL INSPECTION REPORT – 2010

The inspecting agency may provide alternate report formats meeting internal guidelines, as long as the criteria set forth in the manual are met. The following sample report is intended to serve as a guide for how the report may be set up. Alternate reporting formats may be provided subsequent to the review and approval by the Indiana Department of Transportation (INDOT).

Reviewing Owner Representative:
Name – County Engineer or Commissioner: ________________________________

Prepared by: __________________________________________________________

Certified: _______________________
(Name, P.E.)

Date: ________________________________
### UNNAMED COUNTY – SPECIAL DETAIL BRIDGE INSPECTION

**PERSONNEL LISTING & TEAM LEADER STATEMENT**

<table>
<thead>
<tr>
<th>Biennial Insp.</th>
<th>Fracture Critical</th>
<th>Under-water</th>
<th>Special Detail</th>
<th>Load Rating</th>
<th>NAME AND TITLE</th>
<th>QUALIFICATIONS</th>
<th>RESPONSIBILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>P.E. 00000000 Indiana BSCE XXX University, 1900X</td>
<td>Team Leader</td>
<td>Project Supervision</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Team Leader</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Final Review of Load Ratings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Final QC Review of Detail Insp. Report</td>
</tr>
</tbody>
</table>

Team Leaders, name, name and name were present and were actively involved in the Field Inspections of the special detail bridge in Unnamed County.

---

name, name, name, Quality Control Officer
I. INTRODUCTION

A. Location and Description

Bridge No. 001 is located 0.1 miles east of State Road 99. Map location is at D-3. The bridge carries traffic on Main Street over Nameless Creek. The bridge is located at latitude of 39°00'01.1" and longitude of 86°00'01.1".

Bridge No. 001 is a single-span, timber, covered, burr arch, truss bridge that is on the National Register of Historic Places. The structure has no skew, has a length of 190 feet, and a maximum span length of 182 feet. The structure has a clear roadway width of 14.4 feet, which categorizes it as a “One-Lane Bridge.” The average daily traffic was estimated to be 100 vehicles per day in 2010. The bridge has an H rating of five tons, an HS Inventory Rating of 9, and an HS Operating Rating of 12.

B. History

The estimated year of construction for Bridge No. 001 is 1888 and it has been reconstructed in 2003 and repaired in 2008.

II. FIELD INVESTIGATION

A. Members and Connections to be Inspected

Inspect all main load-carrying members, including splices and panel points, timber through arch truss, and all connections.

B. Inspection Procedures

An up-close, visual inspection was performed to locate possible problem areas of the superstructure. Borings for determining decay of members was not warranted at this location due to the condition of the members.

C. Equipment Required for Inspection

Tools and equipment used to inspect each member or connection included a hard hat,
safety glasses, hammer, tape measure, camera, and a flashlight. A drill for borings was available for a more detailed inspection of rotting members if needed. A 20' extension ladder was used to inspect the upper chord connections and various members, and lower chord connections and various members were inspected from the bridge deck.

D. Bridge Cleaning Requirements

The bearings contained heavy dirt and roadway debris. A shovel and hand brush were utilized by the inspector to clean these locations.

E. Traffic Maintenance Requirements

Due to the low vehicular speeds and average daily traffic (ADT) of the bridge, no temporary roadway closures were required. A flagger and temporary signage was provided during the inspection.

F. Date and Conditions of Inspection

Date: 6/27/2009
Temperature: 83° F
Conditions: Sunny
Inspection Duration: Three hours

G. Other Items

Original bridge plans were not available. Rehabilitation and repair plans, dated 2001, were provided by the county. The previous Inspection Consultant provided copies of load ratings, as well as previous inspection reports. Field notes tracking several deficiencies were made available by the previous Inspection Consultant in order to monitor the development of several deficiencies at the bridge.

III. SUMMARY OF INSPECTION RESULTS

The overall condition of the cover timber bridge deck is very good, while the superstructure is in fair condition, and the substructure is in good condition. The bridge was damaged by a tractor in 2007, and all damage was repaired in 2008. New floor beams, stringers, siding, and arch and truss members were added during the 2001 reconstruction. The structure is posted with a weight limit of five tons, and is posted as a one-lane bridge with a 12’-6” vertical height clearance.

A. Connections

All of the connections were in satisfactory to good condition with the exception of:

a) SE L3U4 lower connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 2" from its original position. Minor cracking and splitting are present with no additional signs of overstressing or deterioration.

b) E L3U4 upper connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 1/2" from its original position. Minor cracking and splitting are present with no additional signs of overstressing or deterioration.
c) SW L3U4 lower connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 1 3/4" from its original position. Moderate cracking and splitting are present with some potential signs of overstressing.

d) W L3U4 lower connection, which is in fair condition. This connection exhibits separation of the connection and has migrated approximately 3/4" from its original position. Minor cracking and splitting are present with no additional signs of overstressing or deterioration.

B. Members

All of the members are in satisfactory to good condition. Most members typically exhibit minor splitting at various locations. Minor vehicular damage is still present at the arch and SE L3U3, SE L2U2, and SE L2U3.

C. Floor System

The floor beam connections are in satisfactory condition and exhibit minor cracking and splitting at various members.

IV. NBIS CODING INFORMATION

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CODE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>92C: Special Inspection (Other)</td>
<td>Y24</td>
<td>Special Inspection every 24 months</td>
</tr>
<tr>
<td>Inspection Date</td>
<td>0609</td>
<td>Inspection Date was June, 2009</td>
</tr>
</tbody>
</table>

V. SUMMARY OF RECOMMENDATIONS

Programmed Repairs: In general, the timber covered bridge requires routine maintenance such as re-nailing the deck. The bridge requires standard bridge rail, adequate approach rail with end treatments, and bridge end markers at all bridge corners.

Urgent Repairs: Repairs to connections SE lower L3U4, upper E L3U4, lower SW L3U4, and upper W L3U4 are recommended. These recommendations include repairing the movement of the members at the connections because there is a potential for failure at the connections if these locations are overstressed or deterioration persists.
### Panel Point at Southeast L0:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing</td>
<td>6</td>
<td>Heavy debris build-up. Member shows minor signs of rot with localized areas of moderate rotting at bearing beam. No signs of distress.</td>
</tr>
<tr>
<td>Floor Beam</td>
<td>8</td>
<td>Connection was replaced in 2001. No signs of deterioration or distress.</td>
</tr>
<tr>
<td>Vertical (L0U0)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Diagonal (L0U1)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (L0L1)</td>
<td>6</td>
<td>Minor splits and deterioration. Member shows minor signs of rot due to heavy debris build up. No signs of distress.</td>
</tr>
</tbody>
</table>

### Panel Point at Southeast L1:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Beam</td>
<td>8</td>
<td>Connection was replaced in 2001. No signs of deterioration or distress.</td>
</tr>
<tr>
<td>Vertical (L1U1)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Diagonal (L1U2)</td>
<td>6</td>
<td>Minor splits and deterioration. Connection appears to show minor signs of movement. Appears to have migrated approx. ¼&quot; from the original position.</td>
</tr>
<tr>
<td>Lower Chords (L0L1 &amp; L1L2)</td>
<td>6</td>
<td>Minor splits and deterioration. Member shows minor signs of rot due to heavy debris build up. No signs of distress.</td>
</tr>
</tbody>
</table>

### Panel Point at Southeast L2:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Beam</td>
<td>8</td>
<td>Connection was replaced in 2001. No signs of deterioration or distress.</td>
</tr>
<tr>
<td>Vertical (L1U1)</td>
<td>7</td>
<td>Minor splits and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Diagonal (L1U2)</td>
<td>6</td>
<td>Minor splits and deterioration. Connection appears to show minor signs of movement. Appears to have migrated approx. ¼&quot; from the original position.</td>
</tr>
<tr>
<td>Lower Chords (L0L1 &amp; L1L2)</td>
<td>6</td>
<td>Minor splits and deterioration. Member shows minor signs of rot due to heavy debris build up. No signs of distress.</td>
</tr>
</tbody>
</table>

*In order to avoid redundancy, several pages of the Sample Report have been deleted.*
## EAST TRUSS LOWER CHORD MEMBERS:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arch (Southeast A0A2)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Arch (Southeast A2A4)</td>
<td>7</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. Repairs are in good condition. No signs of distress.</td>
</tr>
<tr>
<td>Arch (Northeast A2A4)</td>
<td>7</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. Repairs are in good condition. No signs of distress.</td>
</tr>
<tr>
<td>Arch (Northeast A0A2)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast L0L1)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast L1L2)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast L2L3)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Southeast L3L4)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast L3L4)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast L2L3)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast L1L2)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor splitting and at splice. Heavy rust on several bolts at splice connection. No signs of distress.</td>
</tr>
<tr>
<td>Lower Chord (Northeast L0L1)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L0U0)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L1U1)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L2U2)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (Southeast L3U3)</td>
<td>6</td>
<td>Minor splitting and deterioration. Minor vehicular impact damage. No signs of distress.</td>
</tr>
<tr>
<td>Vertical (East L4U4)</td>
<td>7</td>
<td>Minor splitting and deterioration. No signs of distress.</td>
</tr>
</tbody>
</table>

In order to avoid redundancy, several pages of the Sample Report have been deleted.
8/28/2009

SPECIAL DETAIL INSPECTION REPORT

REPAIRED ARCH MEMBER (TYP.)

REPAIRED TRUSS MEMBER (TYP.)

APPROACH LOOKING WEST

ELEVATION LOOKING NORTH

MOVEMENT AT LOWER SE L3U4 (TYP. SW L3U4)

MINOR VEHICULAR DAMAGE (TYP.)
8/28/2009 SPECIAL DETAIL INSPECTION REPORT BRIDGE NO. 001

MOVEMENT AT UPPER E L3U4 (TYP. WL3U4) MOVEMENT AT LOWER SW L3U4
The inspecting agency may provide alternate report formats meeting internal guidelines as long as the criteria set forth in the manual are met. The following sample report is intended to serve as a guide for how the report may be set up. Alternate reporting formats may be provided subsequent to the review and approval by INDOT.

Reviewing Owner Representative:
(Name) – County Engineer or Commissioner

Prepared by:

Certified ___________________________ Date: _________

name, P.E.
I. INTRODUCTION

A. Location and Description

Bridge No. 001 is located 0.1 miles south of State Road 99. The map location is at E-9. The bridge carries traffic on Main Street over Nameless Creek. The bridge is located at a latitude of N39°00'01.1" and a longitude of W86°00'01.1".

Bridge No. 001 is a single span steel pony truss. The structure is on an approximate zero degree skew. The structure length is 127 feet with a maximum span length of 124.0 feet. The structure has a clear roadway width of 28.0 feet. The average daily traffic was estimated to be 11083 vehicles per day in 2008. The bridge has an H rating of XX tons.

B. History

The estimated year of construction for Bridge No. 001 is 1946. The bridge was reconstructed in 1986 and repaired in 1995.
II. FIELD INVESTIGATION

A. Members to be Inspected

The following truss tension members are considered to be non-redundant, fracture critical bridge members:

- lower chords and lower chord connections
- diagonals and diagonal connections in tension
- verticals and vertical connections in tension
- floor beam connections

B. Inspection Procedures

An up-close visual inspection was performed to locate possible problem areas in the fracture critical members.

If any suspect surface discontinuities were found, a dye penetration test would be performed. This test can help locate stringers (long, thin laminations), scams (shallow, thin voids), laminations (flat, subsurface discontinuities), and cracks in the base metal. It is also of use in checking for weld-related cracking and porous groove welds. This was not needed at this bridge.

C. Equipment Required for Inspection

Tools and equipment used to inspect each member or connection included a hard hat, safety glasses, chipping hammer, scraper, wire brush, feeler gauges, calipers, tape measure, flashlight, magnifying glass, swivel mirror, camera, and a punch.

A dye penetration kit was available for a more detailed inspection if needed.

A 20’ extension ladder was used to inspect the upper chord connections and various members and lower chord connections and various members were inspected by free climbing with safety restraints.

D. Bridge Cleaning Requirements

The lower chord and bearings contained heavy dirt and roadway debris. The highway department power washed all lower chord members and bearings prior to the inspection. The highway department also removed heavy vegetation overgrowth around the bridge to assist in the inspection. Hand brushes and a scraper were utilized by the inspector to clean individual locations.

E. Traffic Maintenance Requirements

All lower chord members and connections were accessible without roadway restrictions. The highway department provided temporary roadway closures at each end of the bridge for the portions of the inspection requiring the utilization of a ladder.

F. Date and Conditions of Inspection

Date : 5/29/10
Temperature : 55° F
Conditions: Overcast
Inspection Duration: 5 hours

G. Other items

Original bridge plans were available to the inspector dated July 1945, as well as rehabilitation plans dated 1986 and repair plans dated 1995. The previous inspection consultant provided copies of load ratings as well as previous inspection reports. Field notes tracking several deficiencies were made available by the previous inspection consultant in order to monitor the development of several deficiencies at the bridge.

III. SUMMARY OF INSPECTION RESULTS

A. Connections

All of the connections were in satisfactory to good condition with the exception of NE L1U1 which is in fair condition. No deterioration or section loss was found that would affect the load capacity of any fracture critical connections. Debris has accumulated at the lower chord connections. No cracks were found.

B. Members

All of the members are in satisfactory to good condition, with the exception of SW L1U1 which is in fair condition. No deterioration or section loss was found that would affect the load capacity of any fracture critical members. Debris has accumulated on the lower chord. No cracks were found.

IV. NBIS CODING INFORMATION

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CODE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>92A: Fracture Critical Details Inspection (Non-Redundant)</td>
<td>Y24</td>
<td>Fracture critical inspection every 24 months</td>
</tr>
<tr>
<td>93A: Fracture Critical Details Inspection Date</td>
<td>05/29/2010</td>
<td>Inspection date, May, 2010</td>
</tr>
</tbody>
</table>

V. SUMMARY OF RECOMMENDATIONS

Programmed Repairs: The lower chord should be cleaned regularly to remove debris.

Urgent Repairs: None
VI. FIELD NOTES

The following rating system was used to rate the fracture critical members and connections:

9 Excellent Condition
8 Very Good Condition - No noteworthy deficiencies
7 Good Condition - Some minor problems
6 Satisfactory Condition - Minor structural deterioration
5 Fair Condition - Minor section loss
4 Poor Condition - Advanced section loss, deterioration
3 Serious Condition - Local failures are possible
2 Critical Condition - Advanced deterioration of primary elements
1 Imminent Failure Condition - Major deterioration - Structure should be closed
0 Failed Condition - Out of service - Bridge condition beyond corrective action

Connection at Southwest L0:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>FATIGUE CAT.</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Chord</td>
<td>D</td>
<td>6</td>
<td>Light surface rust and moderate pitting. Minor expansion rust at floor beam connection angle. Areas of heavy pitting with minor section loss on inside flanges and top and bottom of web. No cracks evident.</td>
</tr>
<tr>
<td>Bearing</td>
<td>D</td>
<td>7</td>
<td>Light surface rust and minor pitting. Minor expansion rust between angles and plates and between gusset plates and lower chord flanges. Bearings near limit of rotation. No cracks evident.</td>
</tr>
<tr>
<td>Floor Beam</td>
<td>B</td>
<td>7</td>
<td>Light surface rust on repairs and bolted connection. No cracks evident</td>
</tr>
</tbody>
</table>


Connection at Southwest L1:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>FATIGUE CAT.</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Chord</td>
<td>E</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting with minor section loss on inside flanges and top of web. One rivet head is missing on each angle. Expansion rust between gusset plate and flange with minor section loss. Welded repairs to member have created a fatigue prone detail however no cracks evident.</td>
</tr>
<tr>
<td>Vertical (L1U1)</td>
<td>D</td>
<td>6</td>
<td>Light surface rust and minor pitting. Minor expansion rust and section loss at floor beam connection on inside flange. 20% section loss at inside flange at plate connection. No cracks evident.</td>
</tr>
<tr>
<td>Floor Beam</td>
<td>D</td>
<td>6</td>
<td>Light surface rust, minor section loss, and minor pitting. Minor expansion rust at floor beam connection on inside flange. No cracks evident.</td>
</tr>
</tbody>
</table>
Connection at Southwest L2:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>FATIGUE CAT.</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Chord</td>
<td>D</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges, top of web, and on rivets. 15-20% section loss of flange at gusset plate and flange connection. Expansion rust between splice plates at the lower chord web. No cracks evident.</td>
</tr>
<tr>
<td>Vertical (L2U2)</td>
<td>D</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flange under railing connection, on web at lower chord splice and on vertical connection plates. Minor out of plane distortion from impact damage below rail. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (L2U1)</td>
<td>D</td>
<td>7</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting, expansion rust and minor section loss on inside flange at gusset plate connection. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (L2U3)</td>
<td>D</td>
<td>7</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting, expansion rust and minor section loss on inside flange at gusset plate connection. No cracks evident.</td>
</tr>
<tr>
<td>Floor Beam</td>
<td>B</td>
<td>7</td>
<td>Light surface rust on repairs and bolted connection. No cracks evident.</td>
</tr>
</tbody>
</table>
Connection at Southwest L3:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>FATIGUE CAT.</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Chord</td>
<td>D</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges, top of web, and on rivets. No cracks evident.</td>
</tr>
<tr>
<td>Vertical (L3U3)</td>
<td>D</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and on inside flange and web. Heavy expansion rust at inside flange and lower chord connection. No cracks evident.</td>
</tr>
<tr>
<td>Floor Beam</td>
<td>D</td>
<td>6</td>
<td>Light surface rust and minor pitting. Minor expansion rust at floor beam connection angles and lower flange connection. No cracks evident.</td>
</tr>
</tbody>
</table>

*In order to avoid redundancy, several pages of the Sample Report have been deleted.*
West Truss Lower Chord Members:

<table>
<thead>
<tr>
<th>MEMBER</th>
<th>FATIGUE CAT.</th>
<th>RATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Chord (Southwest L0L1)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. No cracks evident.</td>
</tr>
<tr>
<td>Lower Chord (Southwest L1L2)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. No cracks evident.</td>
</tr>
<tr>
<td>Lower Chord (Southwest L2L3)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. No cracks evident.</td>
</tr>
<tr>
<td>Lower Chord (Southwest L3L4)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. Heavy section loss of rivet heads (50-75%) at splice in web only. No cracks evident.</td>
</tr>
<tr>
<td>Lower Chord (Northwest L3L4)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. Heavy section loss of rivet heads (20%) at splice in web only. No cracks evident.</td>
</tr>
<tr>
<td>Lower Chord (Northwest L2L3)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. No cracks evident.</td>
</tr>
<tr>
<td>Lower Chord (Northwest L1L2)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. No cracks evident.</td>
</tr>
<tr>
<td>Lower Chord (Northwest L0L1)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting and minor section loss on inside flanges and on top of web. No cracks evident.</td>
</tr>
<tr>
<td>Vertical (Southwest L1U1)</td>
<td>A</td>
<td>5</td>
<td>Light surface rust and moderate pitting. Areas of heavy pitting on inside of south web with 20% section loss on web. No cracks evident.</td>
</tr>
<tr>
<td>Vertical (Southwest L2U2)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. Localized areas of surface rust and moderate pitting. No cracks evident.</td>
</tr>
<tr>
<td>Vertical (Southwest L3U3)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of heavy pitting, surface rust and minor section loss on inside flanges and on north face of web.</td>
</tr>
</tbody>
</table>
No cracks evident.

<table>
<thead>
<tr>
<th>Vertical (West L4U4)</th>
<th>A</th>
<th>7</th>
<th>Light surface rust and minor pitting. No cracks evident.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical (Northwest L3U3)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. No cracks evident.</td>
</tr>
<tr>
<td>Vertical (Northwest L2U2)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. No cracks evident.</td>
</tr>
<tr>
<td>Vertical (Northwest L1U1)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (Southwest L2U1)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (Southwest L2U3)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. Localized areas of surface rust and moderate pitting. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (Southwest L4U3)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. Localized areas of surface rust. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (Northwest L4U3)</td>
<td>A</td>
<td>6</td>
<td>Light surface rust and minor pitting. Areas of web with heavy pitting and section loss. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (Northwest L2U3)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. No cracks evident.</td>
</tr>
<tr>
<td>Diagonal (Northwest L2U1)</td>
<td>A</td>
<td>7</td>
<td>Light surface rust and minor pitting. No cracks evident.</td>
</tr>
</tbody>
</table>

Note: Heavy debris accumulation on lower chords. Large areas of paint are beginning to peel on members.

West Gusset Plates with Corrosion and Requiring Non-Destructive Evaluation:

<table>
<thead>
<tr>
<th>CONNECTION</th>
<th>THICK.</th>
<th>LOCATION/METHOD OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southwest L0</td>
<td>½&quot;</td>
<td>Ultra-sonic Testing. Dimension taken 3&quot; past the end of the interior lower chord.</td>
</tr>
<tr>
<td>Northwest U3</td>
<td>½&quot;</td>
<td>Ultra-sonic Testing. Dimension taken between vertical Northwest L3U3 and Diagonal Northwest L2U3. A man-lift was required for testing</td>
</tr>
</tbody>
</table>
In order to avoid redundancy, several pages of the Sample Report have been deleted.