Inspection of Bridge Decks (BIRM)

Course No: S06-002
Credit: 6 PDH

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Topic 5.1 Timber Decks

5.1.1 Introduction

Timber bridges make up approximately 7% of the bridges listed in the National Bridge Inventory (NBI). Furthermore, approximately 7% of the steel bridges, which are categorized as steel bridges in the NBI also have timber decks. Timber can be desirable for use as a bridge decking material because it is resistant to deicing agents, which typically harm concrete and steel, and it is a renewable source of material. Timber can also withstand relatively larger loads over a short period of time when compared to other bridge materials. Finally, timber is easy to fabricate in any weather condition and is lightweight.

5.1.2 Design Characteristics

Timber decks are normally referred to as decking or timber flooring, and the term is generally limited to the roadway portion which receives vehicular loads. Timber decks are usually considered non-composite because of the inefficient shear transfer through the attachment devices between the deck and superstructure. The basic types of timber decks are:

- Plank decks
- Nailed laminated decks
- Glued-laminated deck panels
- Stressed-laminated decks
- Structural composite lumber decks

Plank Decks

Plank decks consist of timber planks laid transversely across the bridge (see Figure 5.1.1). The planks are individually attached to the bridge beams using spikes or bolt clamps, depending on the beam material. It is common for plank decks to have 50 mm (2-inch) depth timbers nailed longitudinally on top of the planks to distribute load and retain the bituminous wearing surface.

Figure 5.1.1 Plank Deck

Nailed Laminated Decks

Nailed laminated decks consist of timber planks with the wide dimensions of the planks in the vertical position and laminated by through-nailing to the adjacent planks (see Figure 5.1.2). On timber beams, each lamination is toenailed to the beam. On steel beams, clamp bolts are used as required. In either case, laminates are generally perpendicular to the roadway centerline.

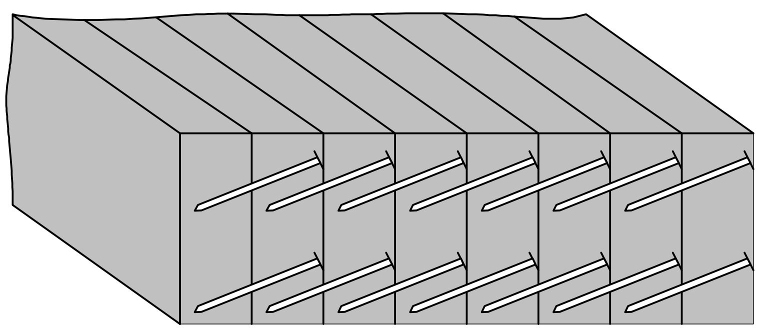

Figure 5.1.2 Section of a Nailed Laminated Deck

Glued-laminated Deck Panels

Glulam is an engineered wood product in which pieces of sawn lumber are glued together with waterproof adhesives. Glued laminated deck panels come in sizes usually 1.2 m (4 feet) wide. The panels are laid transverse to the traffic and are attached to the superstructure. In some applications, the panels are interconnected with dowels. There are several techniques used to attach glued-laminated decks to the superstructure or a floor system, including nailing, bolting, reverse bolting, clip angles and bolts, and nailers (see Figure 5.1.3).

The nailing method is generally not preferred due to the possibility of the nails being pried loose by the vehicle traffic.

Bolting the deck to the superstructure or floor system provides a greater resistance to uplift than nailing, but bolts may still be pried loose.

Reverse bolting involves fastening the bolts to the underside of the deck on either side of the superstructure members, thereby preventing the lateral movement of the deck. This is a rare type of connection.

Clip angles and bolts involve attaching clip angles to the beams or stringers and then using bolts to attach the clip angles to the deck.

Nailers are planks that run along the top of steel superstructure flanges. This technique involves the bolting of the nailers to the flanges and nailing the timber planks to the nailers. This prevents the costly bolting of all planks to the steel superstructure.

Figure 5.1.3 Glued-laminated Deck Panels

Stressed-laminated Decks

Stressed-laminated decks are constructed of sawn lumber glulam wood post-tensioned transversely utilizing high strength steel bars. Stressed timber decks consist of thick, laminated timber planks which usually run longitudinally in the direction of the bridge span. The timber planks vary in length and size. The laminations are squeezed together by prestressing (post-tensioning) high strength steel bars, spaced approximately 600 mm (24 inches) on center. With a hydraulic jacking system tensioning the bars, they are passed through predrilled holes in the laminations. Steel channel bulkheads or anchorage plates are then used to anchor the prestressing bars. This prestressing operation creates friction connections between the laminations, thereby enabling the laminated planks to span longer distances (see Figure 5.1.4).

Prestressed laminated decks are used on a variety of bridge superstructures, such as trusses and multi-beam bridges, and they can be used as the superstructure itself for shorter span bridges.

Figure 5.1.4 Stressed-laminated Deck

Structural Composite Lumber Decks

Structural composite lumber (SCL) decks include laminated veneer lumber (LVL) and parallel strand lumber (PSL). Laminated veneer lumber is fabricated by gluing together thin sheets of rotary-peeled wood veneer with a waterproof adhesive. Parallel strand lumber is fabricated by taking narrow strips of veneer and compressing and gluing them together with the wood grain parallel. SCL bridge decks are gaining popularity and are comprised of a parallel series of fully laminated LVL or PSL T-beams or a parallel series of fully laminated LVL or PSL box beams. The T-beams and box sections run parallel with the direction of traffic and are cambered to meet the needs of the specific bridge site. The box sections or T-beams are stress laminated together by either placing steel bars or prestressing strands through the top flanges (timber deck area) and/or through the outside edges of the box section top flanges. Steel channels or bearing plates are then placed on the bars or strands with double nuts. Standard strand chucks are placed on the opposite end to initiate the prestressing process. The prestressing bars or strands are generally epoxy coated to resist corrosion (see Figure 5.1.5).

Structural composite lumber decks are capable of full preservative penetration, and asphalt overlays are typical.

Figure 5.1.5 Structural Composite Lumber Deck Using Box Sections

5.1.3 Wearing Surfaces

The wearing surface of a timber deck is constructed of timber, bituminous materials, or concrete. Timber wearing surfaces usually run parallel with traffic and are used with transverse plank decks. Bituminous wearing surfaces can either be hot mix asphalt or a chip and seal method. Concrete wearing surfaces for timber decks are less common than timber or bituminous wearing surfaces, although some exist.

Timber

A timber wearing surface may consist of longitudinal timbers placed over the transverse decking. Runner planks or "running boards" are planks placed longitudinally only in the wheel paths where the vehicles ride (see Figure 5.1. 6).

Figure 5.1.6 Timber Wearing Surface on a Timber Deck

Bituminous

Bituminous or asphalt wearing surfaces generally utilize a coarse aggregate mix. The aggregate is mixed with a binder substance that holds the aggregate together and bonds the surfacing to the deck. Asphalt is a popular bituminous wearing surface for timber decks. However, it is not commonly used on plank decks because deflection of the planks will cause the asphalt to break apart.

Concrete

While concrete may be used as a wearing surface on timber decks, it is not frequently used for this purpose. However, new composite studies between concrete overlays and timber decks are being performed. These studies generally involve a timber deck with steel shear studs doweled into the timber deck with a concrete overlay completing the composite action.

5.1.4 Protective Systems

Protective systems are necessary to resist decay in timber bridge decks. Water repellents, preservatives, fumigants, fire retardants, and paints are some of the common timber protective materials. In order for the protective material to serve its purpose, the surface of the timber must be properly prepared.

Water Repellents

Water repellents help to prevent water absorption in timber decks, which slows decay by molds and weathering. The amount of water in wood directly affects the amount of expansion and contraction due to temperature. Water repellents are used to lower the water content of timber deck members and must be reapplied periodically. Because it needs to be applied rather frequently, it is not the best means of protecting timber structures.

Preservatives

Timber preservatives are usually applied by pressure, which forces the preservative into the timber deck member. The deeper the preservative penetration, the greater the protection from decay by fungi. Preservatives are the best way to protect against decay.

Preservatives are either oil-based or water-based. Some common oil-based preservatives are coal-tar creosote and pentachlorophenol. Chromated copper arsenate (CCA) is a very common water-based preservative.

Fumigants

Fumigants are applied to timber members in a liquid form through drilled holes. Once in the hole, the hole is plugged and the fumigant volatilizes and moves through the member as a gas, thus preserving the internal heartwood. Two common types of fumigants are chloropicrin and metham. These two fumigants are very hazardous and should only be applied by a professional. Also, the locations in which these fumigants can be applied are limited.

Fire Retardants

Fire retardants slow the spread of fire and prolong the time required to ignite the wood. The two main types of fire retardants are pressure impregnated salts and intumescent paints. These retardants insulate the wood, but adversely affect the material properties of wood.

Paint

Paints for timber decks can either be oil-based, oil-alkyd or latex-based. Oil-based paints provide the best barrier from moisture but is not very durable. Oil-alkyd paints have more durability than oil-based paints but contain lead pigments which cause various health hazards. Latex-based paints, on the other hand, are very flexible and resistant to chemicals.

5.1.5 Overview of Common Defects

A prepared bridge inspector should know what to look for prior to the inspection. The following is a list of common defects that may be encountered when inspecting timber bridge decks. Refer to Topic 2.1 for a detailed description of these common defects:

- Fungus decay
- Damage by parasites
- Deflection
- Checks
- Splits
- Shakes
- Loose connections
- Surface depressions
- Chemical attack

5.1.6 Inspection Procedures and Locations

Procedures

Visual

The inspection of timber decks for deterioration and decay is primarily a visual activity. All surfaces of the deck planks should receive a close visual inspection.

Physical

However, physical examinations must also be used for suspect areas. The most common physical inspection techniques for timber include sounding, probing, drilling, core sampling, and electrical testing. An inspection hammer should be used initially to evaluate the subsurface condition of the planks and the tightness of the fasteners. In suspect areas, probing can be used to reveal decayed planks using a pick test or penetration test (see Figure 5.1.7). A pick test involves lifting a small sliver of wood with a pick or pocketknife and observing whether or not it splinters or breaks abruptly. Sound wood splinters, while decayed wood breaks abruptly.

Figure 5.1.7 Inspector Probing Timber with a Pick at Reflective Cracks in the Asphalt Wearing Surface

Advanced Inspection Techniques

Several advanced techniques are available for timber inspection. Nondestructive methods, described in Topic 13.1.2, include:

- Pol-Tek
- Spectral analysis

- Ultrasonic testing
- Vibration

Other methods, described in Topic 13.1.3, include:

- Boring or drilling
- Moisture content
- Probing
- Shigometer

If the deck planks are over 50 mm (2 inches) thick, suspect planks should be drilled to determine the extent of decay. If decks are drilled, a protectant should be applied and the hole should be plugged with a wooden dowel.

Locations

Timber deck inspection generally includes visually interpreting the degree of decay on the top and, if visible, the bottom and sides of the deck. Also, all visible fastening devices and bearing areas should be inspected. In all instances, it is helpful if the inspector has the previous inspection report so that the progression of any deterioration can be noted. This provides a more meaningful inspection.

The primary locations for timber deck inspection include:

- **Areas exposed to traffic** – examine for wear, weathering, and impact damage (see Figure 5.1.8)
- **Bearing and shear areas** where the timber deck contacts the supporting superstructure – inspect for crushing, decay, and fastener deficiencies (see Figure 5.1.9)
- **Tension areas** between the support points – investigate for flexure damage, such as splitting, sagging, and cracks
- **Areas exposed to drainage** – check for decay, particularly in areas exposed to drainage (see Figure 5.1.10)
- **Outside edges of deck** – inspect for decay
- **Connections –** note any looseness that may have developed from inadequate nailing or bolting, or where the spikes have worked loose. Observation under passing traffic will reveal looseness or excessive deflection in the members
- **Nailed laminated areas –** swelling and shrinking from wetting and drying cause a gradual loosening of the nails, displacing the laminations; this permits moisture to penetrate the deck and superstructure, eventually leading to decay and deterioration of the deck. Check for loose, corroded or damaged nails
- **Prestressing anchorages** – check for tightness, corrosion, crushing, and decay
- **Fire damage** – check for any section loss or member damage caused by fire

Figure 5.1.8 Wear and Weathering on a Timber Deck

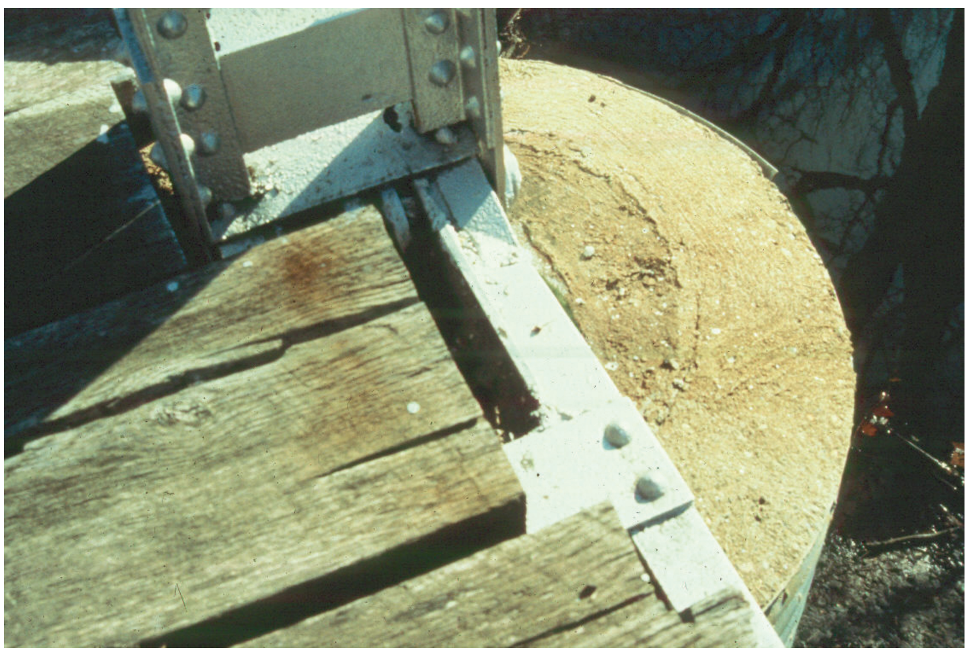

Figure 5.1.9 Bearing and Shear Area on a Timber Deck

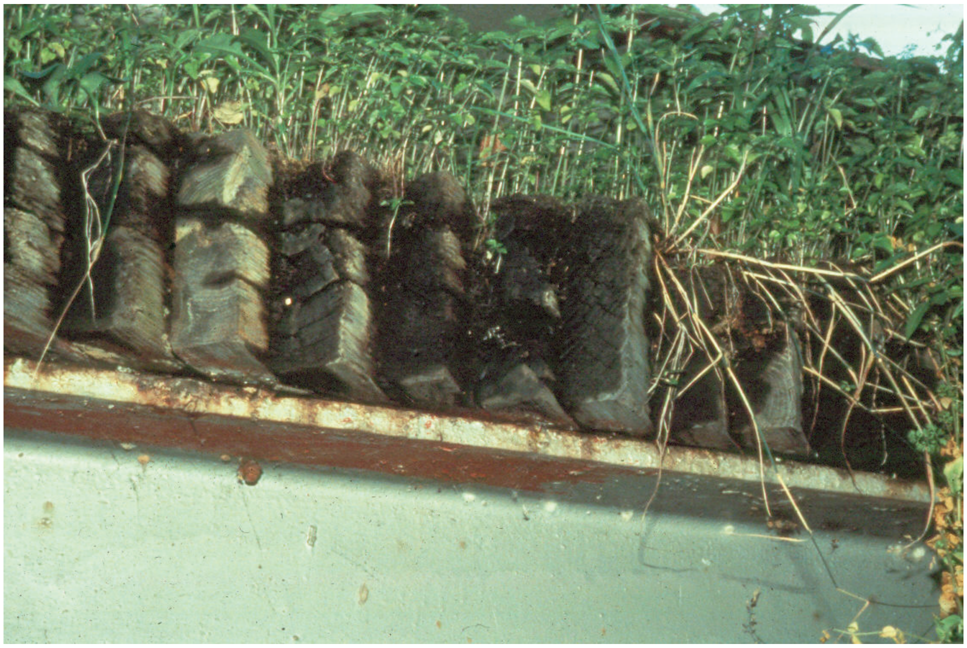

Figure 5.1.10 Edge of Deck Exposed to Drainage, Resulting in Plant Growth

5.1.7 Evaluation

State and federal rating guideline systems have been developed to aid in the inspection of all bridge members, including timber decks. The two major rating guideline systems currently in use are the FHWA's *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges* used for the National Bridge Inventory (NBI) component rating method and the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* used for element level condition state assessment.

NBI Rating Guidelines

Using NBI rating guidelines, a 1-digit code on the Federal Structure Inventory and Appraisal (SI&A) sheet indicates the condition of the deck. Rating codes range from 9 to 0, where 9 is the best rating possible. See Topic 4.2 (Item 58) for additional details about the NBI rating guidelines. The previous inspection data should be used along with current inspection findings to determine the correct rating.

Element Level Condition State Assessment

In an element level condition state assessment of a timber deck, the AASHTO CoRe element is one of the following, depending on the riding surface:

Core Element No.	Description
031	Timber Deck
032	Timber Deck – with AC Overlay
054	Timber Slab
055	Timber Slab – with AC Overlay

The unit quantity for these elements is “each”, and the entire element must be placed in one of the four available condition states based on the condition of the deck. Condition state 1 is the best possible rating. Some states have elected to use the total area (m^2 or ft^2). When a total area is used, the total area must be assigned to one of the four available condition states depending on the extent and severity of deterioration. See the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* for condition state descriptions.

For the purposes of this manual, a deck is supported by a superstructure and a slab is supported by substructure units.

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Topic 5.2 Concrete Decks

5.2.1 Introduction

The most common bridge deck material is concrete. The physical properties of concrete permit placing in various shapes and sizes, providing the bridge designer and the bridge builder with a variety of construction methods. This topic discusses various aspects of concrete bridge decks and related bridge inspection issues.

5.2.2 Design Characteristics

The role of a concrete bridge deck is to provide a smooth riding surface for motorists, divert runoff water, distribute traffic and deck weight loads to the superstructure, and act compositely or non-compositely with the superstructure. Increased research and technology are providing the bridge deck designer with a variety of concrete mix designs, from lightweight concrete to fiber reinforced concrete to high performance concrete, as well as different reinforcement options, to help concrete bridge decks better perform their role.

There are four common types of concrete decks:

- Reinforced cast-in-place (CIP)
- Precast
- Precast prestressed
- Precast prestressed deck panels with CIP topping

Reinforced Cast-in-Place

Concrete decks that are cast in place on the bridge are referred to as “cast-in-place” (CIP). 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 construction. There are two types of forms used when placing cast-in-place concrete: removable and stay-in-place.

Removable forms are usually wood planking or plywood but can also be fiberglass reinforced plastic. These forms are taken away from the deck after the concrete has cured.

Stay-in-place (SIP) forms are corrugated metal sheets permanently installed between the supporting superstructure members. After the concrete has cured, these forms, as the name indicates, remain in place as permanent, nonworking members of the bridge (see Figure 5.2.1).

Figure 5.2.1 Stay-in-Place Forms

Precast

Precast deck panels are reinforced concrete panels that are cast and cured somewhere other than on the bridge. Precast decks are typically reinforced with conventional mild reinforcement. The deck panels are transported to the bridge site, then placed on the bridge, leveled, and attached to the superstructure/floor system. Proper deck elevations are generally accomplished using leveling bolts and a grouting system.

The precast deck panels fit together using match cast keyed construction. After leveling, precast deck panels are attached to the superstructure/floor system. Mechanical clips can be used to connect the deck panels to the superstructure. An alternate method involves leaving block-out holes in the precast panels as an opening for shear connectors. The deck panels are positioned over the shear connectors, and the block-out holes are then filled with concrete or grout.

Precast Prestressed

Precast prestressed decks are also reinforced concrete decks cast and cured away from the bridge site. However, they are reinforced with prestressing steel in addition to some mild reinforcement. The prestressing tendons or bars are tensioned prior to placing the deck (pretensioned) or after the deck is cured (post-tensioned). The tendons are held in position until the deck has sufficiently cured. This creates compressive forces in the deck, which reduce the amount of tension cracking in the cured concrete.

Precast Prestressed Deck Panels with Cast-in-Place Topping

Precast prestressed deck panels can also be used in conjunction with a cast-in-place concrete overlay. Partial depth reinforced precast panels are placed across the beams or stringers and act as forms (see Figure 5.2.2). A cast-in-place layer, which may be reinforced, is then placed which engages both the supporting superstructure members and the precast deck units. After the cast-in-place layer has cured, composite action is achieved with the shear connectors and superstructure.

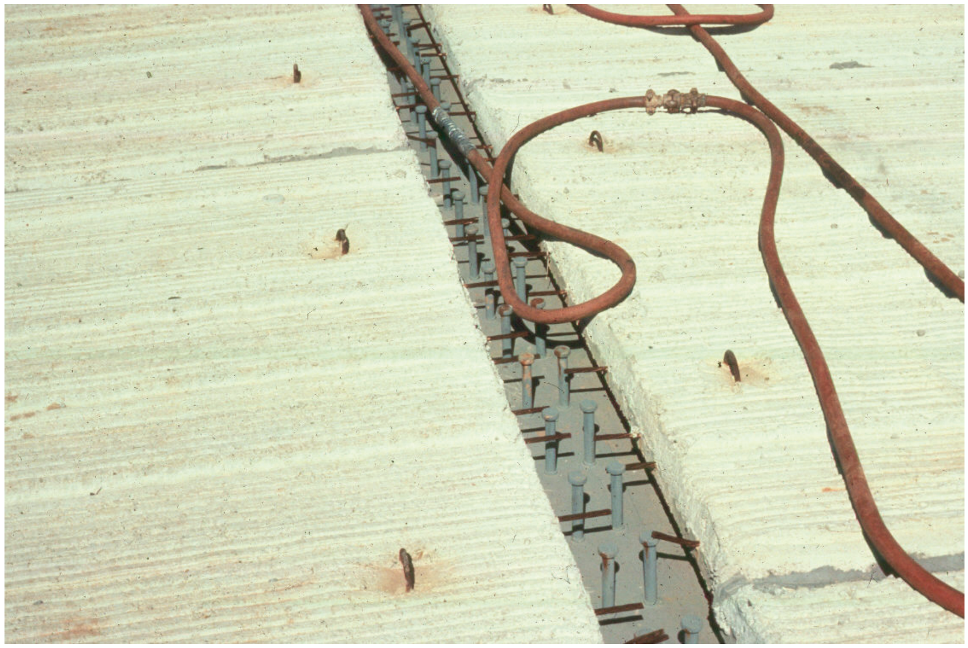

Figure 5.2.2 Precast Deck Panels (with Lifting Lugs Evident and Top Beam Flange Exposed)

In addition to the four common concrete decks, there are two new types of decks that may become more common in the future:

- Fiber reinforced polymer (FRP)
- Fiber reinforced concrete (FRC)

Fiber Reinforced Polymer

New and innovative research is being performed in the area of fiber reinforced polymer (FRP) bridge decks. Most of the FRP composite deck systems use glass reinforcing fibers set in a polyester or vinyl ester resin matrix. The two most common FRP deck systems use prefabricated panels comprised of pultruded tubes that are glued together with adhesive and honeycomb or sandwich core systems that are hand-laid up or utilize vacuum assisted resin transfer molding techniques. These deck systems are factory built to the specified deck panel dimension and are then shipped to the erection site. Once at the site, the individual deck panels are bonded together with high performance adhesives. If beams support this type of deck system, a grouted haunch or fillet is required to take into account the imperfections of the beams. Composite action can be developed with FRP deck systems by cutting pockets in the deck to access welded shear studs on the beams and then grouting the pockets. The effectiveness of composite action in FRP deck systems is still being researched.

FRP decks require an overlay due to the low skid resistance of the materials. Latex concrete, micro-silica concrete, or dense concrete are not very compatible with FRP deck systems in the areas of stiffness, tensile strength, or compressive strength. Thin epoxy or polymer modified concrete overlays are better suited for use with FRP deck systems. Hot asphalt has been used as an overlay and has worked well over several years on some decks.

An 200 mm (8 inch) deep FRP deck weighs only 98 kg/m^2 (20 pounds per square foot (puff)) compared to 488 kg/m^2 (100 (puff)) for a conventional 200 mm (8 inch) concrete bridge deck (see Figure 5.2.3).

Figure 5.2.3 Fiber Reinforced Polymer (FRP) Deck

Fiber Reinforced Concrete

Another new bridge deck material is fiber reinforced concrete (FRC). This type of bridge deck uses common Portland cement concrete mixes with 0.2 to 0.8 percent fiber by volume (see Figure 5.2.4). The most common type of fiber reinforcement is polypropylene. The purpose of the fiber is to minimize shrinkage cracking of fresh concrete and increase the impact strength of cured concrete.

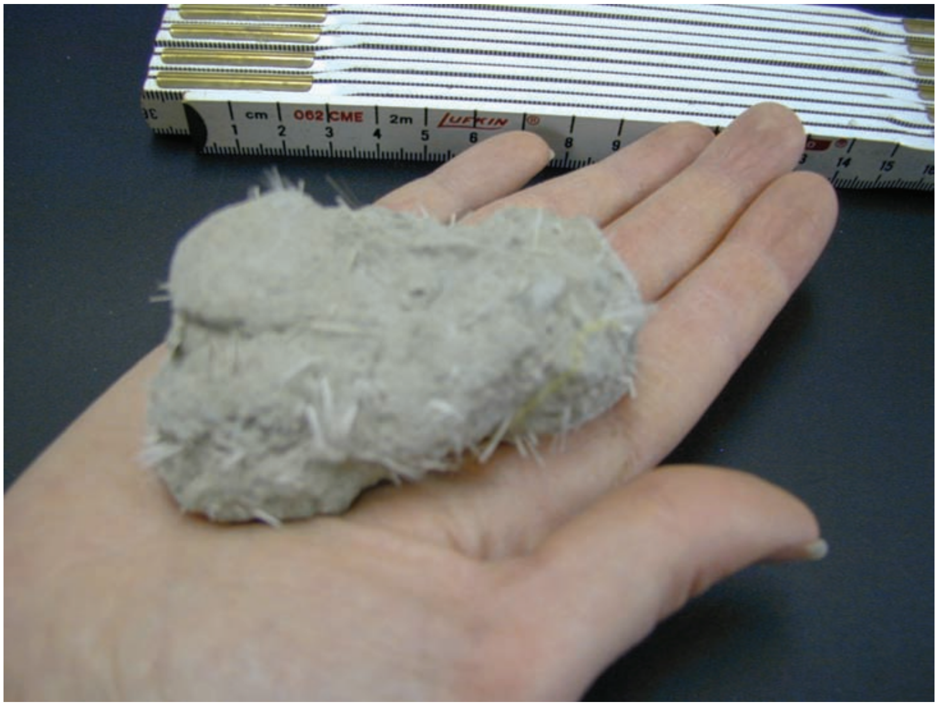

Figure 5.2.4 Fiber Reinforced Concrete (FRC)

An FRC bridge deck can either be reinforced with conventional rebar or have no conventional steel reinforcement included in the deck. Initial research testing the ability of polypropylene fibers to block the corrosion of steel reinforcement in concrete bridge decks proved that the fibers did not significantly retard the corrosion process. Therefore, some FRC bridge decks have been designed and constructed without steel reinforcement. FRC decks without steel reinforcement have transverse steel straps welded to the top flange of steel girders and are made composite with the superstructure via shear studs welded to the top flange (see Figure 5.2.5). The steel straps run the entire width of the deck and provide lateral restraint of the supporting girders. Since no steel reinforcement is included in the deck itself, the deck does not deteriorate due to steel reinforcement corrosion. Therefore, steel-free bridge decks give designers a viable alternative in areas where deicing salts are used.

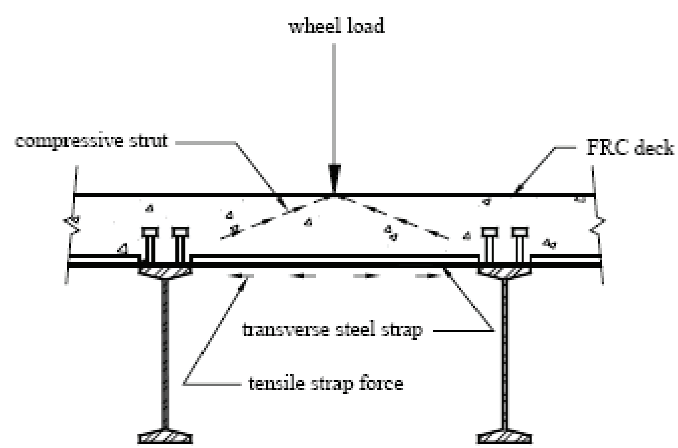

Figure 5.2.5 Fiber Reinforced Concrete (FRC) Bridge Deck Cross-Section

Composite Action

A concrete deck is generally required when composite action is desired in the superstructure (refer to Topic P.2.10). Composite action is defined as dissimilar materials joined together so they behave as one structural unit. A composite bridge deck structure is one in which the deck acts together structurally with the beams to resist the applied loads. An example of composite action is a cast-in-place concrete deck joined to steel or prestressed concrete beams or a steel floor system using shear connectors (see Figures 5.2.6 and 5.2.7). A precast deck can also develop composite action through grout pockets, which engage shear connectors. Some examples of shear connectors are studs, spirals, channels, or stirrups. Shear connectors are generally welded to steel beams. In concrete beams, shear connectors are simply extended portions of shear stirrups which protrude beyond the top of the beam. Composite action does not occur until the CIP deck is placed and cured or the precast deck grout pockets have been filled and cured.

Non-Composite Action

A non-composite concrete deck is not mechanically attached to the superstructure and does not contribute to the capacity of the superstructure. A non-composite concrete deck only carries vehicular loads.

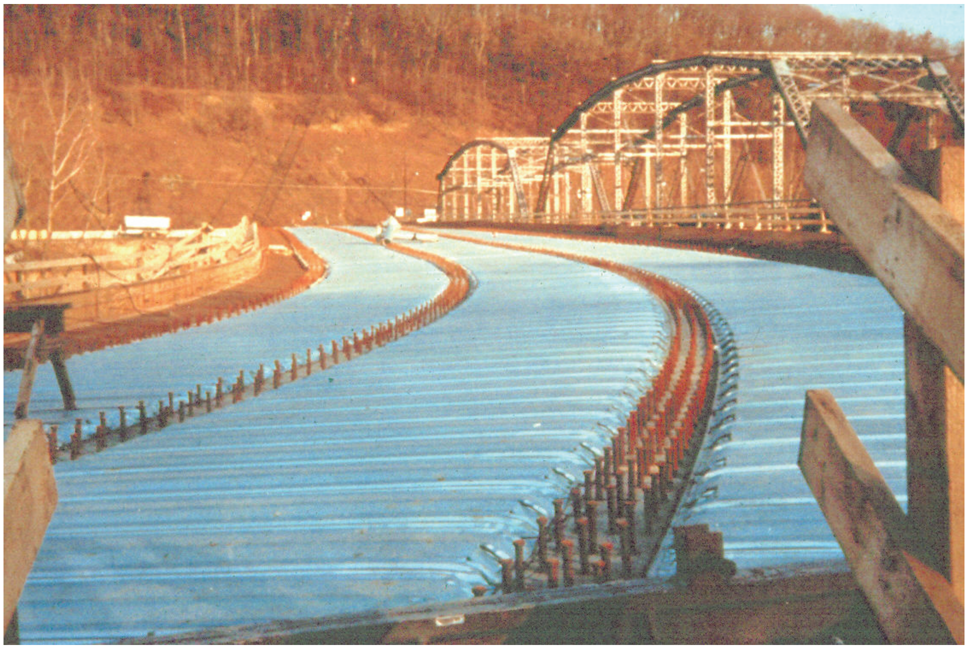

Figure 5.2.6 Shear Connectors Welded to the Top Flange of a Steel Girder

Figure 5.2.7 Prestressed Concrete Beams with Shear Connectors Protruding

Steel Reinforcement

Because concrete has relatively little tensile strength, steel reinforcement is used to resist the tensile stresses in the deck. When reinforcement was first used for bridge decks, it was either round or square steel rods with a smooth finish and had a tendency to debond with the surrounding concrete when a tension force was applied. Today, the most common reinforcement is steel deformed reinforcing bars, commonly referred to as "rebars." These bars are basically round in cross section with lugs or deformations rolled into the surface to create a mechanical bond between the reinforcement and the concrete. Lap splices and bar development are dependent on that mechanical bond. A lap splice is the amount of overlap that is needed between two rebars to successfully have the two bars act as one. A typical lap splice length is approximately 30 bar diameters. Mechanical end anchorages or lock devices can also be used to splice rebar. Bar development is the length of embedded rebar needed to develop the design stress and varies based on material properties and bar diameter. For large bars, this length is significant. When space is limited, a mechanical hook (90° or 180° bend) is placed at the end of a bar to achieve full development.

Although concrete decks could not function efficiently without reinforcement, the corrosion of the reinforcing steel is the primary cause of deck deterioration. Since about 1970, epoxy coatings have been a common method of protecting steel rebars against corrosion. Less common methods of protection include galvanizing and use of stainless steel.

Primary reinforcement carries the tensile stress in a concrete deck and is located on both the top and bottom of the deck. Secondary reinforcement is temperature and shrinkage steel and is placed perpendicular to the primary reinforcement. Additional longitudinal deck reinforcement is generally placed over piers to help resist the negative moments in the composite superstructure.

The inspector must be able to identify the direction of the primary reinforcement to properly evaluate any cracks in the deck. Primary reinforcement is placed perpendicular to the deck's support points. For example, the support points on a multi-beam bridge and a stringer type floor system are parallel with the direction of traffic. Therefore, the primary deck reinforcement on these deck types is perpendicular to the direction of traffic (see Figure 5.2.8). The support points on a floorbeam-only type floor system are perpendicular with the traffic flow, and the primary deck reinforcement is therefore parallel with the traffic flow. In all cases, the primary reinforcement is closer to the top and bottom concrete surface.

Figure 5.2.8 Spall Showing Deck Reinforcing Steel Perpendicular to Traffic

Primary reinforcement is generally a larger bar size than temperature and shrinkage steel. However, to improve design and construction efficiencies, concrete decks may be reinforced with the same size bar in both the top and bottom rebar mats. Reinforcement cover is generally 50 to 64 mm (2 to 2-1/2 inches) minimum for cast-in-place decks without a wearing surface, and 25 mm (1 inch) minimum for precast decks with a separate wearing surface.

5.2.3 Wearing Surfaces

Wearing surfaces are placed on top of the deck and protects the deck and provides a smooth riding surface. The wearing surface materials most commonly used on concrete decks are generally either special concrete mixes or asphalt concrete. Wearing surfaces are incorporated in many new deck designs and are also a common repair procedure for decks.

Concrete

There are two categories of concrete wearing surfaces: integral and overlays. An integral concrete wearing surface is cast with the deck, typically adding an extra 13 to 25 mm (1/2 to 1 inch) of thickness to the deck. When the wearing surface has deteriorated to the extent that readability is affected, it is milled, leveled and replaced with an overlay.

A concrete overlay wearing surface is cast separately over the previously cast concrete deck. Some concrete wearing surfaces may have transverse grooves cut into them as a means of improving traction and preventing hydroplaning. The grooves can be tined while the concrete is still plastic or they can be diamond-sawed after the concrete has cured. There are various types of concrete overlays in use or being researched at the present time. These include:

- Low slump dense concrete (LSDC)
- Polymer/latex modified concrete (LMC)
- Internally sealed concrete
- Lightweight concrete (LWC)
- Fiber reinforced concrete (FRC)

Low slump dense concrete (LSDC) uses a dense concrete with a very low water-cement ratio (approximately 0.32). LSDC overlays were first used in the early 1960's for patches and overlays on bridges in Iowa and Kansas (hence the common term "Iowa Method"). The original overlays were 31 mm (1¼ inches) thick, but now a 50 mm (2-inch) minimum is specified. This type of overlay is generally used because it cures rapidly and has a low permeability. The low permeability resists chloride penetration, while the fast curing decreases the closure period. Low slump dense concrete overlays are placed mainly in locations where deicing salts are used. Surface cracking is a problem in areas where the freeze/thaw cycle exists. The number of applications of deicing salts also plays a role in the deterioration of LSDC overlays. Higher strength dense concrete has been used in the recent past, and results have shown that LSDC overlaid bridge decks will require resurfacing after about 25 years of service, regardless of the concrete deck deterioration caused by steel reinforcement corrosion.

Polymer/latex modified concrete overlay involves the incorporation of polymer emulsions into the fresh concrete. The polymer emulsions have been polymerized prior to being added to the mixture. This is commonly known as latex-modified concrete (LMC). LMC is conventional Portland cement concrete with the addition of approximately 15 percent latex solids by weight of the cement. The typical thickness of 31 mm (1¼ inches) is used for LMC.

The primary difference between the LSDC and the LMC overlays is that low slump concrete uses inexpensive materials but is difficult to place and requires special finishing equipment. Conversely, latex-modified concrete utilizes expensive materials but requires less manpower and is placed by conventional equipment. The performance of LMC has generally been satisfactory, although in some cases, extensive map cracking and debonding have been reported. The causes for this are likely the improper application of the curing method, application under high temperature, or shrinkage due to high slump.

Lightweight concrete (LWC) overlays use concrete with lightweight aggregates and a higher entrained air content. This produces an overlay of approximately 1280 to 1600 kg/m^3 (80 to 100 pcf) compared to 2240 to 2400 kg/m^3 (140 to 150 pcf) for conventional concrete. This type of overlay has a reduced dead load compared to a traditional concrete overlay. Lightweight concrete is also used for cast-in-place and precast decks.

Fiber reinforced concrete (FRC) overlays using Portland cement and metallic, glass, plastic, or natural fibers are becoming a popular solution to bridge deck surface problems. This type of reinforcement strengthens the tension properties in the concrete, and tests have shown that FRC overlays can stop a deck crack from reflecting through the overlay. This type of overlay is gaining acceptance but is still in the research stage.

Asphalt

The most common overlay material for concrete decks is asphalt. Asphalt overlays generally range from 25 mm (1 inch) up to 63 mm (2½ inches), depending on the severity of the repair and the load capacity of the superstructure. When asphalt is placed on concrete, a waterproof membrane may be applied first to protect the reinforced concrete from the adverse effects of water borne deicing chemicals, which pass through the permeable asphalt concrete layer. Not all attempts at providing a waterproof membrane are successful.

5.2.4 Protective Systems

With increasing research, the uses of protective systems are increasing the life of reinforced concrete bridge decks. Most reinforced concrete bridge decks need repair years before the other components of the bridge structure. Therefore protecting the bridge deck from contamination and deterioration is gaining importance.

Sealants

Reinforced concrete deck sealants are used to stop chlorides from contaminating the steel reinforcement. These sealants are generally pore sealers or hydrophobing agents, and their performance is affected by environmental conditions, traffic wear, penetration depth of the sealer, and ultraviolet light.

Boiled linseed oil is a popular sealant that is used to cure or seal a concrete deck. It is applied after the concrete gains the appropriate amount of strength. This material resists water and the effects of deicing agents.

Elastomeric membranes are another approach when sealing a concrete bridge deck. This type of sealant is mixed on site and cures to a seamless viscous waterproof membrane. It is generally applied prior to placing an asphalt overlay.

Epoxy Coated Reinforcement Bars

Steel reinforcement corrosion causes detrimental effects on concrete decks. An epoxy coating is often used on all steel deck reinforcement to prevent corrosion. The epoxy coating is resistant to chemicals, water, and atmospheric moisture. Epoxies utilize an epoxy polymer binder that forms a tough, resilient film upon drying and curing. Drying is by solvent evaporation, while curing entails a chemical reaction between the coating components.

Galvanized Reinforcement Bars

Another method of protecting steel reinforcement is by galvanizing the steel. Galvanizing slows down the corrosion process and lengthens the life of the reinforced concrete deck. Galvanizing is achieved by coating the bare steel reinforcement with zinc. The two unlike metals form an electrical current between them, and one metal virtually stops its corrosion process while the other's accelerates due to the electrical current. In this situation, the steel stops corroding while the zinc has accelerated corrosion.

Stainless Steel Reinforcement Bars

The corrosion process is negligible when stainless steel reinforcement is used.

Fiberglass Reinforced Polymer (FRP) bars

Fiberglass Reinforced Polymer (FRP) bars for concrete reinforcement have the advantage of resistance to corrosion. They are also lightweight, weighing about one-quarter the weight of an equivalent size steel bar.

Cathodic Protection of Reinforcement Bars

Cathodic Protection is sometimes used on decks with black bare steel reinforcement (not epoxy coated). Steel reinforcement corrosion can also be slowed down by cathodic protection. Corrosion of steel reinforcing bars in concrete occurs by an electrical process in a moist environment at the steel surface. During corrosion, a voltage difference (less than 1 volt) develops between rebars or between different areas on the same rebar. Electrons from the iron in the rebar are repelled by the negative anode area of the rebar and attracted to the positive cathode area. This electron flow constitutes an electrical current that is necessary for the corrosion process. Corrosion occurs only at the anode, where the electrons from the iron are given up.

By cathodic protection, this electrical current is reversed, slowing or stopping corrosion. By the impressed current method, an electrical DC rectifier supplies electrical current from local electrical power lines to a separate anode embedded in the concrete. The anode is usually a wire mesh embedded just under the concrete surface. Another type of anode consists of an electrically conductive coating applied to the concrete surface. The wires from the rectifier are embedded in the coating at regular intervals (see Figure 5.2.9).

When the impressed current enters the mesh or coating anode, the voltage on the rebars is reversed, turning the entire rebar network into a giant cathode. Since natural corrosion occurs only at the anode, the rebars are protected.

The natural corrosion process is allowed to proceed by electrons leaving the iron atoms in the anode. With impressed current cathodic protection, however, the electrons are supplied from an external source, the DC rectifier (see figure 5.2.9).

Thus, the artificial anode mesh or coating is also spared from corrosion.

Figure 5.2.9 Cathodic Protection

Waterproofing Membrane

There are two types of bridge deck waterproofing membrane systems.

- Self-adhering membrane – is a high strength polyester reinforced membrane with a rubber/bitumen compound, which is cold applied. A layer of bituminous base and wearing course is then applied over the membrane.
- Liquid waterproofing membrane – is a two-component compound, which is simply mixed on site to produce a viscous seamless rubber/bitumen liquid that cures to an elastomeric waterproof membrane.

These systems are used to retard reflective cracking and provide waterproofing.

5.2.5 Overview of Common Defects

Common concrete deck defects are listed below. Refer to Topic 2.2 for a detailed description of these defects:

- Cracking
- Scaling
- Delamination
- Spalling
- Chloride Contamination
- Efflorescence
- Ettringite formation
- Honeycombs
- Pop-outs
- Wear
- Collision damage
- Abrasion

- Overload damage
- Reinforcing steel corrosion
- Prestressed concrete deterioration

5.2.6 Inspection Procedures and Locations

Procedures

Visual

The inspection of concrete decks for cracks, spalls, and other defects is primarily a visual activity. All surfaces of the concrete deck should receive a close visual inspection.

Physical

Hammers can be used to detect areas of delamination. A delaminated area will have a distinctive hollow “clacking” sound when tapped with a hammer or revealed with a chain drag. A hammer hitting sound concrete will result in a solid "pinging" type sound.

The physical examination of a deck with a hammer can be a tedious operation. In most cases, a chain drag is used. A chain drag is made of several sections of chain attached to pipe that has a handle attached to it. The inspector drags this across a deck and makes note of the resonating sounds. A chain drag can usually cover about a 915 mm (3-feet) wide section of deck at a time (see Figure 5.2.10).

Figure 5.2.10 Sounding for Delaminated Areas of Concrete

Many of the problems associated with concrete bridge decks are caused by corrosion of the rebar. When the deterioration of a concrete deck progresses to the point of needing rehabilitation, an in-depth inspection of the deck is required to determine the extent, cause, and possible solution to the problem. Several techniques and methods are available.

Advanced Inspection Techniques

Several advanced techniques are available for concrete inspection. Nondestructive methods, described in Topic 13.2.2, include:

- Acoustic wave sonic/ultrasonic velocity measurements
- Delamination detection machinery
- Electrical methods
- Electro magnetic methods
- Pulse Velocity
- Flat jack testing
- Ground-penetrating radar
- Impact-echo testing
- Infrared thermography
- Laser ultrasonic testing
- Magnetic field disturbance
- Neutron probe for detection of chlorides
- Nuclear methods
- Pachometer
- Rebound and penetration methods
- Ultrasonic testing
- Smart concrete

Other methods, described in Topic 13.2.3, include:

- Core Sampling
- Carbonation
- Concrete permeability
- Concrete strength
- Endoscopes and video scopes
- Moisture content
- Petrographic examination
- Reinforcing steel strength
- Chloride test
- Matrix analysis
- ASR evaluation

If the inspector deems it necessary, core samples can be taken from the deck and sent to a laboratory to determine the extent of any chloride contamination.

Locations

Both the top and bottom surfaces of concrete decks should be inspected for cracking, scaling, spalling, corroding reinforcement, chloride contamination, delamination, and full or partial depth failures. In all instances, it is helpful if the inspector has available the previous inspection report so that the progression of any deterioration can be noted. This provides a more meaningful inspection. Refer to Topic 2.2 for a detailed description of concrete defects.

For concrete deck inspections, special attention should be given to the following locations:

- **Areas exposed to traffic** – examine for surface texture and wheel ruts due to wear. Check cross-slopes for uniformity. Verify that repairs are acting as intended.
- **Areas exposed to drainage** – investigate for ponding water, scaling, delamination, and spalls.
- **Bearing and shear areas** where the concrete deck is supported – check for cracks, spalls and crushing near supports.
- **Shear key joints** between precast deck panels – inspect for leaking joints, cracks, and other signs of independent action.
- **Anchorage zones** of precast deck tie rods – check for deteriorating grout pockets or loose lock-off devices. If a previous inspection report is available, this should be used by the inspector so that the progression of any deterioration can be noted.
- **Top of the deck** over the supports – examine for flexure cracks which would be perpendicular to the primary reinforcement.
- **Bottom of the deck** between the supports – check for flexure cracks (see Figure 5.2.11).
- **Asphalt overlays** – if present, they should be inspected. Cracks, delaminations, and spalls are to be noted. Often water penetrates overlays and then penetrates into the structural deck. Asphalt overlays prevent visual inspection of the top surface of the deck. The wearing surface does not affect the evaluation of the structural deck.
- **Stay-in-place forms** – investigate for deterioration and corrosion of the forms, often indicating contamination of the concrete deck; these forms can retain moisture and chlorides which have penetrated full depth cracks in the deck (see Figure 5.2.12).
- **Cathodic protection** – during the bridge inspection, check that all visible electrical connections and wiring from the rectifier to the concrete structure are intact. If cathodic protection appears not to be working, notify maintenance personnel. Some agencies that use cathodic protection have specialized inspection/maintenance crews for these types of bridge decks.

Figure 5.2.11 Underside View of Longitudinal Deck Crack

Figure 5.2.12 Deteriorated Stay-in-Place Form

5.2.7 Evaluation

State and federal rating guideline systems have been developed to aid in the inspection of concrete decks. The two major rating guideline systems currently in use are the FHWA's *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges* used for the National Bridge Inventory (NBI) component rating method and the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* used for element level condition state assessment.

NBI Rating Guidelines

Using NBI rating guidelines, a 1-digit code on the Federal Structure Inventory and Appraisal (SI&A) sheet indicates the condition of the deck. Rating codes range from 9 to 0, where 9 is the best rating possible. See Topic 4.2 (Item 58) for additional details about the NBI rating guidelines. The previous inspection data should be used along with current inspection findings to determine the correct rating.

Element Level Condition State Assessment

In an element level condition state assessment of a concrete deck, the AASHTO CoRe element is one of the following, depending on the riding surface:

Element No.	Description
012	Concrete Deck – Bare
013	Concrete Deck – Unprotected with AC Overlay
014	Concrete Deck – Protected with AC Overlay
018	Concrete Deck – Protected with Thin Overlay
022	Concrete Deck – Protected with Rigid Overlay
026	Concrete Deck – Protected with Coated Bars
027	Concrete Deck – Protected with Cathodic System

For the purpose of this manual, a deck is supported by a superstructure, and a slab is supported by substructure units.

The unit quantity for the CoRe elements is “each”, and the entire element must be placed in one of the five available condition states based solely on the top surface condition. Condition state 1 is the best possible rating. The inspector must know the total deck surface area in order to calculate a percent deterioration and fit into a given condition state description. Some states have elected to use the total area (m^2 or ft^2). When a total area is used, the total area must be assigned to one of the five available condition states depending on the extent and severity of deterioration. See the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* for condition state descriptions.

A Smart Flag is used when a specific condition exists, which is not described in the CoRe element condition state. The severity of the damage is captured by coding the appropriate Smart Flag condition state. The Smart Flag quantities are measured as each, with only one each of any given Smart Flag per bridge.

For structural cracks in the top surface of bare decks, the “Deck Cracking” Smart Flag, Element No. 358, can be used and one of four condition states assigned. Do not use Smart Flag, Element No. 358, if the bridge deck/slab has any overlay because the top surface of the structural deck is not visible. For concrete defects on the underside of a deck element, the “Soffit” Smart Flag, Element No. 359, can be used and one of five condition states assigned.

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Section 5
Inspection and Evaluation of Decks

Topic 5.3 Steel Decks

5.3.1 Introduction

Steel decks are found on many older bridges and moveable bridges. Their popularity grew until concrete decks were introduced. Today, steel bridge decks have various advantages and disadvantages, depending on the application, and are mainly used for bridge deck rehabilitation or for very long spans.

5.3.2 Design Characteristics

Steel bridge decks are mainly used when weight is a major factor. The weight of a steel deck per unit area is less than that of concrete. This weight reduction of the deck means the superstructure and substructure can carry more live load. The trade-off for this weight savings is that water is permitted to pass through, which corrodes the superstructure. Steel decks are sometimes filled with concrete to prevent the water from passing through. The four basic types of steel decks are:

- Orthotropic decks
- Buckle plate decks
- Corrugated steel flooring
- Grid decks

Orthotropic Decks

An orthotropic deck consists of a flat, thin steel plate stiffened by a series of closely spaced longitudinal ribs at right angles to the floor beams. The deck acts integrally with the steel superstructure. An orthotropic deck becomes the top flange of the entire floor system (see Figure 5.3.1).

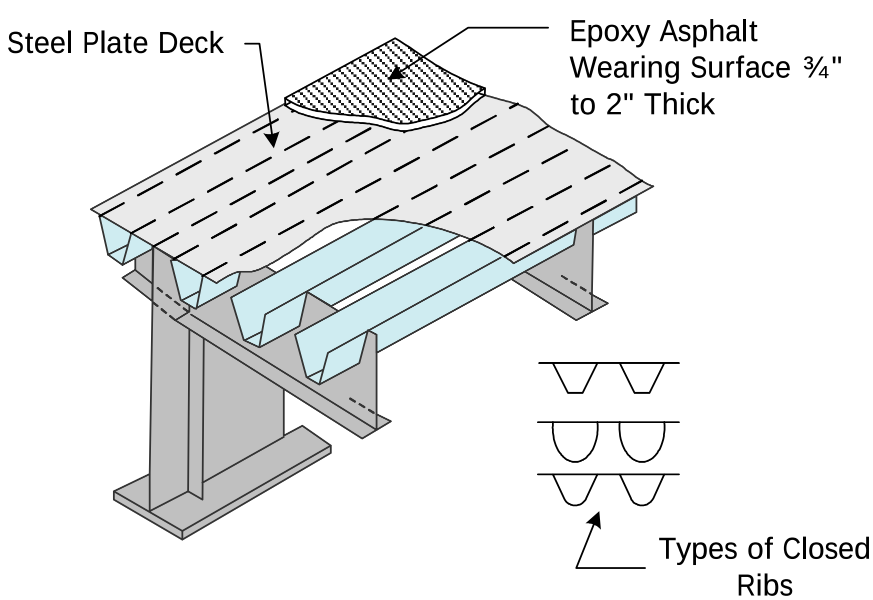

Figure 5.3.1 Orthotropic Bridge Deck

Buckle Plate Decks

Buckle plate decks are found on older bridges. They consist of steel plates attached to the floor system which support a layer of reinforced concrete (see Figure 5.3.2). The plates are concave or "dished" with drain holes in the center. All four sides are typically riveted to the floor system. Buckle plate decks serve as part of the structural deck and as the deck form. They are obsolete, however, and are no longer used today.

Figure 5.3.2 Underside View of Buckle Plate Deck

Corrugated Steel Flooring

Corrugated steel flooring is popular because of its light weight and high strength. This deck consists of corrugated steel planks covered by a layer of asphalt (see Figure 5.3.3). The planks are set upon the superstructure so that the corrugations run perpendicular to the length of the bridge. Corrugations are smaller than stay-in-place (SIP) forms, but the steel is thicker, ranging from 3 mm (0.1 inch) to 5 mm (0.18 inch). The steel planks are welded in place to steel superstructure. In the case of timber beams, the planks are attached by lag bolts. The corrugations are filled with bituminous pavement, and then a wearing surface is applied. This deck is used primarily for the rehabilitation of small bridge decks.

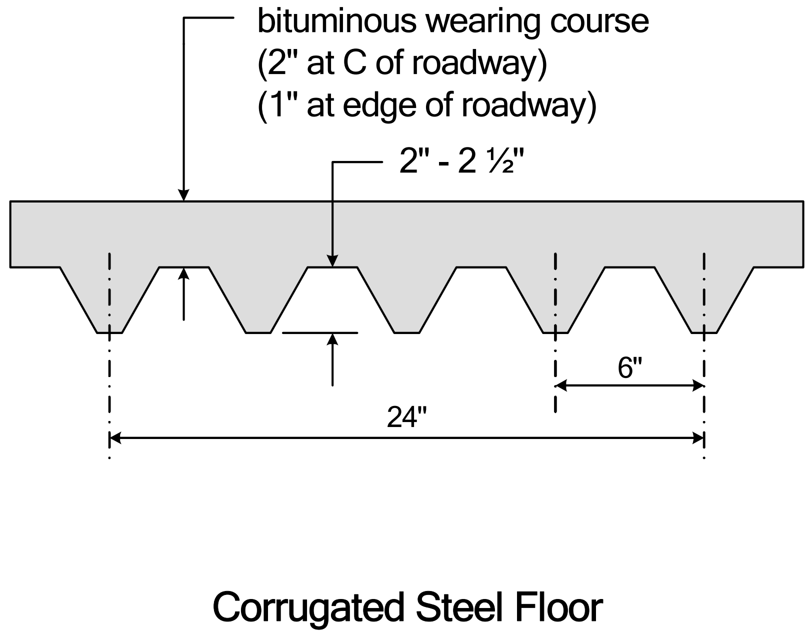

Figure 5.3.3 Sectional View of Corrugated Steel Floor

Grid Decks

Grid decks are probably the most common type of steel deck because of their light weight and high strength. They are commonly welded units, which may be open or filled with concrete.

Open decks are lighter than concrete-filled decks, but they are vulnerable to corrosion since they are continually exposed to weather, debris, and traffic. Another disadvantage of open decks is that they allow dirt and debris to fall onto the supporting members.

Concrete-filled grid decks offer protection for the floor system against water, dirt, debris, and deicing chemicals that usually pass directly through open grid decks. They can be partially-filled or fully-filled.

Partially-filled decks are grid decks which have been partially filled with concrete. This provides a reduction in the dead load and the protection of a concrete-filled floor system. Grid decks are often found on rehabilitated bridges. Their low weight reduces the dead load on a rehabilitated bridge, and their easy installation reduces the time that the bridge must be closed for repairs.

Fully-filled decks are grid decks that have been completely filled with concrete (see Figure 5.3.4). These decks provide the maximum load carrying capacity. Form pans are welded within the grid to hold the concrete. Filled decks often contain rebars for extra strength.

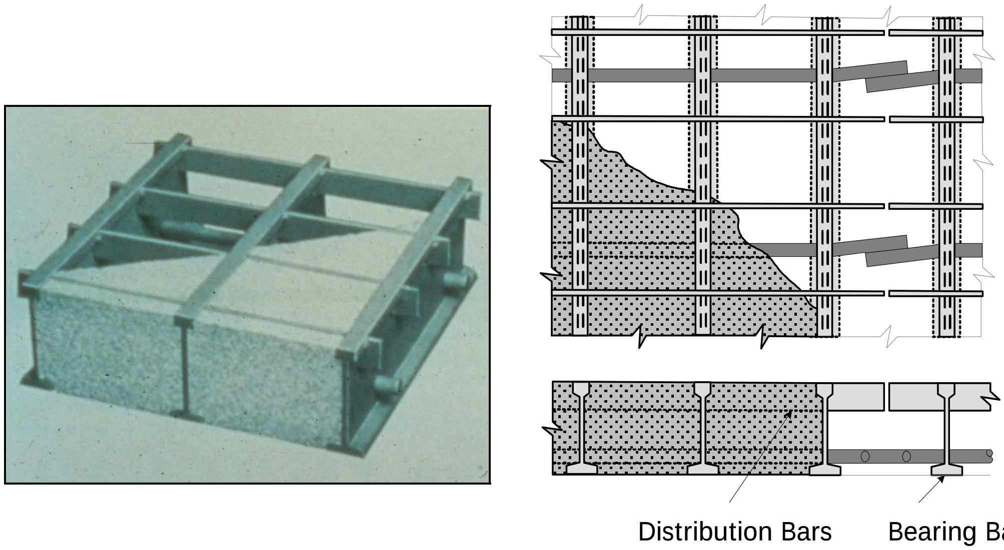

Figure 5.3.4 Concrete Filled Grid Deck

Figure 5.3.5 Filled and Un-filled Steel Grid Deck

The three types of grid decks include:

- Welded grid decks
- Riveted grate decks
- Exodermic decks

Welded Grid Decks

Welded grid decks have their components welded together. These components consist of bearing bars, cross bars, and supplementary bars (see Figure 5.3.6).

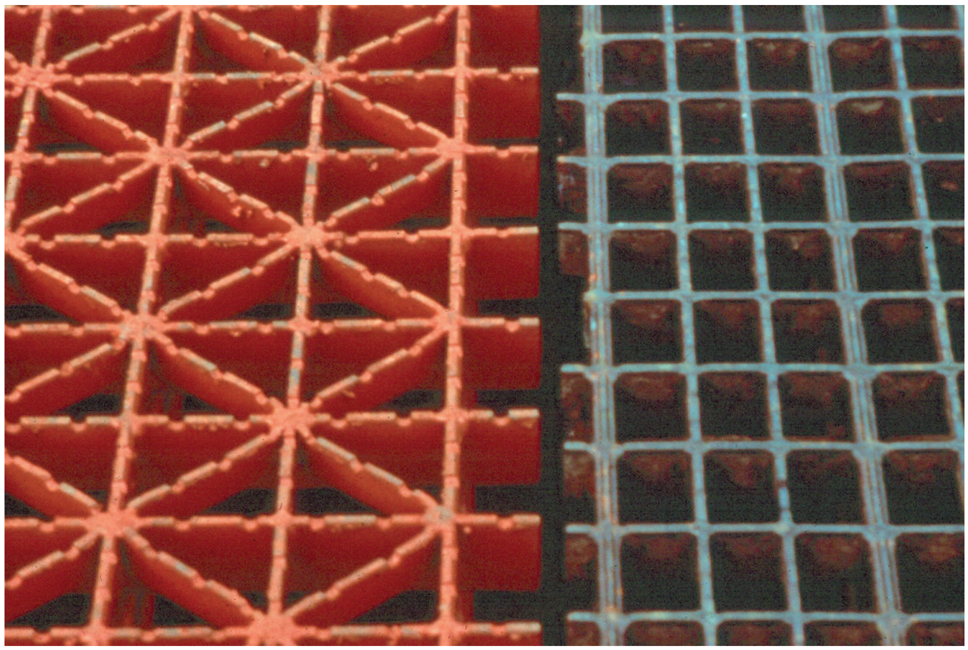

Figure 5.3.6 Various Patterns of Welded Steel Grid Decks

The bearing bars support the grating. Bearing bars are laid on top of the beams or stringers perpendicularly and are then field-welded or bolted to the superstructure. These bars are also referred to as the primary or main bars (see Figure 5.3.4).

The distribution bars are grating bars that are laid perpendicular on top of the bearing bars. They may be either shop- or field-welded to the grating system. Cross bars, also referred to as secondary bars or distribution bars, are generally serrated for improved traction (see Figure 5.3.4).

The supplementary bars are grating bars parallel to the bearing bars. They are also shop- or field-welded to the cross bars. Not all grating systems have supplementary bars. These supplementary bars are also referred to as tertiary bars.

Riveted Grid Decks

A riveted grid deck consists of bearing bars, crimp bars, and intermediate bars and can either be fully or partially filled with concrete (see Figure 5.3.7).

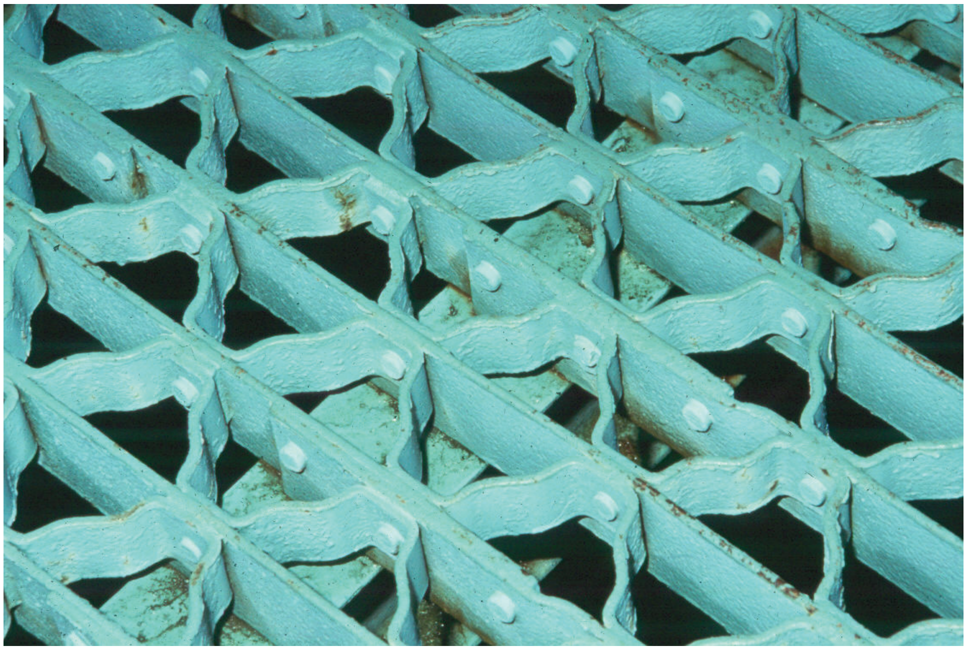

Figure 5.3.7 Riveted Grid Deck

Bearing bars run perpendicular to the superstructure and are attached to the beams or stringers by either welds or bolts. They are similar to the bearing bars in welded grates.

Crimp bars are riveted to the bearing bars to form the grating.

Intermediate bars are parallel to the bearing bars but, in order to reduce the weight of the deck, are not as long. The crimp bars are riveted to intermediate bars. Intermediate bars may not be present on all riveted grate decks.

Welds and rivets used to construct steel grid decks have long been be a source of cracking. In recent years, steel grid decks have been fabricated to eliminate the use of welds or rivets. The bearing bars are fabricated with slotted holes. Transverse distribution bars are inserted into the slots rotated into position and locked into place without the use of any welds or rivets (see Figure 5.3.8).

Exodermic Decks

Exodermic decks are a newer type of bridge deck. Reinforced concrete is composite with the steel grid (see Figure 5.3.9). Composite action is achieved by studs that extend into the reinforced concrete deck and are welded to the grid deck below. Galvanized sheeting is used as a bottom form to keep the concrete from falling through the grid holes. Exodermic decks generally weigh 50% to 65% lighter than precast reinforced concrete decks.

Figure 5.3.8 Steel Grid Deck with Slotted Holes (to eliminate welding and riveting)

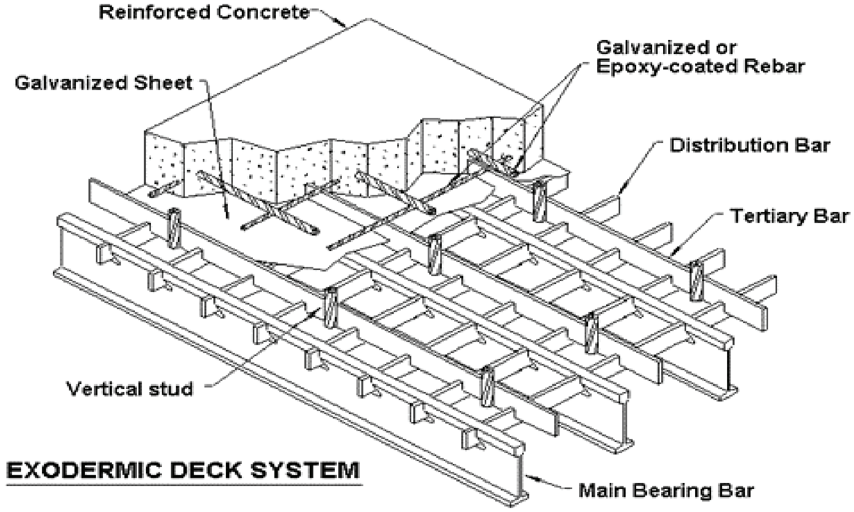

Figure 5.3.9 Schematic of Exodermic Composite Profile

5.3.3 Wearing Surfaces

Wearing surfaces protect the steel deck, provide an even riding surface, and may reduce the water on the deck and superstructure. Wearing surfaces for steel decks can consist of:

- Serrated steel
- Concrete
- Asphalt

Studs can be welded to steel decks for skid resistance.

Serrated Steel

Open grid decks usually have serrated edges on the grating (see Figure 5.3.5). Designed not to wear, these serrations are the riding surface of an open grid deck.

Concrete

Concrete flush with the top of the grids, acts as the wearing surface for filled grid decks. This concrete wearing surface and the concrete used to fill the grids are generally placed at the same time. Different types of concrete wearing surfaces are listed and described in Topic 5.2.3. In the case of an exodermic bridge deck, the wearing surface is part of a reinforced deck.

Asphalt

Steel plate decks, such as orthotropic decks, typically have a layer of asphalt as the wearing surface. Asphalt overlays generally range from 25 mm (1 inch) up to 63 mm (2½ inches), depending on the severity of the repair and the load capacity of the superstructure. Corrugated steel plank decks also have asphalt wearing surfaces.

An epoxy asphalt polymer concrete also is used for orthotropic bridge deck wearing surfaces. Unlike conventional asphalt mixes, epoxy asphalt polymer concrete will not melt after it has cured because of the thermoset polymer in the mix. This polymer is different than thermoplastic polymer used in conventional asphalt mixes. Epoxy asphalt polymer concrete is used when high strength and elastic composition are important.

5.3.4 Protective Systems

Paints

Paints provide protection from moisture, oxygen, and chlorides. Usually three coats of paint are applied. The first coat is the primer, the next is the intermediate coat, and the final coat is the topcoat. Various types of paint are used, such as oil/alkyd, vinyl, epoxy, urethane, zinc-rich primer, and latex paints.

Galvanizing

Galvanizing is used to protect steel decks. The galvanized coating retards the corrosion process and lengthens the life of the steel deck. This occurs by coating the bare steel with zinc. The two dissimilar metals form an electrical current between them and one metal virtually stops its corrosion process while the other's accelerates due to the electrical current. In this situation, the steel stops corroding, while the zinc has accelerated corrosion.

There are two methods of galvanizing steel decks (shop applied and field applied). Hot-dipping the steel deck member usually takes place at a fabrication shop prior to the initial placement of the steel deck. When sections of the deck are too large or when maintenance painting is to take place, the zinc-rich-primers can be applied in the field. The zinc paint must be mixed properly, and the surface must be prepared correctly.

Overlay

Another protective system for steel decks is the overlay material itself. The overlay covers the steel deck to create a barrier from corrosive agents. Overlays slow down the deterioration process for steel decks.

Epoxy Coating

Epoxy coating steel grates is another means of protecting the steel decking. This protective coating is rare. However, there are a limited number of steel decks with epoxy coating still in service.

5.3.5 Overview of Common Defects

Some of the common steel deck defects are listed below. Refer to Topic 2.3 to review steel defects in detail.

- Bent, damaged, or missing members
- Corrosion
- Fatigue cracks
- Other stress-related cracks

5.3.6 Inspection Procedures and Locations

Procedures

Visual

The inspection of steel decks for corrosion, section loss, buckling, and cracking is primarily a visual activity. All surfaces of the steel deck should receive a close visual inspection. See Topic 2.3 for a more detailed explanation of visual inspection procedures for steel bridge members.

Physical

Once the defects are identified visually, physical procedures must be used to verify the extent of the defect. Use an inspection hammer or wire brush to remove loose corrosion. This partial loss of cross section due to corrosion is known as section loss. Section loss should be measured using a straight edge and a tape measure. However, a more exact method of measurement, such as calipers or a D-meter, should be used to measure the remaining section of steel. The inspector must remove all corrosion products (rust scale) prior to making measurements.

The inspector should also measure the non-corroded bridge members to verify that the sizes recorded in the plans or inspection report are accurate. If incorrect member sizes are used, the load rating analysis for safe load capacity of the bridge is not accurate.

Broken or cracked welds and rivets can be found by listening to the bridge deck. As vehicles drive across the steel deck, list for any unusual or clanking noises.

Advanced Inspection Techniques

In addition, several advanced techniques are available for steel inspection. Nondestructive methods, described in Topic 13.3.2, include:

- Acoustic emissions testing
- Computer programs
- Computer tomography
- Corrosion sensors
- Smart paint 1
- Smart paint 2
- Dye penetrant
- Magnetic particle
- Radiographic testing
- Robotic inspection
- Ultrasonic testing
- Eddy current

Other methods, described in Topic 13.3.3, include:

- Brinell hardness test
- Charpy impact test
- Chemical analysis
- Tensile strength test

Locations

The primary locations for steel deck inspection include:

- **Bearing and shear areas** – check the primary bearing bars for cracked welds or broken fasteners, or missing bars which connect the steel deck to the supporting floor system.

- **Areas exposed to traffic** – examine the top surface for wheel ruts or wear. Verify that the deteriorated deck will not damage tires.

- **Tension areas** – on steel grid decks, check positive and negative moment regions of the primary bearing bars. Look for damage such as broken, bent, fatigue cracks or other stress related cracks, or missing bars.

- **Areas exposed to drainage** – check areas where drainage can lead to corrosion. Look at areas along the curb lines that collect dirt and debris.

- **Corrugated flooring** – check between the support points for section loss due to corrosion. Vertical movement of the deck under live load may indicate weld failure.

- **Orthotropic decks** – check orthotropic steel plate decks for debonding of the overlay, rust-through or cracks in the steel plate, and for the development of fatigue cracks in the web elements or connecting welds. The connection between the orthotropic plate deck and supporting members should be checked.

- **Check for slipperiness** – on steel grid decks caused by excessive wear.

- **Section loss** – in areas where corrosion is evident, all scale should be removed with an inspection hammer in order to evaluate the amount of remaining material.

- **Connections** – examine for broken connections, and listen for rattles as traffic passes over the deck.

- **Filled grid decks** – inspect for grid expansion at joints and bridge ends, often caused by corrosion. Check the condition of the concrete.

- **Areas previously repaired** – document the location and condition of any repair plates and their connections to the deck.

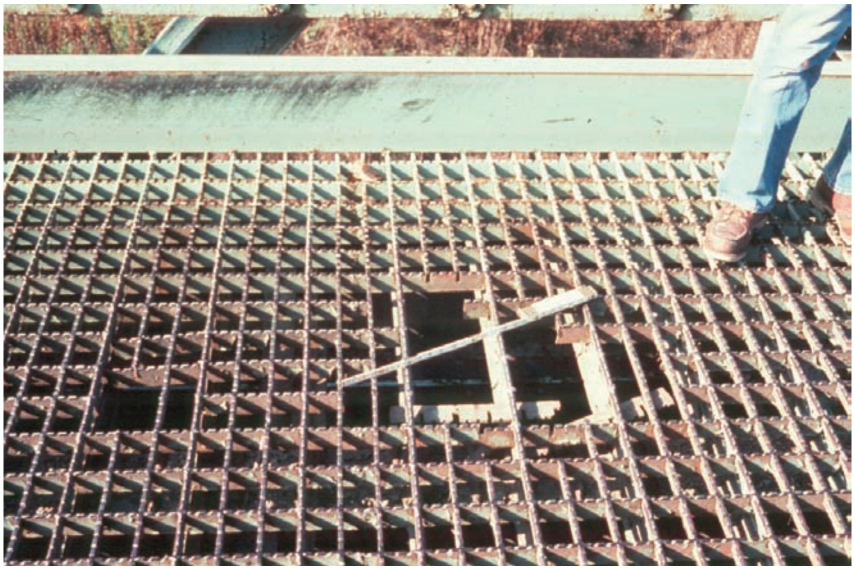

Figure 5.3.10 Broken Members of an Open Steel Grid Deck

5.3.7 Evaluation

State and federal rating guideline systems have been developed to aid in the inspection of steel decks. The two major rating guideline systems currently in use are the FHWA's *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges* used for the National Bridge Inventory (NBI) component rating method and the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* used for element level condition state assessment.

NBI Rating Guidelines

Using NBI rating guidelines, a 1-digit code on the Federal Structure Inventory and Appraisal (SI&A) sheet indicates the condition of the deck. Rating codes range from 9 to 0, where 9 is the best rating possible. See Topic 4.2 (Item 58) for additional details about the NBI rating guidelines. The previous inspection data should be used along with current inspection findings to determine the correct rating.

Element Level Condition State Assessment

In an element level condition state assessment of a steel deck, the AASHTO CoRe element is one of the following, depending on the riding surface:

Element No.	Description
028	Steel Deck – Open Grid
029	Steel Deck – Concrete Filled Grid
030	Steel Deck – Corrugated/ Orthotropic

The unit quantity for the CoRe elements is "each", and the entire element must be placed in one of the five available condition states based solely on the top surface condition. Condition state 1 is the best possible rating. The inspector must know the total deck surface area in order to calculate a percent deterioration and fit into a given condition state description. Some states have elected to use the total area (m^2 or ft^2). When a total area is used, the total area must be assigned to one of the five available condition states depending on the extent and severity of deterioration. See the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* for condition state descriptions.

A Smart Flag is used when a specific condition exists, which is not described in the CoRe element condition state. The severity of the damage is captured by coding the appropriate Smart Flag condition state. The Smart Flag quantities are measured as each, with only one each of any given Smart Flag per bridge.

For connections of steel decks showing rust packing between steel plates, the "Pack Rust" Smart Flag, Element No. 357, can be used and one of four condition states assigned. The unit quantity for Element Level Smart Flags is "each" and the entire element must be placed into one condition state.

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Section 5

Inspection and Evaluation of Decks

Topic 5.4 Deck Joints, Drainage Systems, Lighting and Signs

5.4.1 Function of Deck Joints, Drainage Systems, Lighting and Signs

Deck Joints

The deck joint is a very important part of a bridge. The primary function of deck joints is to accommodate the expansion, contraction and rotation of the deck and superstructure. In most bridges, the deck joints must accommodate this movement and prevent runoff from reaching bridge elements below the surface of the deck. In addition, the deck joint provides a smooth transition from the approach roadway to the bridge deck. The deck joint must be able to withstand all possible weather extremes in a given area. It must do all of this without compromising the ride quality of vehicles crossing the bridge.

Drainage Systems

The purpose of a drainage system is to remove water and all hazards associated with it from the structure. The purpose is also to protect the superstructure, bearings and substructure. The drainage system should also require as little maintenance as possible and be located so that it does not cause safety hazards.

Lighting and Signs

Lighting serves various functions on bridge structures. Highway lighting is used to increase visibility on a bridge structure. Traffic signal lighting controls traffic on a structure. Aerial obstruction lighting warns aircrafts of a hazard around and below the lights. Navigational lighting is used for the safe control of waterway traffic under a bridge structure. Finally, sign lighting ensures proper visibility for traffic signs.

Typical signs that are present on or near bridges provide regulatory (e.g., speed limits) information and advisory (e.g., clearance warnings) information. Such signs serve to inform the motorist about bridge or roadway conditions that may be hazardous.

5.4.2 Components of Deck Joints, Drainage Systems, Lighting and Signs

Deck Joints

Deck joints should not be confused with construction joints. While deck joints are used primarily to facilitate expansion and contraction of the deck and superstructure, construction joints mark the beginning or end of concrete placement sections during the construction of the bridge deck. The two major categories of deck joints are open joints and closed joints.

Open Joints

Open joints allow water and debris to pass through the joint. The two types of open joints are as follows:

- Formed joints
- Finger plate joints

Formed Joints

Formed joints are little more than a gap between the bridge deck and the abutment backwall or, in the case of a multiple span structure, between adjacent deck sections. They are usually found on very short span bridges where expansion is minimal. The formed joint is usually unprotected, but the deck and backwall can be armored with steel angles. Formed joints are common on short span bridges with concrete decks (see Figures 5.4.1 and 5.4.2).

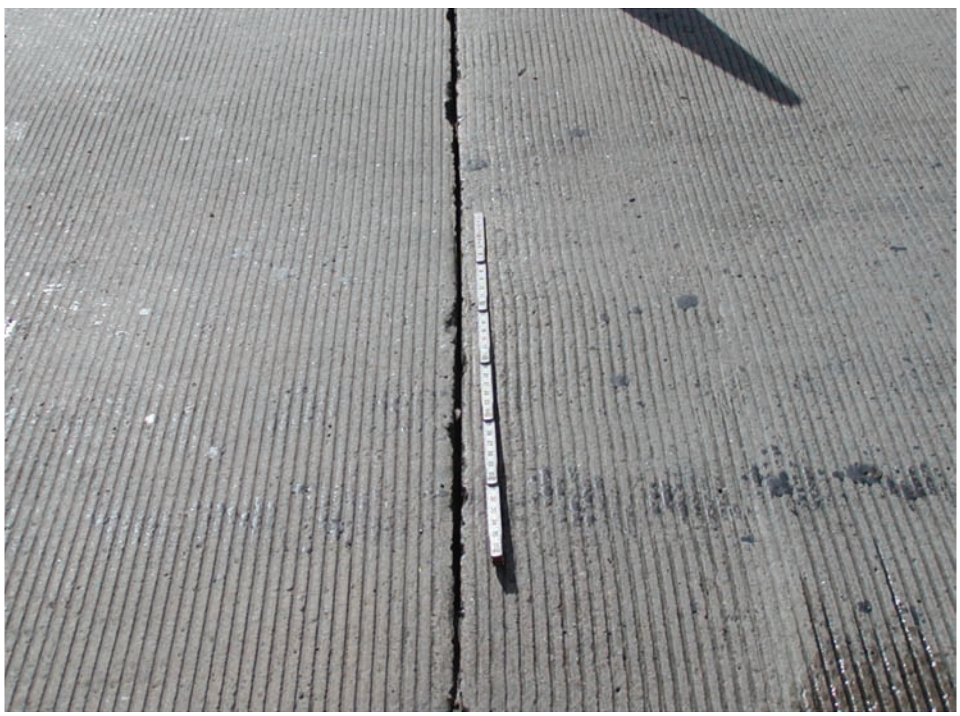

Figure 5.4.1 Formed Joint

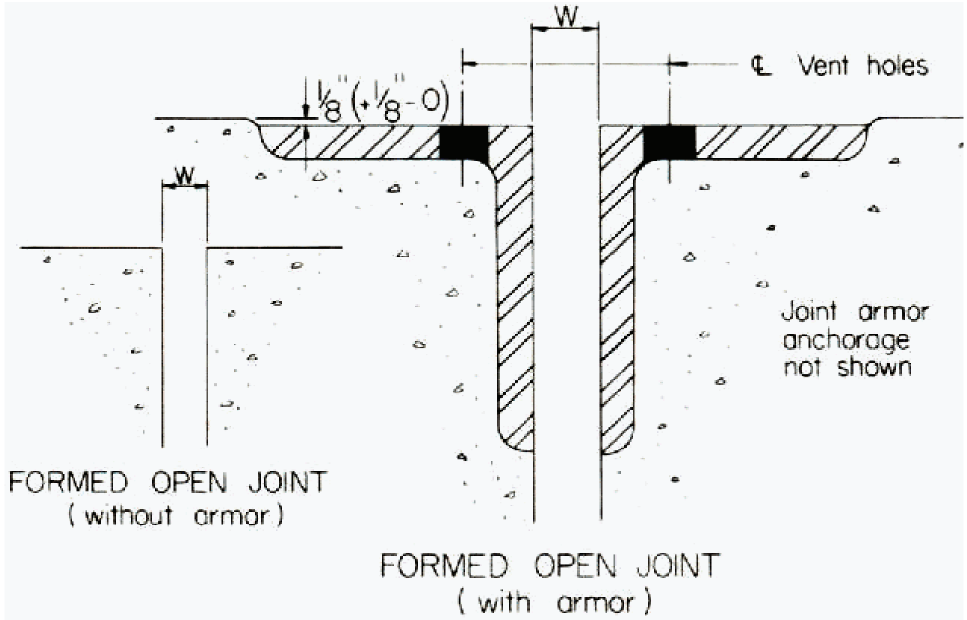

Figure 5.4.2 Cross Section of a Formed Joint

Finger Plate Joints

A finger plate joint, also known as a tooth plate joint or a tooth dam, consists of two steel plates with interlocking fingers. These joints are usually found on longer span bridges where greater expansion is required. The two types of finger plate joints are cantilever finger plate joints and supported finger plate joints.

The cantilever finger plate joint is used when relatively little expansion is required. The fingers on this joint cantilever out from the deck side plate and the abutment side plate. The supported finger plate joint is used on longer spans requiring greater expansion. The fingers on this joint have their own support system in the form of transverse beams under the joint. Some types of finger plate joints are segmental, allowing for maintenance and replacement if necessary. Finger plate joints are used to accommodate movement from 100 to over 600 mm (4 to over 24 inches) (see Figures 5.4.3 through 5.4.5).

Troughs are sometimes placed under open finger plate joints. Their purpose is to direct water that passes through the joint away from the superstructure, bearings and substructure.

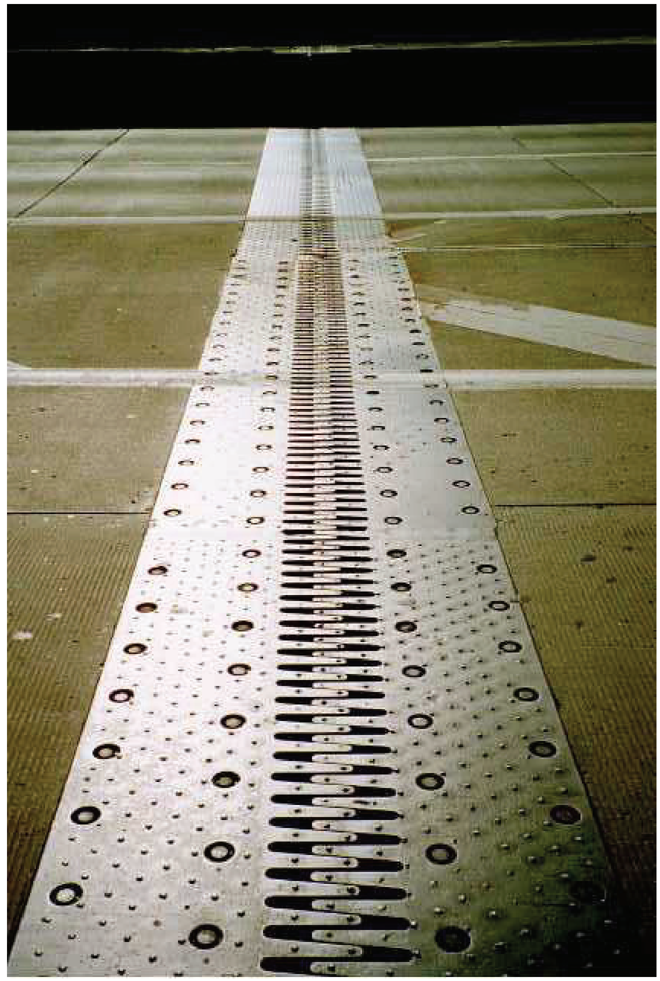

Figure 5.4.3 Finger Plate Joint

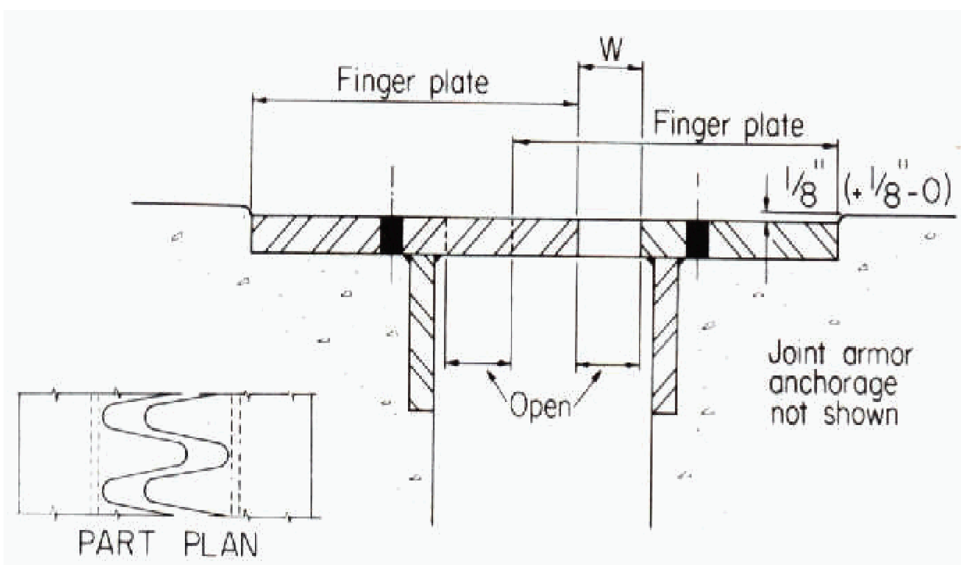

Figure 5.4.4 Cross Section of a Cantilever Finger Plate Joint

Figure 5.4.5 Supported Finger Plate Joint

Closed Joints

Closed joints are designed so that water and debris do not pass through them. The superstructure and substructure members directly below the joint are protected from the effects of water and debris buildup. There are several types of closed joints, including the following:

- Poured joint seal
- Compression seal
- Cellular seal
- Sliding plate joint
- Prefabricated elastomeric seal
- Modular elastomeric seal
- Asphaltic expansion joint

Poured Joint Seal

A poured joint seal is made up of two materials: a base and a poured sealant. The base consists of a preformed expansion joint filler. The top of this material is 25 to 50 mm (1 to 2 inches) from the top of the deck. The remaining joint space consists of the poured sealant that is separated from the base by a backer rod or a bond breaker. Since the poured joint seal can only accommodate a movement of about 6 mm (1/4 inch), it is usually found on short span structures.

Compression Seal

A compression seal consists of neoprene formed in a rectangular shape with a honeycomb cross section (see Figure 5.4.6). The honeycomb design allows the compression seal to fully recover after being distorted during bridge expansion and contraction. It is called a compression seal because it functions in a partially compressed state at all times. Compression seals can have steel angle armoring on the deck and backwall. In some cases, the deck joint is saw cut to accept the installation of the compression seal. In such cases, no armoring is provided. These seals come in a variety of sizes and are often classified by their maximum movement capacity. A large compression seal can accommodate a maximum movement of approximately 50 mm (2 inches).

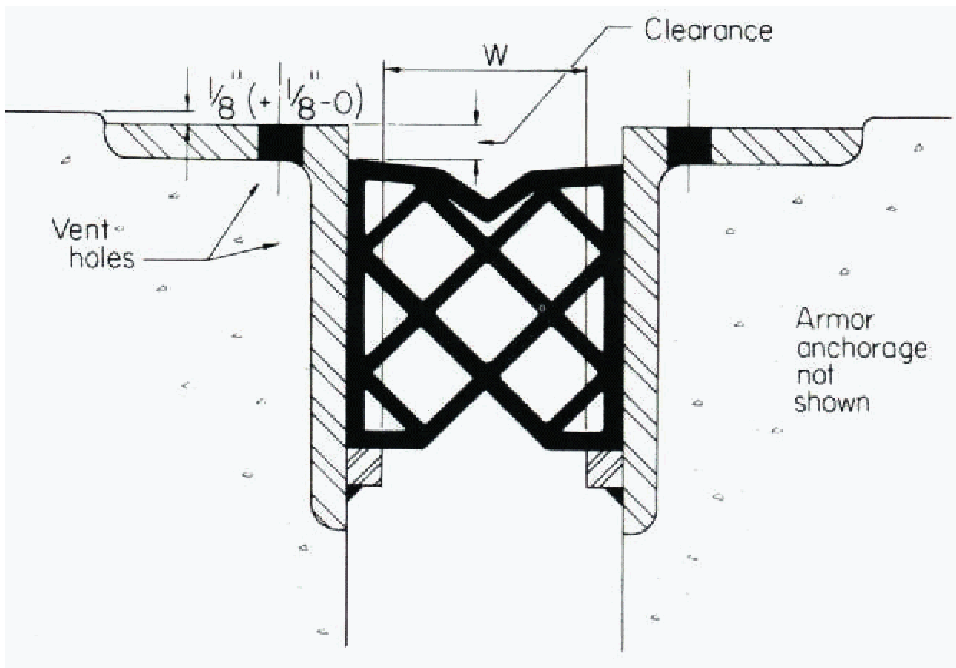

Figure 5.4.6 Cross Section of a Compression Seal with Steel Angle Armoring

Cellular Seal

The cellular seal is similar to the compression seal, and its armoring is almost identical. However, they differ in the type of material used to seal the joint. Unlike the compression seal, the cellular seal is made of a closed-cell foam that allows the joint to move in different directions without losing the seal. This foam allows for expansion and contraction both parallel and perpendicular to the joint. The parallel movement is referred to as racking and occurs during normal expansion and contraction of a curved structure or a bridge on a skew.

Sliding Plate Joint

A sliding plate joint is composed of two plates. The top plate slides across the bottom plate. Although classified as a closed joint, the sliding plate joint is usually not watertight. In an attempt to seal the joint, an elastomeric sheet is sometimes used. This sheet is attached between the plates and the joint armoring. The resulting trough serves to carry water away to the sides of the deck (see Figure

5.4.7). The sliding plate joint can accommodate a maximum movement of approximately 100 mm (4 inches).

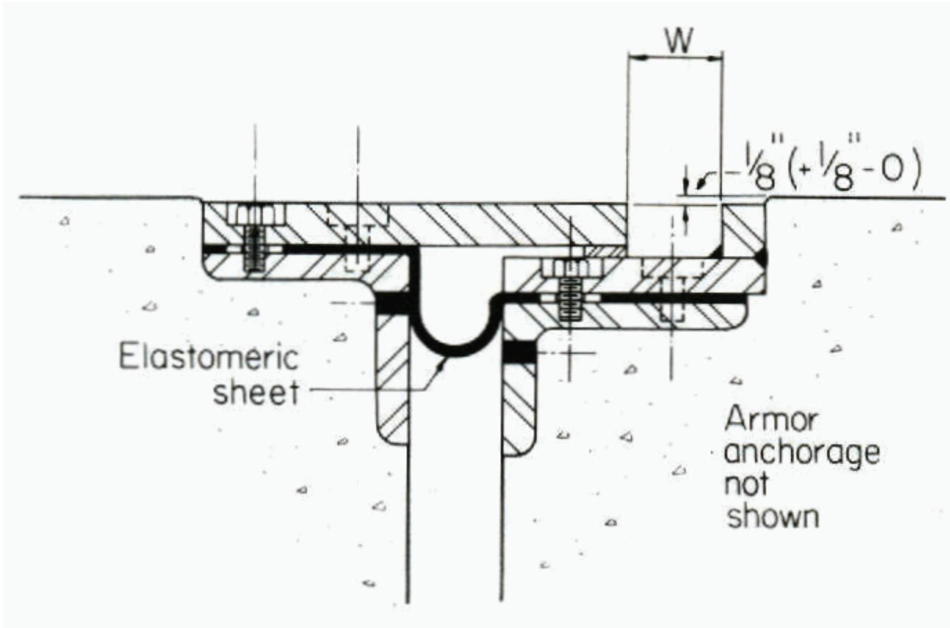

Figure 5.4.7 Cross Section of a Sliding Plate Joint

Prefabricated Elastomeric Seal

Prefabricated elastomeric seals are frequently proprietary products and include three basic types:

- Plank seal
- Sheet seal
- Strip seal

A plank seal consists of steel reinforced neoprene that supports vehicular wheel loads over the joint. This type of seal is bolted to the deck and is capable of accommodating movement ranges from 50 to 330 mm (2 to 13 inches) (see Figure 5.4.8).

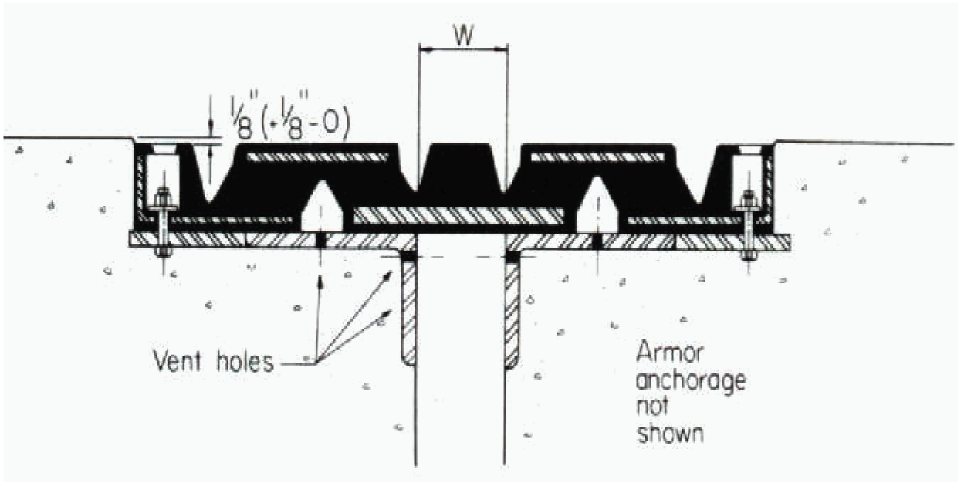

Figure 5.4.8 Plank Seal

A sheet seal consists of two blocks of steel reinforced neoprene. A thin sheet of neoprene spans the joint and connects the two blocks. This joint can accommodate a maximum movement of approximately 100 mm (4 inches) (see Figure 5.4.9).

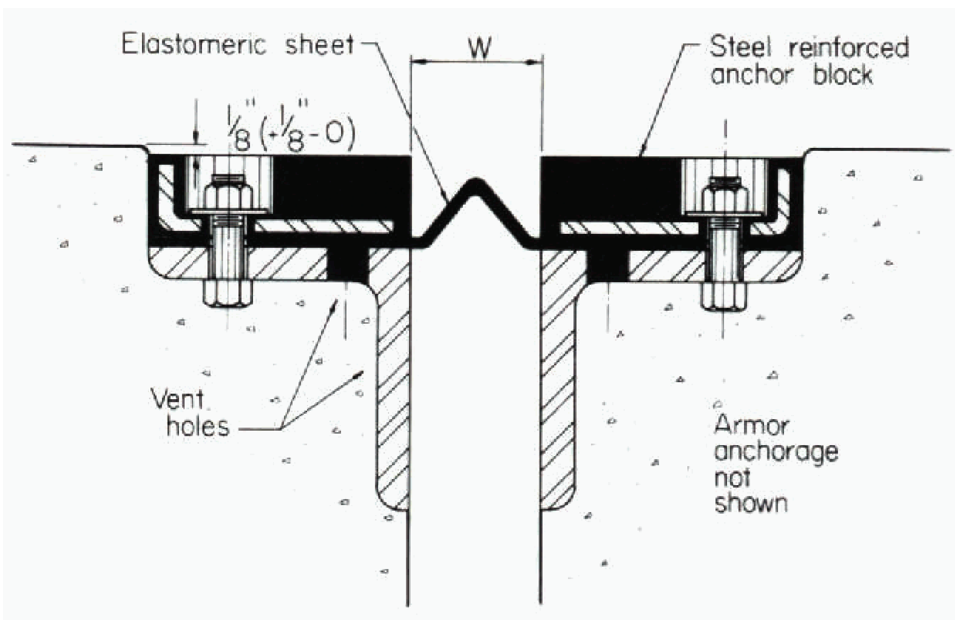

Figure 5.4.9 Sheet Seal

A strip seal consists of two slotted steel anchorages cast into the deck or backwall. A neoprene seal fits into the grooves to span the joint extrusion. This joint can accommodate a maximum movement of approximately 100 mm (4 inches) (see Figure 5.4.10).

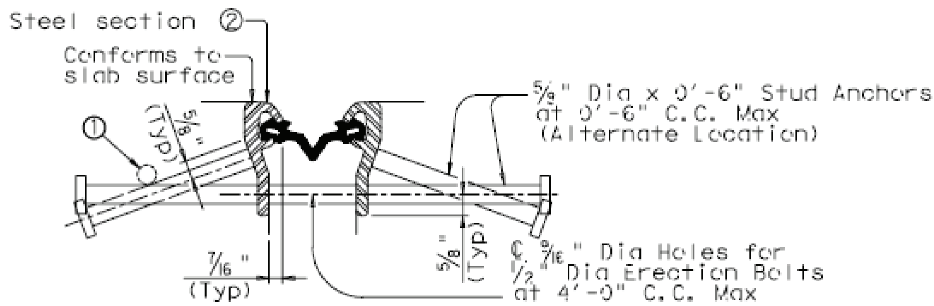

Figure 5.4.10 Strip Seal (Drawing Courtesy of the D.S. Brown Co.)

Modular Elastomeric Seal

The modular elastomeric seal is another neoprene type seal which can support vehicular wheel loads. It consists of hollow, rectangular neoprene block seals, interconnected with steel and supported by its own stringer system (see Figure 5.4.11). The normal range of operation for movement is between 100 and 600 mm (4 and 24 inches). It can, however, be fabricated to accommodate movements up to 1200 mm (48 inches).

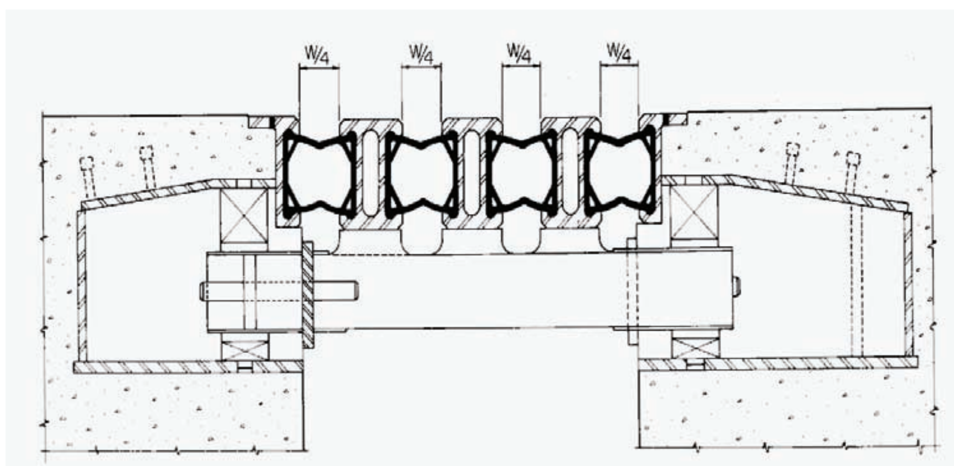

Figure 5.4.11 Schematic Cross Section of a Modular Elastomeric Seal

Asphaltic Expansion Joint

An asphaltic expansion joint is typically used on short bridges that are to be overlaid with asphalt. The joint expansion must be 50 mm (2 inches) or less. The original joint is usually a formed open joint that has deteriorated. Once the bridge joint is overlaid, the overlay material on the joint and a set distance in both directions of the joint is removed down to the original deck. A backer rod is then placed in the open joint and a sealant material is placed in the joint. Next, an aluminum or steel plate is centered over the joint to bridge the opening, and pins are put through the plate into the joint to hold it in place. A heated binder material is then poured on the plate to create a watertight seal. Layers of aggregate saturated with hot binder are then placed to the depth needed. The filled joint is then compacted. This type of joint allows for bridge decks to be overlaid without damaging existing expansion joints and is gaining popularity (see Figure 5.4.12).

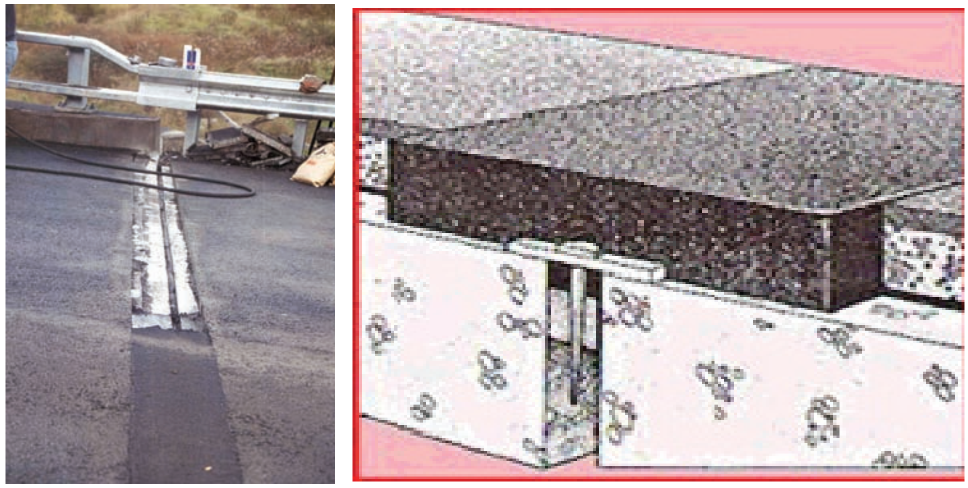

Figure 5.4.12 Asphaltic Expansion Joint

Drainage Systems

In order to perform an inspection of a deck drainage system, it is necessary to become familiar with its various elements:

- Runoff
- Bridge deck cross slope and profile
- Deck drains
- Outlet pipes
- Downspout pipes
- Cleanout plugs

Runoff

Runoff is the water and any contents from the surface of the bridge deck.

Bridge Deck Cross Slope and Profile

The cross slope of the bridge deck is the first component of the drainage system that the runoff encounters. The proper cross slope and profile directs the runoff to the deck drains and eliminates or reduces ponding.

Deck Drains

The deck drain is the second component of the drainage system that runoff encounters. A deck drain is a receptacle to receive water. Deck drains may be nothing more than openings in a filled grid deck, holes in a concrete deck, or slots in the base of a parapet. Inlet boxes and scuppers are also examples of deck drains (see Figure 5.4.13).

Figure 5.4.13 Bridge Deck Drain

Inlet boxes have a grate, which is a ribbed or perforated cover. Grates are fabricated from steel bars that are frequently oriented with the longitudinal direction of the bridge and spaced at approximately 50 mm (2 inches) on center. A bicycle safety grate has steel rods placed perpendicular to the grating bars, spaced at approximately 100 mm (4 inches) on center.

Grates keep larger debris from entering the drainage system while allowing water to pass through. They also serve to support traffic and other live loads.

Outlet Pipes

If present, the outlet pipe leads water away from the drain. For bridges over roadways, the outlet pipe connects to other pipes. When the bridge is not over a roadway, the outlet pipe may simply extend just below the superstructure so that drainage water is not windblown onto the superstructure.

Downspout Pipes

When a bridge is located over a roadway, the deck drainage must be directed from the outlet pipe to a nearby storm sewer system or another appropriate release point. This is accomplished with a downspout pipe network (see Figure 5.4.14).

Cleanout Plugs

The cleanout plug is a removable plug in the piping system that allows access for cleaning.

Drainage Troughs

Drainage troughs may be located under open joints to divert runoff away from underlying superstructure, bearings and substructure members.

Figure 5.4.14 Downspout Pipes and Cleanout Plugs

Lighting

The four basic types of lighting which may be encountered on a bridge are:

- Highway lighting
- Traffic control lighting
- Aerial obstruction lighting
- Navigation lighting

Highway Lighting

The typical highway lighting standard consists of a lamp or luminary attached to a bracket arm. Both the luminary and bracket arm are usually made of aluminum. The bracket arm is attached to a shaft or pole made of concrete, steel, cast iron, aluminum, or, in some cases, timber. It is generally tapered toward the top of the pole.

The shaft is attached at the bottom to an anchor base. Steel and aluminum shafts are fitted inside and welded to the base. In the case of concrete, the shaft is normally cast as an integral part of the base. Sometimes the thickness of the parapet or median barrier is increased to accommodate the anchor base. This area of the barrier or parapet is called a "blister". Where the standard is exposed to vehicular traffic, a breakaway type base or guardrail may be used. Anchor bolts hold the light standard in place. These L-shaped or U-shaped bolts are normally embedded in a concrete foundation, parapet, or median barrier.

Traffic Control Lighting

Traffic control lights are used to direct traffic on a structure. Lights can serve a similar purpose to those found at intersections, but they can also indicate which lanes vehicular traffic is to use. These are referred to as lane control signals. Red and green overhead lights indicate the appropriate travel lanes.

Aerial Obstruction Lighting

Aerial obstruction lights are used to alert aircraft pilots that a hazard exists below and around the lights. They are red and should be visible all around and above the structure. Aerial obstruction lights are located on the topmost portion of any bridge considered by the Federal Aviation Administration (FAA) to present a hazard to aircraft. Depending on the bridge size, more than one light may be required.

Navigation Lighting

Navigation lights are used for the safe control of waterway traffic. The United States Coast Guard determines the requirements for the type, number, and placement of navigation lights on bridges. The lights are either green, red, or white and the specific application for each bridge site is unique.

Green lights usually indicate the center of a channel. These lights are placed at the bottom midspan of the superstructure. Red lights indicate the existence of an obstacle. When placed on the bottom of the superstructure, a red light indicates the limit of the channel. Lights placed to indicate a pier are placed on the pier near the waterline. Three white lights in a vertical fashion placed on the superstructure indicate the main channel.

Signs

Among the various types of signs to be encountered are signs indicating:

- Warning signs
- Traffic regulatory signs
- Guide signs

Warning Signs

Warning signs alert drivers to existing or potentially hazardous conditions.

Vertical Clearance

Vertical clearance signs indicate the minimum vertical clearance for the structure. This clearance is measured at the most restrictive location within the traveling lanes.

Lateral Clearance

Lateral clearance signs indicate that the bridge width is less than the approach roadway width. Lateral clearance restrictions may be called out with a "Narrow Bridge" sign or with reflective stripe boards at the bridge.

Narrow Underpass

Narrow underpass signs indicate where the roadway narrows at an underpass or where there is a pier in the middle of the roadway. Striped hazard markings and reflective hazard markers should be placed on these abutment walls and pier edges. The approaching pavement should be appropriately marked to warn motorists of the hazard.

Traffic Regulatory Signs

Regulatory signs instruct drivers to do or not do something. Traffic regulatory signs indicate speed restrictions which are consistent with the bridge and roadway design. Additional traffic markers may be present to facilitate the safe and continuous flow of traffic.

Weight Limit

Weight limit signs are very important since they indicate the maximum vehicle load that can safely use the bridge.

Guide Signs

Guide signs come in a variety of shapes and colors and have information to help drivers arrive safely at their destination.

5.4.3 Common Problems of Deck Joints, Drainage Systems, Lighting and Signs

Deck Joints

Common problems encountered when inspecting deck joints include the following:

- Debris and accumulation of dirt in deck joints and troughs under finger joints
- Corrosion on joints and their supports
- Damaged, torn, or missing joint seals due to snow plows, traffic, or debris buildup
- Spalled edges on joints without armor
- Spalled edges on joints due to misalignment of both sides of the joint
- Broken or misaligned fingers
- Leaking closed joint systems (or evidence of leaking)

Drainage Systems

Common problems encountered when inspecting drainage systems include the following:

- Debris buildup at inlet grate where water from the deck enters the drainage system
- Clogged or partially clogged deck drains and/or inlets
- Disconnected/clogged downspout piping
- Cracked or split pipes
- Loose or missing connections (from drain pipe below the deck to outlet

pipe)

- Corrosion or section loss in metal pipes

Lighting and Signs

Common problems encountered when inspecting lighting and signs include the following:

- Lighting and signs obstructed from view due to tree growth or other signs
- Lighting and signs not present at bridge site
- Signs presented unacceptably or incorrectly
- Signs defaced or covered with graffiti
- Corrosion or section loss on lighting or sign supports
- Loose or missing anchorages at supports
- Missing signs
- Lighting outages

5.4.4 Inspection Locations and Procedures for Deck Joints, Drainage Systems, Lighting and Signs

Deck Joints

The deck joints must allow for the expansion and contraction of the bridge deck and superstructure. The inspector must be aware of and record conditions that keep the deck joint from functioning properly.

Using the NBIS guidelines, there is not a separate item on the Structure Inventory and Appraisal (SI&A) sheet to code the serviceability of deck joints. Deck joint conditions are not considered in the rating of the deck. However, it is important for the inspector to note their condition since leaking deck joint problems are the root cause of the majority of the deterioration of superstructure and substructure elements beneath the joints.

The Element Level Inspection system, however, does rate deck joints. For a detailed description of deck joint condition states, see the <u>AASHTO Guide for Commonly Recognized (CoRe) Structural Elements</u> and the evaluation section of this topic.

Deck joints should be inspected for:

- Dirt and debris accumulation
- Proper alignment (horizontal/vertical)
- Damage to seals and armored plates
- Indiscriminate overlays

- Joint supports
- Joint anchorage devices

Dirt and Debris Accumulation

Dirt and debris lodged in the joint may prevent normal expansion and contraction, causing cracking in the deck and backwall, and overstress in the bearings. In addition, as dirt and debris is continually driven into a joint, the joint material can eventually fail (see Figures 5.4.15 and 5.4.16).

Figure 5.4.15 Debris Lodged in a Sliding Plate Joint

Figure 5.4.16 Dirt in a Compression Seal Joint

Proper Alignment

Both sides of the joint should be at the same level with no vertical displacement between the two. On straight bridges, the joint opening should be parallel across the deck.

In a finger plate joint, the individual fingers should mesh together properly, and they should be in the same plane as the deck surface (see Figure 5.4.17).

Figure 5.4.17 Improper Vertical Alignment at a Finger Plate Joint

It is important that the relative movements of the joint are consistent with the temperature. During the coldest and the warmest times of the day, the air temperature and the superstructure temperature should be recorded, and the joint opening should be documented. Measurements should be taken at each curb line and the centerline of the roadway. Since heat causes expansion, the joint opening should be smallest when the temperature is greatest. The superstructure temperature can be taken by placing a surface temperature thermometer or the bulb of a standard thermometer against the superstructure member itself. The superstructure temperature is generally about 1.7 to 2.8 °C (3 to 5 ºF) lower than the air temperature.

Damage to Seals and Armored Plates

Damage from snow plows, traffic, and debris can cause the joint seals to be torn, pulled out of the anchorage, or removed altogether (see Figure 5.4.18). It can also cause damage to armored plates. Any of these conditions should be noted by the inspector. Also look for evidence of leakage through closed joints.

Figure 5.4.18 Failed Compression Seal

Indiscriminate Overlays

When new pavement or wearing surface is applied to a bridge, it is frequently placed over the deck joints with little or no regard for their ability to function properly. This occurs most frequently on small, local bridges. Transverse cracks in the pavement may be evidence that a joint has been covered by the indiscriminate application of new overlay, and the joint function may be severely impaired (see Figure 5.4.19).

Figure 5.4.19 Asphalt Wearing Surface over an Expansion Joint

Joint Supports

Where larger expansions and contractions must be accommodated, the joint may be fully or partially supported from beneath by transverse beams. These joint supports should be carefully inspected for proper function and for corrosion and section loss (see Figure 5.4.20).

Figure 5.4.20 Support System under a Finger Plate Joint

Joint Anchorage Devices

Deficiencies in joint anchorage devices are a common source of deck joint problems. Therefore, joint anchorage devices should be carefully inspected for proper function and for corrosion. The concrete area in which the joint anchorage device is cast should also be inspected for signs of deterioration. This area adjacent to the joint is known as the joint header.

Drainage Systems

A properly functioning drainage system removes water, and all hazards associated with it, from a structure. There is not a separate item on the NBIS SI&A Sheet to code the serviceability of drainage systems, and drainage system conditions are not considered in the rating of the bridge. However, it is important for the inspector to note their condition, since drainage system problems can eventually lead to structural problems.

The following drainage system elements should be inspected:

- Bridge deck cross slope and profile
- Grates
- Deck drains and inlets

- Drainage troughs
- Outlet pipes

Bridge Deck Cross Slope and Profile

The cross slope and profile should not prevent runoff from entering the deck drains and inlets. Adequate cross slope should be provided so that water runs off the bridge deck at a sufficient rate. Ponding is an indication of insufficient cross slope or profile.

Grates

Grates should be clear of debris (e.g., plants and grass) and free to allow deck runoff to enter. Grates that are deteriorated, broken, or missing should be reported.

Deck Drains and Inlets

Deck drains and inlets must be of sufficient size and spacing to carry the runoff away from the structure effectively. Since runoff conditions can change due to development, these drainage elements should be carefully examined with each bridge inspection. Clogged deck drains lead to accelerated deck deterioration and the undesirable condition of standing water in the traffic lanes (see Figure 5.4.21). Standing water on the deck is a safety hazard.

Figure 5.4.21 Clogged Drainage Inlet

Drainage Troughs

Drainage troughs located under the joint should be carefully examined. A buildup of debris can accelerate the deterioration of the trough and allow water to drain onto structural members (see Figure 5.4.22). If possible, use a shovel to clean as much debris as practical; report the remaining condition for appropriate maintenance work. Once cleaned, any holes found in the trough should be noted. Any evidence that indicates the trough is overflowing should also be recorded.

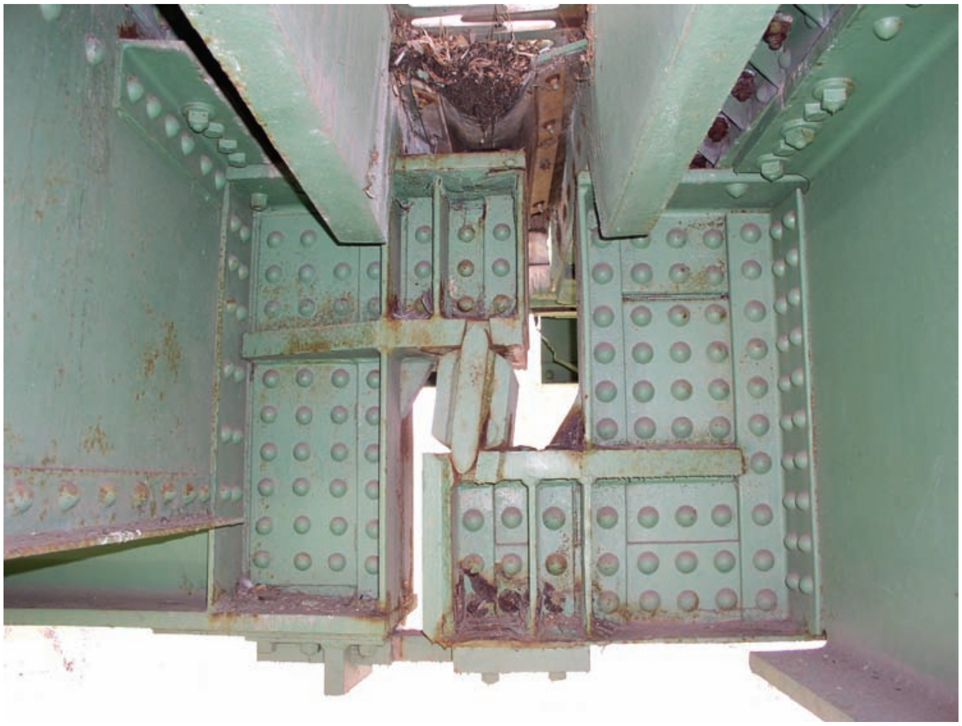

Figure 5.4.22 Drainage Trough with Debris Accumulation

Outlet Pipes

Outlet pipes carry runoff away from the structure. The outlet pipe may be a straight extension of the deck drain, in which case it should be long enough so that runoff is not discharged onto the structure. The outlet pipe may also be a series of pipes, called downspouting. This type of outlet pipe should be examined for split or disconnected pipes that may allow runoff to accelerate deterioration of the structure. Check the connections between the outlet pipes and substructure. If a pipe is embedded inside of a substructure unit such as a concrete pier wall, check for cracking, delamination, or other freeze-thaw damage to the substructure. Open clean out plugs to verify pipes are not clogged and functioning properly.

Lighting

All lights should be clearly visible. Verify that all lights are functioning and that they are not obstructed from view. Check for corrosion and collision damage to light supports. Verify that appropriate lighting is provided. Exercise caution against electrical shock. The inspector should contact the maintenance department to de-energize the lighting.

Signs

Signs should be located sufficiently in advance of the structure to permit the driver adequate time to react. All signs should be clearly legible. Verify that signs have not been defaced and are not obstructed from view. Inspect for corrosion and collision damage to sign supports. Verify that appropriate signing is provided.

5.4.5 Evaluation

State and federal rating guideline systems have been developed to aid in the inspection of deck joints, drainage systems, lighting, and signs. The two major rating guideline systems currently in use are the FHWA's *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges* used for the National Bridge Inventory (NBI) component rating method and the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* used for element level condition state assessment.

NBI Rating Guidelines

Deck joints, drainage systems, lighting, and signs should not impact the deck rating, but their condition should be described on the inspection form. Deficiencies in deck joints, drainage systems, lighting, and signs should be placed on the maintenance sheet showing estimated quantities.

Element Level Condition State Assessment

In an element level condition state assessment of expansion joints, the AASHTO CoRe element is one of the following, depending on the type of joint:

Element No.	Description
300	Strip seal expansion joint
301	Pourable joint seal
302	Compression joint seal
303	Assembly joint seal (modular)
304	Open expansion joint

Individual states have the option to change or add element numbers. In the case of expansion joints, some states have added a miscellaneous expansion joint element number.

The unit quantity for these elements is in meters or feet, and the total length must be distributed among the three available condition states depending on the extent and severity of deterioration. The sum of all condition states must equal the total quantity of the CoRe element. Condition state 1 is the best possible rating. See the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* for condition state descriptions.

Drainage systems, lighting, and signs have no separate element numbers. The condition of the drainage systems, lighting, and signs should, however, be noted on the inspection form.

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Section 5
Inspection and Evaluation of Decks

Topic 5.5 Safety Features

5.5.1 Introduction

Highway design includes a special emphasis on providing safe roadsides for errant vehicles that may leave the roadway. Obstacles or fixed object hazards have typically been removed from within a specified roadside recovery area. Whenever this has not been feasible (for example, at bridge waterway crossings), then safety features such as highway or bridge barrier systems have been provided to screen motorists from the hazards present (see Figure 5.5.1). Such barriers sometimes constitute fixed object hazards themselves, though hopefully of less severity than the hazard they screen.

Figure 5.5.1 Bridge Safety Feature

Purpose

The barriers on bridges and their approaches are typically intended to provide vehicular containment and prevent motorist penetration into the hazard being over-passed, such as a stream or under-passing roadway or railroad. Containment of an errant vehicle is a primary consideration, but survival of vehicle occupants is of equal concern. Thus the design of bridge railing systems and bridge approach guardrail systems is intended to first provide vehicular containment and redirection, but then to also prevent rollover, to minimize snagging and the possibility of vehicle spinout, and to provide smooth vehicular redirection parallel with the barrier system. In addition, the bridge railing and bridge approach guardrail systems must do all of this within tolerable deceleration limits for seat-belted occupants.

Four Basic Components

Barrier systems at bridges are composed of four basic components:

- Bridge railings
- Transitions
- Approach guardrail
- Approach guardrail ends

Bridge Railings

The function of bridge railing is to contain and redirect errant vehicles on the bridge (see Figured 5.5.2 and 5.5.3). Many rails could conceivably do this, but the safety of the driver and redirection of the vehicle must be taken into account.

Transitions

A transition occurs between the approach guardrail system and bridge railing (see Figures 5.5.2 and 5.5.3). Its purpose is to provide both a structurally secure connection to the bridge end post and also a zone of gradual stiffening and strengthening of the more flexible approach guardrail system where it is connected with the rigid bridge railing. Stiffening is essential to prevent “pocketing” or “snagging” of a colliding vehicle just before the rigid bridge railing end.

If, on impact, a redirective device undergoes relatively large lateral displacements within a relatively short longitudinal distance, pocketing is said to have occurred. Depending on the degree, pocketing can cause large and unacceptable vehicular decelerations. When a portion of the test vehicle, such as a wheel, engages a vertical element in the redirective device, such as a post, snagging is said to have occurred. The degree of snagging depends on the degree of engagement. Snagging may cause large and unacceptable vehicular decelerations.

Approach Guardrail

The approach guardrail system is intended to screen motorists from the hazardous feature beneath the bridge as they are approaching the bridge (see Figures 5.5.2 and 5.5.3). This approach guardrail screening is often extended in advance of the bridge so as to also screen motorists from any hazardous roadside features on the approach to the bridge.

Approach guardrail must have adequate length and structural qualities to safely contain and redirect an impacting vehicle within tolerable deceleration limits. Redirection should be smooth, without snagging, and should minimize any tendency for vehicle rollover or subsequent secondary collision with other vehicles. Similar to bridge railing, approach guardrail systems must satisfy agency standards, which specify acceptable heights, materials, strengths, and geometric features.

Approach Guardrail Ends

The approach guardrail end treatment is the special traffic friendly anchorage of the approach guardrail system (see Figures 5.5.2 and 5.5.3). It is located at the end at which vehicles are approaching the bridge. Ground anchorage is essential for adequate performance of the guardrail system. Special end treatment is necessary in order to minimize its threat to motorists as another fixed object hazard within the roadside recovery area.

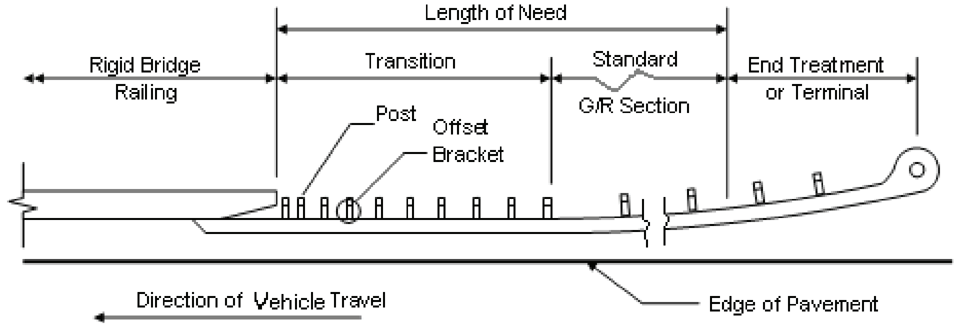

Figure 5.5.2 Traffic Safety Features

Figure 5.5.3 Bridge Railing, Transition, Approach Guardrail and End Treatment (Turn down end treatment no longer acceptable for this roadway type)

5.5.2 Evaluation

Each of the various elements of traffic safety features are designed to meet a specific function. Based on items from an inspection checklist, the inspector can make a determination of whether or not these elements function as intended. The elements for bridge railings and guardrail systems including transitions and end treatments must pass the minimum standard criteria established by AASHTO and FHWA and NCHRP minimum standards for structures on the NHS.

Design Criteria

Until the mid 1980's, bridge railings were designed consistent with earlier precedent, the guidance provided in the *AASHTO Standard Specifications for Highway Bridges*, and professional judgment. The *AASHTO Standard Specifications* called for application of a 10-kip horizontally applied static load at key locations, and certain dimensional requirements were also specified. Full-scale crash testing was not required, although a design that "passed" such testing was also considered acceptable for use. Subsequent crash testing of several commonly used, statically designed bridge railings revealed unexpected failures of the systems. It was soon concluded that static design loadings were not sufficient to ensure adequate railing performance. As a result of these findings, the FHWA issued guidance in 1986 requiring that bridge railing systems must be successfully crash tested and approved to be considered acceptable for use on Federal-aid projects.

Longitudinal roadside barriers, such as guardrail systems, had also been designed consistent with earlier precedent and judgment. Subsequent crash testing of these systems again revealed some unacceptable designs and prompted development of several new guardrail systems and details that were then identified as acceptable for new highway construction on Federal-aid projects.

History of Crash Testing

Full scale crash testing began in 1962. "Highway Research Correlation Circular 482" listed procedures including specified vehicle mass, impact speed and approach angle.

National Cooperative Highway Research Program (NCHRP) Project 22-2 in 1973 addressed questions not covered in "Circular 482". The final report is "NCHRP Report 183" which gives more complete set of testing procedures. Several parts of the document were known to be based on inadequate information. Procedures gained wide acceptance after their publication in 1974, but the need for periodic updates was recognized. In 1976, Transportation Research Board (TRB) committee A2A04 accepted responsibility for reviewing procedure efficiency. The minor changes were addressed and "Transportation Research Circular 191" was published in 1978.

NCHRP Project 22-2(4) initiated in 1979 was intended to address the major changes required in "NCHRP Report 183". The objective was to review, revise and expand the scope of "Circular 191" to reflect current technology. Final report was published as NCHRP Report 230 "Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances" in 1980. This report served as the primary reference for full scale crash testing of highway safety appurtenances.

In 1987, AASHTO recognized the need to update Report 230. This was due to changes in vehicle fleet, emergence of many new designs, matching safety performance to levels of roadway utilization, new policies requiring use of safety belts, and advances in computer simulation and other evaluation methods. NCHRP Project 22-7 was initiated to update Report 230.

Efforts began in 1989 with a series of white papers. A panel met to discuss the issues, debate and develop a consensus on procedures to be included in the update. The draft document was distributed for review, and the panel met two more times to discuss comments and to develop a final document. This document is NCHRP Report 350. This report differs from Report 230 in the following ways:

- Presented as all-metric document
- Provides wider range of test procedures to permit safety performance evaluations for a wider range of safety features and utility poles
- Uses a 2000 kg (4,409 pound) pick-up truck in place of a 2040 kg (4500 pound) passenger car
- Defines other test vehicles including a mini-compact passenger car at 700 kg (1,543 pounds), single-unit cargo trucks 8000 kg (17,637 pounds), and

tractor-trailer vehicles 36000 kg (77,366 pounds) for optional testing.

- Includes a broader range of tests for each category of safety feature that consider the levels of used of the roadway facility. Six (6) basic test levels are defined as well as a number of optional test levels to support more or less stringent performance criteria
- Guidelines for selection of critical impact point on redirecting type hardware
- Enhance measurement techniques related to occupant risk, and incorporates guidelines for device installation and test instrumentation
- Three basic evaluation categories remain the same: occupant risk, lateral occupant impact velocity, redirection criteria
- Critical review of methods and technologies for safety performance evaluation and incorporates state-of-the-art methods
- Provides optional criteria for side impact testing

Crash Test Criteria

Test requirements generally accepted at first were those contained in the National Cooperative Highway Research Program (NCHRP) Report 230 and in several earlier Transportation Research Board publications. In 1989, AASHTO published its “Guide Specifications for Bridge Railings,” wherein not only were the required tests specified but they were categorized into three separate performance levels. A warrant selection procedure was also included for determining an appropriate performance level for a given bridge site. As the crash test criteria differed in some respects from Report 230, use of the “Guide Specification” was, and continues to be, optional.

In 1990, the FHWA identified a number of crash-tested railing systems that met the requirements of NCHRP Report 230 or one of the performance levels in the *AASHTO Guide Specifications*. At this point, the FHWA considered that any railing that was acceptable based on Report 230 testing could also be considered acceptable for use, at least as a PL-1 (performance level 1) as described by the *AASHTO Guide Specifications*. They also stated that any SL-1 (service level 1) railing developed and reported in NCHRP Report 239, “Multiple-Service-Level Highway Bridge Railing Selection Procedures,” could be considered equivalent to a PL-1 railing.

In 1993, NCHRP Report 230 was superseded by NCHRP Report 350, “Recommended Procedures for the Safety Performance Evaluation of Highway Features.” Its current testing criteria include provisions for six different test levels, all of which differ in some ways from the previous Report 230 tests, as well as those in the *AASHTO Guide Specifications*. No selection procedures or warrants for the use of a specific test level are included in Report 350, although a separate research effort is underway to establish such warrants. Adding to the conflicting guidance for selection of an appropriate bridge railing system, the 1994 *AASHTO LRFD Bridge Design Specifications* were issued as an alternate to the long-standing *AASHTO Standard Specifications for Highway Bridges*. The 2005 *AASHTO LRFD Bridge Design Specifications* now have six test levels to correspond to the six levels in Report 350.

Current FHWA Policy

Bridge railings to be installed on National Highway System (NHS) projects must meet the acceptance criteria contained in NCHRP Report 350 or a recognized successor to those criteria. The minimum acceptable bridge railing for high-speed highways is a Test Level 3 (TL-3) unless supported by a rational selection procedure (see Table 5.5.1). For locations where the posted speed limit is less than 72 km/hr (45 mph), a TL-2 bridge railing is considered acceptable.

Test Level	Impact Speed	Vehicle Type
TL-1	50 kph (30 mph)	820 kg car; 2000 kg pickup
TL-2	70 kph (45 mph)	820 kg car; 2000 kg pickup
TL-3	100 kph (62 mph)	820 kg car; 2000 kg pickup
TL-4	100 kph (62 mph) 80 kph (50 mph)	820 kg car; 2000 kg pickup 8000 kg single unit truck
TL-5	100 kph (62 mph) 80 kph (50 mph)	820 kg car; 2000 kg pickup 36000 kg tractor trailer
TL-6	100 kph (62 mph) 80 kph (50 mph)	820 kg car; 2000 kg pickup 36000 kg tanker truck

Table 5.5.1 NCHRP Report 350 Test Level Index

Railings that have been found acceptable under the crash testing and acceptance criteria of NCHRP Report 230, the *AASHTO Guide Specifications for Bridge Railings*, or the *AASHTO LRFD Bridge Design Specifications* will be considered as meeting the requirements of NCHRP Report 350, provided they are equivalent to appropriate Report 350 Test Levels. This comparison of equivalencies has been tabulated by the FHWA in their May 30, 1997 memorandum on crash testing of bridge railings, with an attached May 14, 1996 document on bridge railing design and testing.

The FHWA continues to encourage support for development of railing test level selection procedures. In the interim, until AASHTO adopts a new railing test level selection procedure, the FHWA will accept the procedures in the *AASHTO Guide Specifications* or, as an alternate, a rational, experience-based, cost beneficial, consistently applied procedure proposed by an individual state. A 1996 document includes a listing of railings considered acceptable under the NCHRP Report 350 guidelines or their presumed equivalent guidelines. New crash-tested railings continue to be approved and added, and their identity and features can be obtained from the FHWA roadside hardware website, http://safety.fhwa.dot.gov/roadway_dept/road-_hardware.htm.

For non-NHS projects, the setting of criteria for establishing acceptability for bridge railings has been relegated by the FHWA to the individual states. Some states require conformity with the FHWA's NHS criteria for all bridges, on any of the highway systems. In other states, lesser performance criteria are accepted for bridges on non-NHS roads, so there may be variations between states as to safety feature acceptability.

Railing Evaluation Results/Resources

The FHWA maintains a website, http://safety.fhwa.dot.gov/roadway_dept/road-_hardware.htm which identifies all of the bridge and longitudinal roadside barrier systems, transitions, and end treatments which have been found to meet the various crash test requirements of NCHRP Reports 350 and 230. The website includes acceptance letters as well as links to manufacturers' websites for information on proprietary systems. Listings for several categories of safety features are accessible. New listings of bridge barriers more recently tested may be found on the longitudinal barrier list, so a thorough search of all listings is advisable to identify a specific feature and its test results. The May 30, 1997 memorandum and its attached document with test level equivalencies can also be found on the website.

Longitudinal barriers specifically used as bridge barriers which meet current crash test performance are found at www.fhwa.dot.gov/bridge/bridgerail/ . The "2005 Bridge Rail Guide" can be found at this web site. This document contains photographs, drawings, test level, contact information and cost for the currently accepted bridge rails.

Additional information can also be found in the current AASHTO "Roadside Design Guide" and in the current AASHTO-AGC-ARTBA Report, "A Guide to Standardized Highway Barrier Hardware."

Available Courses

FHWA-NHI 380032 AASHTO Roadside Design Guide

This two-day course discusses the use of the *Roadside Design Guide* including applying the clear zone concept, identifying the need for a traffic barrier, recognizing unsafe roadside design features and elements.

FHWA-NHI 380034 Design, Construction, and Maintenance of Highway Safety Appurtenances and Features

This one-day course allows participants to identify advantages and disadvantages of different types of longitudinal barriers and crash cushions, identify NCHRP 350 tested safety appurtenances, and recognize substandard or potentially hazardous highway appurtenances or features.

FHWA-NHI 380034A Design, Construction, and Maintenance of Highway Safety Appurtenances and Features

This two-day course allows participants to identify advantages and disadvantages of different types of longitudinal barriers and crash cushions, identify NCHRP 350 tested safety appurtenances, and recognize substandard or potentially hazardous highway appurtenances or features.

FHWA-NHI 380034B Design, Construction, and Maintenance of Highway Safety Appurtenances and Features

This three-day course allows participants to identify advantages and disadvantages of different types of longitudinal barriers and crash cushions, identify NCHRP 350 tested safety appurtenances, and recognize substandard or potentially hazardous highway appurtenances or features.

The courses listed above can be found by using the following website link www.nhi.fhwa.dot.gov/category.asp?category_id=16

5.5.3 Identification and Appraisal

Identification of conforming and non-conforming bridge safety features will vary depending upon highway classification and the jurisdiction involved. With various acceptance criteria to consider and with continuing crash testing and approvals of new barriers, it is advisable to rely on the most current specific acceptance criteria for the particular state or jurisdiction within which a bridge is located. A listing of currently conforming versus non-conforming bridge safety features should be obtained for each jurisdiction prior to identification and appraisal of these features in the course of bridge inspections within that jurisdiction.

Appraisal Coding

The FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (*Coding Guide*) requires an evaluation and reporting as to whether each of the four basic components satisfactorily conform to current safety design criteria for the respective component.

The condition of the safety features is not considered in the appraisal, but should be well documented in the inspection report. After determining whether the safety features at the site are acceptable, the inspector should assign an appraisal code. The FHWA *Coding Guide* contains four entries for safety features: one each for the bridge railing, approach guardrail, transition, and end treatment. Some states have modified and set different coding standards.

After making the determination as to whether or not safety features at the site meet currently acceptable standards, the inspector assigns an appraisal code of either 1 (meets) or 0 (does not meet) or N (Not applicable or a safety feature is not required*) for each element of Item 36 (page 17), FHWA *Coding Guide*:

36A Bridge railings
36B Transitions
36C Approach guardrail
36D Approach guardrail ends

* For structures on the NHS, national standards are set by federal regulation. For those not on the NHS, it shall be the responsibility of the highway agency (state, county, local or federal) to set standards.

While there is only one safety features coding for each element, there are at least two bridge railings and up to four approach guardrail treatments. Therefore, the bridge inspector should code the worst condition for each element even though they may occur at different locations on the bridge.

The following descriptions of Appraisal Items 36A – 36D are for bridge sites on the National Highway System (NHS). Local bridge owners may set different criteria to evaluate Items 36A – 36D.

36A Bridge Railings

Factors that affect the appraisal ratings of NHS bridge railings, Item 36A, include height, material, strength and geometric features (see Figure 5.5.4). The railing must be able to smoothly redirect the impacting vehicle. Bridge railings should be evaluated using the current *AASHTO Standard Specifications for Highway Bridges* for specific geometric criteria and static loading. The railings must be crash tested as per FHWA policy (see Figure 5.5.5). If the railings meet these criteria and loading conditions, they are considered acceptable. Other railings that have been crash tested but may not meet static load or geometric requirements are considered acceptable.

Figure 5.5.4 Acceptable Bridge Rail

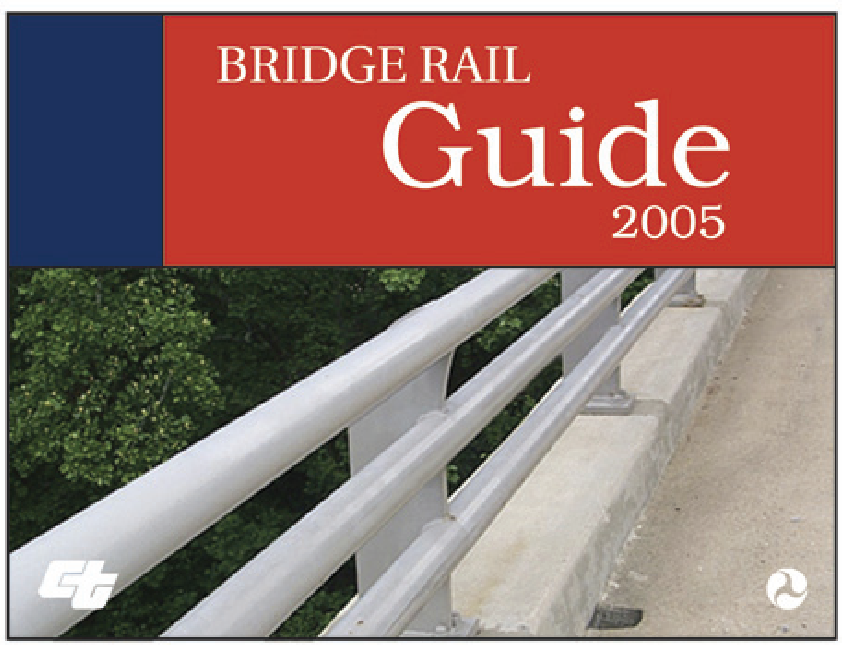

Figure 5.5.5 Bridge Rail Guide

36B Transitions

Appraisal Item 36B, transitions, requires the transition from the approach guardrail to the bridge railing be firmly attached to the bridge rail and gradually stiffened as it approaches the bridge rail (see Figure 5.5.6). Transition stiffening is usually accomplished through use of:

- Decreased post spacing
- Increased post size
- Embedment of posts in concrete bases
- Increased rail thickness, using a thicker gage rail element or by nesting two layers

Figure 5.5.6 Acceptable Transition

The ends of curbs or safety walks must be gradually tapered out or shielded. Vehicle snagging is discouraged by providing an increased rail surface projection with either a broader rail face (e.g., thrie beam) or a rub rail being placed beneath the primary rail, to minimize both guardrail post and bridge endpost exposure as potential snag points.

Older transitions usually have some of the essential features but are often lacking in some. There may be guardrail anchorage to the bridge but insufficient stiffening, or perhaps some degree of stiffening but insufficient concealment of potential snag points such as the front corner of the bridge endpost or exposed guardrail posts. Cable connections to the bridge railing do not meet minimum criteria because they do not provide a smooth stiffened transition. Timber approach rail attached to the bridge rail is not an acceptable transition on the NHS. No transition is provided at all when the bridge railing and approach guardrail are not structurally connected.

36C Approach Guardrail

Because the need for a barrier generally does not stop at the end of the bridge, the approach guardrail, Item 36C, must also be evaluated for adequacy. The structural adequacy and design compatibility of the approach rail and transition must be evaluated. The approach guardrail must be of adequate length and strength to shield motorists from the hazards at the bridge site. The guardrail must be able to safely redirect the impacting vehicle without snagging or pocketing. Acceptable design suggestions may be found in the *AASHTO Roadside Design Guide*, subsequent AASHTO guidelines, or the previously referenced FHWA website.

The strong post (steel or wood) W-beam guardrails with wood or approved plastic blocks (see Figure 5.5.7) are examples of systems meeting the requirements of Test Level 3, as are the strong post thrie-beam systems. The same W-beam barriers used with a steel block are included for Test Level 2.

Figure 5.5.7 Approach Guardrail System

Post and cable systems do not meet minimum criteria for bridge approach guardrail systems because they allow both snagging and pocketing of a vehicle upon impact. Timber approach guardrail does not meet minimum criteria for strength, continuity, or performance.

36D Approach Guardrail Ends

Approach guiderail ends, Item 36D, must be evaluated for adequacy. A variety of guardrail end treatments have been approved for use by the FHWA. The specific installation is dependent on various roadway features and testimony procedures as administered by the National Cooperative Highway Research Program (NCHRP). Current listings of crash tested end treatments and documentation of their performance can be found at http://safety.fhwa.dot.gov/roadway_dept/road_hardware/term_cush.htm. Probably the most universally effective is the buried-in-back-slope treatment where the longitudinal barrier is introduced from a buried anchorage, typically from a cut slope preceding the bridge approach guardrail installation (see Figure 5.5.8). Essential for these installations are keeping a constant rail height relative to the roadway grade and then provision of both a rub rail and an anchorage capable of developing the full strength of the W-beam rail.

Figure 5.5.8 W-Shaped Guardrail End Flared and Buried into an Embankment

Flaring the guardrail end to reduce the likelihood of a vehicular impact is only effective if there is enough space for a substantial flare from the edge of traveled way. The guardrail must be flared beyond the clear zone which is the area beyond the traveled way available for vehicle recovery. This area may consist of shoulder, recoverable or non-recoverable slope, and/or clear run-out area. The required width depends on traffic volume, speed, and roadside geometry.

Burying the guardrail end has been used with and without flaring. If the guardrail end is turned down for burying without flaring, it has frequently produced rollover accidents and is not currently considered an acceptable end treatment.

One of several breakaway treatments can be used. The guardrail end is modified to permit safe penetration through the system for end impacts, yet effective redirection of vehicles for impacts slightly after of the end treatment.

The last method for railing end treatment is shielding of the barrier with an energy-absorbing or attenuating system which dissipates impact energy as an impacting vehicle is gradually brought to a stop before reaching a rigid bridge rail endpost. Though vehicle damage may be severe, deceleration is controlled within tolerable limits to minimize occupant injury.

A variety of impact attenuators have been used, including expendable sand-filled containers, which shatter and absorb energy during impacts. There are also more elaborate telescoping fender systems, which redirect side impacts but also telescope and attenuate crash energy through crushing of replaceable foam-filled cartridges for direct impacts. Older versions absorbed energy through expulsion of water from water-filled tubes as the device collapsed. Most parts for these more elaborate devices are reusable, making them very suitable for approach guardrail end locations where frequent impacts might be expected.

In certain cases, such as at the trailing end of a one-way bridge, guardrail is not required at all.

The type of end treatment, which has sometimes been called a boxing glove, is not an acceptable end treatment unless properly flared away from the traveled way. If the guardrail ends are left unprotected, this is also unacceptable (see Figure 5.5.9).

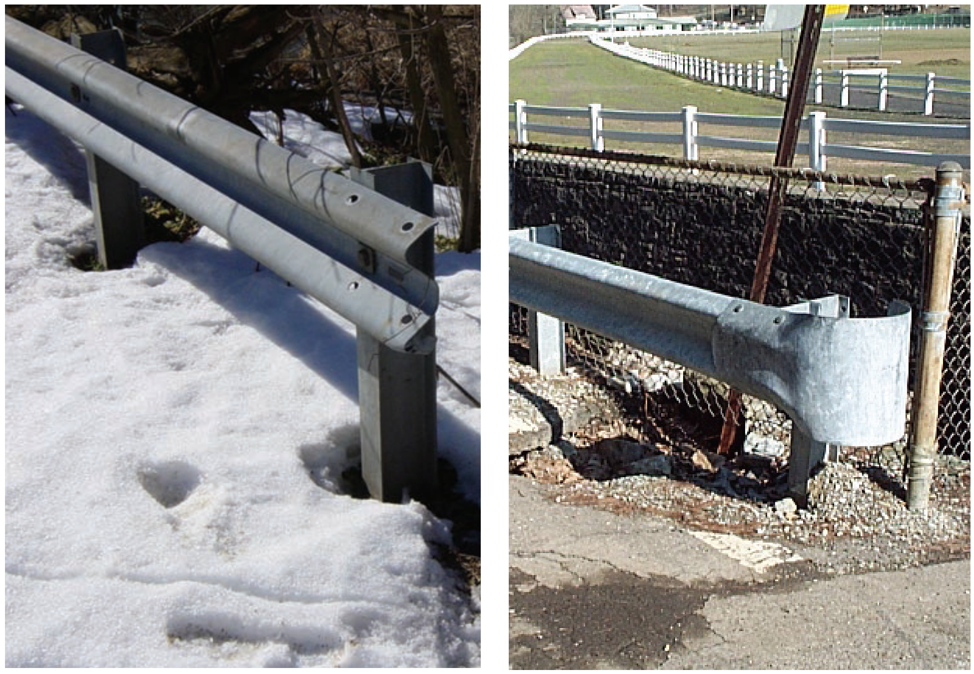

Figure 5.5.9 Unacceptable Blunt Ends

5.5.4 Median Barriers

Median barriers are used to separate opposing traffic lanes when the average daily traffic (ADT) on the road exceeds a specified amount. They are usually found on high speed, limited access highways.

The most commonly used median barrier on bridges is the concrete median barrier. This is a double sided parapet, and it should meet the current criteria for the crash testing of bridge railing. The only acceptable end treatment for a concrete median barrier is an impact attenuator.

Double-faced steel W-beam or thrie beam railing on standard heavy posts are also used for median barriers.

Inspection of Median Barriers

Median barriers should be firmly attached to the deck, and they should be functional. They should meet the requirements for Item 36A, bridge railing. Inspect for collision damage and attachment to any additional safety features. Check for deterioration and spalling on concrete median barriers, and examine for corrosion on steel railings and posts.

5.5.5 Safety Feature Inspection

The inspection of bridge safety features involves evaluation of the condition of the bridge railing, the transition, the approach guardrail, and approach guardrail ends leading from the bridge, the guardrail system leading from the approach roadway to the bridge end, and whether these two systems will likely function acceptably together to safely contain and redirect errant vehicles which may collide with them.

For structures which are over roadways, the adequacy and condition of traffic safety features for both the upper and lower roadways should be evaluated.

Inspection

Criteria that must be considered during the inspection of the bridge railing are the height, material, strength, geometric features, and the likelihood of acceptable crash test performance. See Subtopic 5.5.3 for the appraisal coding of Items 36A – 36D. Keep in mind that only the design of the traffic safety feature is addressed in Items 36 A – 36D. Deficiencies due to the condition must be recorded separately in the inspection notes.

Many state agencies have developed their own acceptance guidelines for bridge railings. The inspector should be familiar with agency guidelines for his or her state.

Bridge Railing

Comparison of existing bridge railing systems with approved crash-tested designs will establish their acceptability and crash worthiness.

Metal bridge railings should be firmly attached to the deck and should be functional. Check especially for corrosion and collision damage, which might render these railings ineffective (see Figure 5.5.10).

Concrete bridge railing is generally cast-in-place and engages reinforcing bars to develop structural anchorage in the deck slab. Verify that the concrete is sound and that reinforcing bars are not exposed. Inspect for impact damage or rotation, and note areas of damage or movement.

Check for evidence of anchorage failure in precast parapets. Sound exposed anchor bolts with a hammer. Check for separations between the base of the precast units and deck, or evidence of active water leakage between parapet and deck. Some states are removing all precast parapets.

Inspect post and beam railing systems for collision damage and deterioration of the various elements. Post bases should be checked for loss of anchorage. The exposed side of the railing must be smooth and continuous.

For a through truss or arch configuration, separate traffic from structural members, especially fracture critical members, with an adequate railing system to prevent major structural damage to the bridge and protect vehicle.

If add-on rails are other than decorative or for pedestrians, their structural adequacy can again be verified by comparison with successfully crash tested designs.

Figure 5.5.10 Damaged Steel Post Bridge Railing

Approach Guardrail

For approach guardrail, the inspector should verify that agency standards are met. Make note of rail element type, post size and post spacing for comparison with approved designs to verify acceptability of the guardrail system. Note any areas where the railing may "pocket" during impact, causing an abrupt deceleration or erratic rebound.

Document any significant collision damage, which is evident (see Figure 5.5.11). Posts which are displaced horizontally should be reported. Note any deterioration of guardrail elements, which could weaken the system. Check for cracks, rust or breakage of elements. Check wood posts for rot or insect damage, especially at the ground line. The connection between rails and posts should be secure and tight. Loose or missing bolts should also be noted.

Check the approach rail for proper alignment. Note any area of settlement or frost heave. Posts embedded in the ground should not be able to be moved by hand. Check the slope beyond the posts for settlement or erosion which may reduce embedment of the posts (see Figure 5.5.12).

Unless specifically designed for impact, timber approach guardrail does not meet minimum criteria for strength.

Figure 5.5.11 Approach Guardrail Collision Damage

Figure 5.5.12 Erosion Reducing Post Embedment

Transition

Check the approach guardrail transition to the bridge railing for adequate structural anchorage to the bridge railing system. Check for sufficiently reduced post spacing to assure stiffening of the guardrail at the approach to the rigid bridge rail end. Check for smooth transition details to minimize the possibility of snagging an impacting vehicle, causing excessive deceleration. For nested installations, be sure that the approach rail is properly nested with the lap splice away from the direction of traffic. (see Figure 5.5.13). Also check railing, post and offset bracket condition.

Timber should not be used for the rails in transitions on the National highway System.

Figure 5.5.13 Proper Nesting of Guardrail at Transition

End Treatment

Note the type, condition, and suitability of any end treatment. Acceptable crash-tested end treatments are identified in the *AASHTO Roadside Design Guide* or with current FHWA issuances. Check impact attenuation devices adjacent to bridge elements for evidence of damage due to impact and that the energy absorbing elements have not ruptured (see Figure 5.5.14). Ensure that any cables and anchorages are secure and undamaged.

End treatments may not be required on the trailing end of a one-way bridge.

Figure 5.5.14 Impact Attenuator

Inspection for Non-NHS Bridges

The requirements for inspection of traffic safety features presented in this topic are applicable to bridges on the National highway System (NHS). For bridges which are not located on the NHS, it is up to each state department of transportation to set its own policies.

There are still various requirements for that should be met as a minimum for these installations. The bridge rail must be crashworthy. The approach guardrail must be adequately connected to the bridge rail. Post spacing from the approach guiderail to the transition should be reduced to limit deflection. It is recommended to have nested rail at the transition, but it is not absolutely necessary. End treatments should be crash worthy with no blunt ends. Existing turned down ends and breakaway cable terminal (BCT) end treatments are acceptable if state policy is so stated. Crash worthy end treatments would be better, but may not be cost effective on low volume, low speed roads.

Figure 5.5.15 Timber Traffic Safety Features, Rocky Mountain National Park