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BRIDGE INSPECTION, MAINTENANCE, AND REPAIR

DEPARTMENTS OF THE ARMY AND THE AIR FORCE
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CHAPTER 6

BRIDGE REDUNDANCY AND FRACTURE CRITICAL MEMBERS (FCMs)

Section I. GENERAL

6-1. Introduction

Due to the nature of their construction and their usage within the structure, some bridge members, referred to as fracture critical members or FCMs, are more critical to the overall safety of the bridge and, thus, are more important from the inspection standpoint. Although their inspection is more critical than other members, the actual inspection procedures for FCMs are no different. Therefore, the inspection of FCMs is not addressed separately in this manual and has been integrated into the normal inspection procedures discussed in this manual. The purpose of this chapter is to introduce the concept of FCMs and to provide guidelines for their identification.

6-2. Fracture critical members

The AASHTO manual, “Inspection of Fracture Critical Bridge Members,” states that “Members or member components (FCMs) are tension members or tension components of members whose failure would be expected to result in collapse of the bridge.” To qualify as an FCM, the member or components of the member must be in tension and there must not be any other member or system of members which will serve the functions of the member in question should it fail. The alternate systems or members represent redundancy.

6-3. Redundancy

With respect to bridge structures, redundancy means that should a member or element fail, the load previously carried by the failed member will be redistributed to other members or elements which have capacity to temporarily carry additional load, and collapse of the structure may be avoided. Redundancy in this manual is divided into three parts as further described:

a. Load path redundancy. Load path redundancy refers to the number of supporting elements, usually parallel, such as girders or trusses. For a structure to be nonredundant, it must have two or less load paths (i.e., load carrying members), like the bridges in figure 6-1 which only have two beams or girders. Failure of one girder will usually result in the collapse of the span, hence these girders are considered to be nonredundant and fracture critical. Examples of multiple load path structures are shown in figure 6-2. There would be no FCMs in these structures.

b. Structural redundancy. Structural redundancy is defined as that redundancy which exists as a result of the continuity within the load path. Any statistically indeterminant structure may be said to be redundant. For example, a continuous two-span bridge has structural redundancy. In the interest of conservatism, AASHTO chooses to neglect structural redundancy and classify all two-girder bridges as nonredundant. The current viewpoint of bridge experts is to accept continuous spans as redundant except for the end spans, where the development of a fracture would cause two hinges which might be unstable.

c. Internal redundancy. With internal redundancy, the failure of one element will not result in the failure of the other elements of the member. The key difference between members which have internal redundancy and those which do not is the potential for movement between the elements. Plate girders, such as the one shown in figure 3-8, which are fabricated by riveting or bolting, have internal redundancy because the plates and shapes are independent elements. Cracks which develop in one element do not spread to other elements. Conversely, plate girders fabricated by rolling or welding, as shown in figures 3-7 and 3-8, are not internally redundant and once a crack starts to propagate, it may pass from piece to piece with no distinction unless the steel has sufficient toughness to arrest the crack. Internal redundancy is not ordinarily considered in determining whether a member is fracture critical but may be considered as affecting the degree of criticality.

6-4. Criticality of FCMs

The guidelines discussed above should be used to identify bridges that warrant special attention due to the existence of fracture critical members. Once an FCM is identified in a given structure, the information should become a part of the permanent record file on that structure. Its condition should be noted and documented on every subsequent inspection. The criticality of the FCM should also be determined to fully understand the degree of inspection required for the member. Criticality will be best determined by an experi-

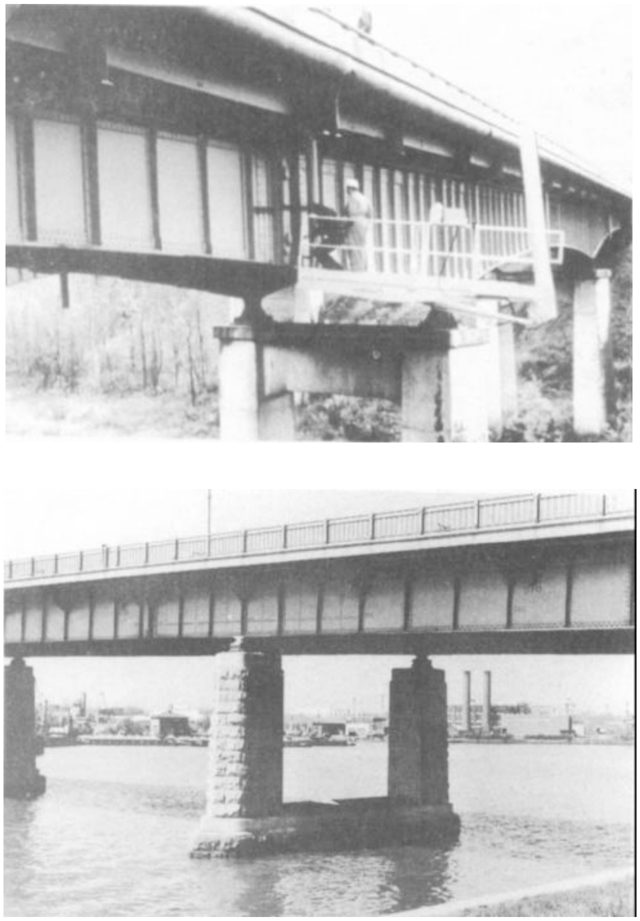


Figure 6-1. Nonload path redundant bridges.

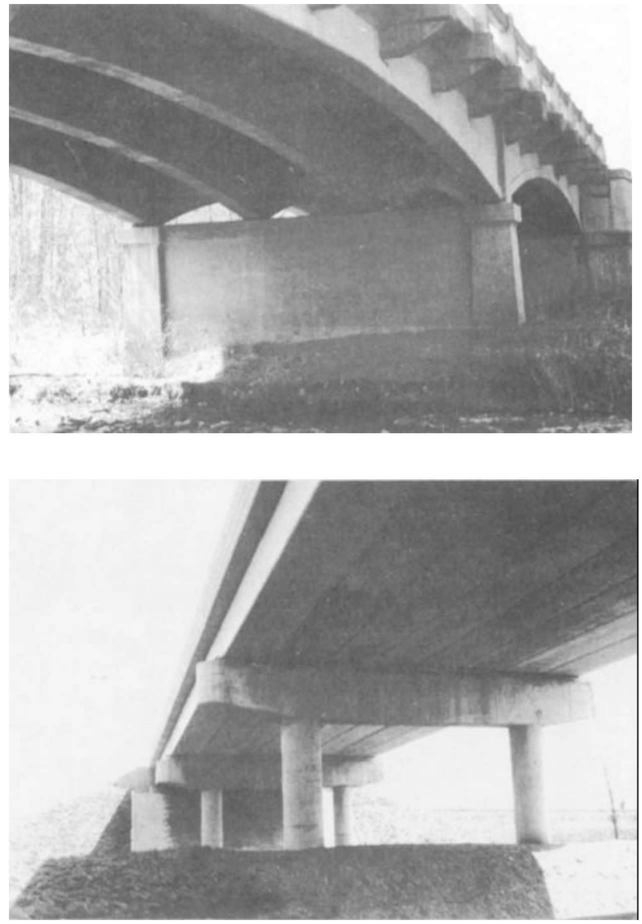


Figure 6-2. Load path redundant bridges.

enced structural engineer and should be based upon the following criteria:

a. Degree of redundancy. This was previously discussed in Section I.

b. Live load member stress. The range of live load stress in fracture critical members influences the formation of cracks. Fatigue is more likely when the live load stress range is a large portion of the total stress on the member.

c. Propensity for cracking or fracture. The fracture toughness is a measure of the material's resistance to crack extension and can be defined as the ability to carry load and to absorb energy in the presence of a crack. FCMs designed since 1978 by AASHTO standards are made of steel meeting minimum toughness requirements. On older bridges, coupon tests may be used to provide this information. If testing is not feasible, the age of the structure can be used to estimate the steel type which will indicate a general level of steel toughness. Welding, overheating, overstress, or member distortion resulting from collision may adversely affect the toughness of the steel. FCMs that are known or suspected to have been damaged should receive a high priority during the inspection, and more sophisticated testing may be warranted.

d. Condition of the FCMs. A bridge that receives proper maintenance normally requires less time to inspect. Bridges with FCMs in poor condition should be inspected at more frequent intervals than those in good condition.

e. Fatigue prone design details. Certain design details have been more susceptible to fatigue cracking. Table 6-1 and figure 6-3 classify the types of details by category. The thoroughness of a fracture critical member inspection should be in the order of their susceptibility to fatigue crack propagation, namely from the highest (E) to the lowest (A) alphabetical classification.

f. Previous and predicted loadings. Repeated heavy loading is a consideration in determining the appropriate level of inspection. While this is not an exact science and new bridges have devel-

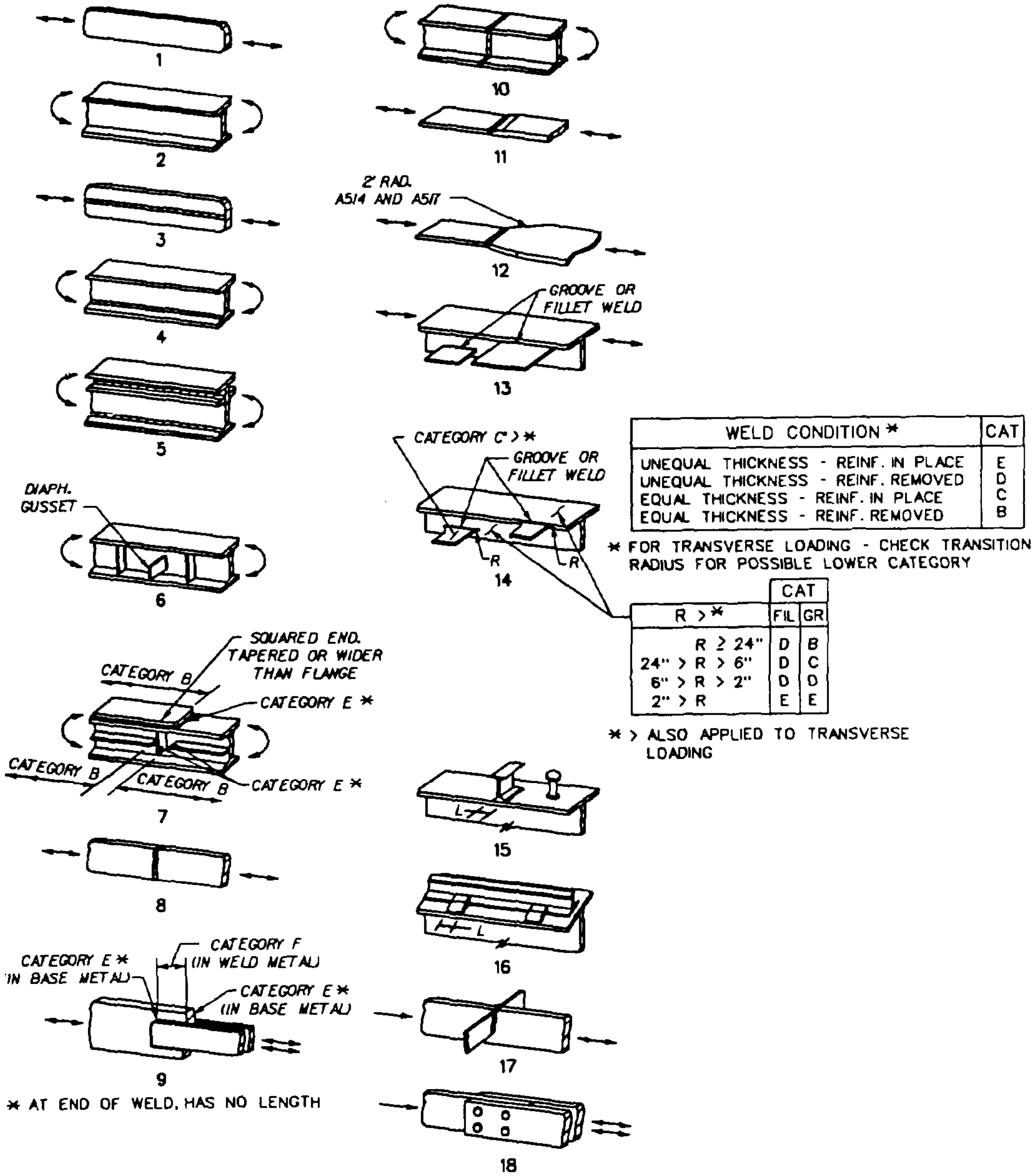


Figure 6-3. Examples of details in table 6-1.

oped fatigue cracks, the longer the bridge has been in service with a high volume of heavy loads, the greater the risk. When the precise number of loads experienced is not available, the location and the age is normally sufficient information to enable someone familiar with traffic in the area to make a reasonable estimate.

Section II. EXAMPLES

6-5. Two-girder system (or single-box girder)

a. Simple spans. A two-girder framing system is shown in figure 6-1. It is composed of two longitudinal girders which span between piers with transverse floorbeams between the girders. Floorbeams support longitudinal stringers. The failure of one girder may cause the span to collapse. These girders may be welded or riveted plate girders or steel boxbeams. The fracture critical elements in all of these girders are in the bottom flange and the web adjacent to the bottom flange as shown in figure 6-4, part a.

b. Anchor-cantilever. An anchor-cantilever span arrangement induces tension in the top flange and adjacent portion of the web in the area over the support as shown in figure 6-4, part b.

Table 6-1. Classification of types of details

General Condition	Type of Detail	Stress Category	Illustrative Example (See Figure 6-3)
Plain material	Base metal with rolled or cleaned surfaces. Flame cut edges with ASA smoothness of 1,000 or less.	A	1 , 2
Built-up members	Base metal and weld metal in members without attachments, built-up plates, or shapes connected by continuous full or partial penetration groove welds or by continuous fillet welds parallel to the direction of applied stress.	B	3,4,5,7
	Calculated flexural stress at toe of transverse stiffener welds on girder webs or flanges.	C	6
	Base metal at of partial length welded cover plates having square or tapered ends, with or without welds across the ends. (a) Flange thickness < 0.8 in. (b) Flange thickness > 0.8 in.	 E E'	 7 7
Groove welds	Base metal and weld metal, at full-penetration groove welded splices of rolled and welded sections having similar profiles when welds are ground flush, and weld soundness established by nondestructive inspection.	B	8,10,14
	Base metal and weld metal, in or adjacent to full-penetration groove welded splices at transitions in width or thickness, with welds ground to provide slopes no steeper than 1 to 2 1/2, with grinding in the direction of applied stress, and weld soundness established by nondestructive inspection.	B	11 , 12
	Base metal and weld metal, in or adjacent to full-penetration groove welded splices, with or without transitions having slopes no greater than 1 to 2 1/2 when reinforcement is not removed and weld soundness is established by nondestructive inspection.	C	8,10,11 12,14
	Base metal at details attached by groove welds subject to longitudinal loading when the detail length, L, parallel to the line of stress is between 2 in. and 12 times the plate thickness but less than 4 in.	D	13
	Base metal at details attached by groove welds subject to longitudinal loading when the detail length, L, is greater than 12 times the plate thickness or greater than 4 in. long.	E	13

c. Continuous spans. Continuous spans should be reviewed by a structural engineer or bridge designer to assess the actual redundancy and consequent presence of FCMs. In general, the fracture critical elements will be located near the center of the spans in the bottom of the girders and over the supports in the top of the girders.

6-6. Two-truss system

a. Simple spans. Most truss bridges have only two trusses. A truss may be considered a specialized girder with most of the web removed. Since tension members are the critical elements, the bottom chord and its connections are of primary concern. The diagonals and verticals which are in tension are also of primary concern. These members should be identified by a qualified structural engineer.

b. Anchor-cantilever. The anchor-cantilever in a truss system is similar to that in a girder system. In the area over an interior support (pier), the top chord is in tension. In the area near the end supports (abutments), the truss is similar to a simple-span truss and the same principles apply. From the center of the anchor span to the interior support, the stress arrangement is more complex and should be analyzed by a structural engineer.

c. Continuous spans. The statements regarding

Table 6-1. Classification of types of details-Continued

General Condition	Type of Detail	Stress Category	Illustrative Example (See Figure 6-3)
Groove welds (Cont'd)	Base metal at details attached by groove welds subjected to transverse and/or longitudinal loading regardless of detail length when weld soundness transverse to the direction of stress is established by nondestructive inspection.		
	(a) When provided with transition radius equal to or greater than 24 in. and weld end ground smooth.	B	14
	(b) When provided with transition radius less than 24 in. but not less than 6 in. and weld end ground smooth.	C	14
	(c) When provided with transition radius less than 6 in. but not less than 2 in. and weld end ground smooth.	D	14
	(d) When provided with transition radius between 0 in. and 2 in.	E	14
Fillet welded connections	Base metal at intermittent fillet welds.	E	--
	Base metal adjacent to fillet welded attachments with length L, in direction of stress less than 2 in. and stud-type shear connectors.	C	13,15, 16,17
	Base metal at details attached by fillet welds with detail lenth, L, in direction of stress between 2 in. and 12 times the plate thickness but less than 4 in.	D	13,15, 16
	Base metal at attachment details with detail length, L, in direction of stress (length of fillet weld) greater than 12 times the plate thickness or greater than 4 in.	E	7,9, 13,16
	Base metal at details attached by fillet welds regardless of length in direction of stress (shear stress on the throat of fillet welds governed by stress category F).		
	(a) When provided with transition radius equal to or greater than 2 in. and weld end ground smooth.	D	14
	(b) When provided with transition radius between 0 in. and 2 in.	E	14
Mechanically fastened connections	Base metal at gross section of high-strength bolted slip resistant connections, except axially loaded joints which induce out-of-plane bending in connected material.	B	18
	Base metal at net section of high-stength bolted bearing-type connections.	B	18
	Base metal at net section of riveted connections.	D	18
Fillet welds	Shear stress on throat of fillet welds.	F	9

continuous girders are also true regarding continuous trusses. In a continuous truss, the number of members in tension varies with the loading. Consequently, the determination of which members are in tension and which are fracture critical should be made by a structural engineer.

6-7. Cross girders and pier caps

The tension portions of simply supported cross girders and steel pier caps, as shown in figure 6-5, are nonredundant. These members usually consist of I sections or box beams. Unlike floorbeams which support only a portion of the deck, cross girders and steel pier caps support the entire end reactions of two longitudinal spans.

6-8. Supports and suspended spans

a. An example of a pin and hanger is shown in figure 3-15. Pin and hanger assemblies are as redundant as the framing system in which they are used. Hangers in a two-girder framing system offer no redundancy while the same assemblies used in a multibeam system have a high degree of redundancy.

b. An alternate support to the pin and hanger assembly is shown in figure 3-14. Portions of this detail (the short cantilever projection from the girder to the right) are fracture critical because part of it is in tension, and its failure will cause collapse unless it is used in a redundant framing system.

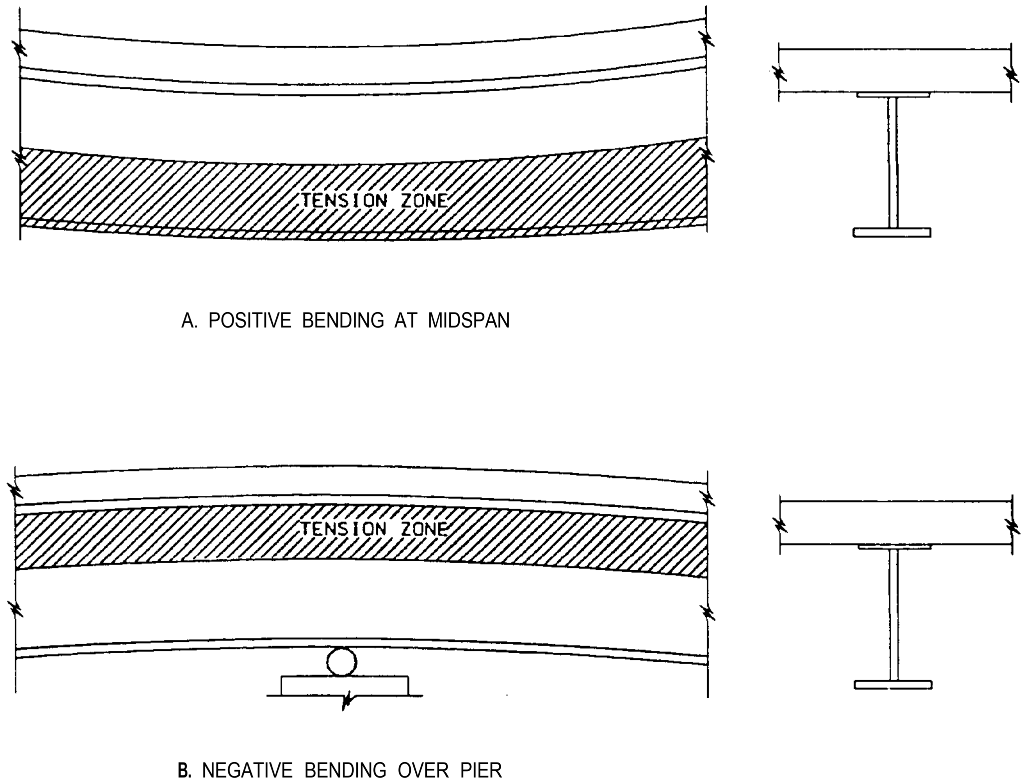


Figure 6-4. Portions of a girder in tension.

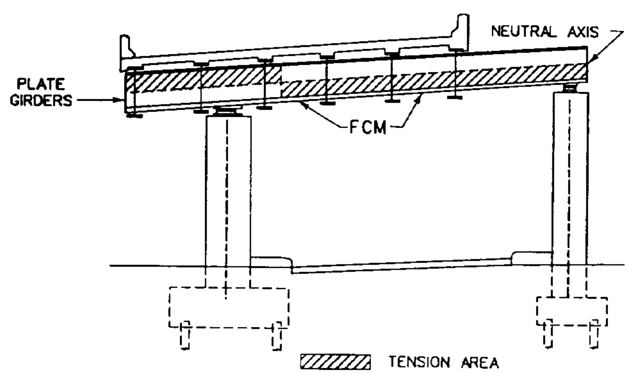


Figure 6-5. Steel cross girder on concrete piers.

CHAPTER 7

INSPECTION CONSIDERATIONS

Section I. TOOLS AND EQUIPMENT

7-1. Basic

For the inspection of bridges of any kind of material and structure, the bridge inspector should be equipped with at least a basic tool kit which includes, but is not necessarily limited to, the following: field books, inspection guide, sketch pad, paper, pencil, clipboard, keel marker, inspection mirror on a swivel head and extension arm for viewing difficult areas, camera (35 mm/Polaroid) for recording observed defects, safety belt for individual protection, tool belt, flashlight for viewing darkened areas, pocket knife, and binoculars.

7-2. Concrete inspection

In addition to the basic tools listed above, the concrete inspection tool kit should also consist of the following: 100-foot tape for measuring long cracks and large areas, 6-foot folding rule with 6-inch extender having 1/32-inch marking for measuring crack lengths and widths, piano wire for measuring the depth of cracks, chipping hammer for sounding concrete and removing deteriorated concrete, whisk broom for removing debris, scraper for removing encrustations, wire brush for cleaning exposed reinforcements, calipers (inside and outside) or micrometer for measuring exposed reinforcing bars, and a tape recorder for recording narratives of deteriorated conditions.

7-3. Steel inspection

In addition to the basic tools listed above, the steel inspection tool kit should also consist of the following: 100-foot tape for measuring long, deformed sections; 6-foot folding rule with 6-inch extender for measuring sections and offsets of deformed members; chipping hammer for cleaning heavily corroded areas; scraper for removing deteriorated paint and light corrosion; center punch for marking the end of cracks; calipers-dialed (inside and outside) or micrometer for measuring loss of section in webs, flanges, etc.; feeler gauges for measuring crack width; dry film paint gauge for measuring paint film thickness; large screwdriver; heavy-duty pliers; open-end wrench; wire brush for removing corrosion products; corrosion meter; dye penetrate kit and wiping cloths for examining small cracks; magnifying glass for viewing suspected areas and small cracks along welds and around connections; shovel for removing debris; ultrasonic testing device; testing hammer for checking connections; and a cold chisel for marking reference points.

7-4. Timber inspection

In addition to the basic tools listed above, the timber inspection tool kit should also consist of the following: industrial crayon; chipping hammer for determining areas of unsound timber; ice pick for prying and picking to determine the extent of unsound timber; knife for prying and picking to determine the extent of unsound timber; prying tool for prying around fittings to determine, tightness, deterioration between surfaces, and extent of timber defects (DO NOT use a screwdriver); increment borer for taking test borings to determine extent of internal damage; creosoted plugs for plugging the holes made in the timber with the increment borer; pocket tape for measuring around piles or other members; 6-foot folding rule with 6-inch extender having 1/32-inch markings for measuring deteriorated areas; scraper for cleaning incrustations off pilings; 100-foot tape for measuring distances from reference points; whisk broom for removing debris; straight edge to be used as a reference point from which to measure section loss; calipers (inside and outside) or micrometer for measuring loss of section; testing hammer; and a cold chisel.

7-5. Cast iron, wrought iron, and aluminum inspection

In addition to the basic tools listed above, the tool kit should also consist of the following: 100-foot tape for measuring long deformed sections, 6-foot folding rule with 6-inch extender for measuring sections and offsets of deformed members, chipping hammer for cleaning heavily corroded areas, scraper for removing deteriorated paint and light corrosion, center punch for marking the end of cracks, calipers (inside and outside) or micrometer for measuring loss of section, feeler gauges for measuring crack width, large screwdriver, heavy-duty pliers, open end wrench, pocket knife, wire brush for removing corrosion products, corrosion meter, dye penetrate kit and wiping cloths for examining small cracks, magnifying glass for viewing suspected areas and small cracks along welds and around connections, and a shovel for removing debris.

7-6. Special equipment

Other specialty items which may be required are: ladders; scaffolds (travelers or cabling); "snooper" or "cherry picker" (truck-mounted bucket on a hydraulically operated boom (or on a platform truck)); burning, drilling, and grinding equipment; sand or shot blasting equipment; boat or barge; diving equipment (scuba or hard hat); sounding equipment (lead lines or electronic depth finders); transit, level, or other surveying equipment; television camera for underwater use on closed circuit television with video tape recorder; magnetic or electronic locator for rebars; helicopters; air jet equipment; air breathing apparatus; mechanical ventilation equipment (blowers and air pipes); preentry air test equipment (devices to test oxygen content and to detect noxious gasses); ultrasound equipment; radiographic equipment; magnetic particle equipment; and dye penetrants. Ultrasound, radiographic, magnetic particle, dye penetrant, and other nondestructive methods are beyond the scope of the average inspection.

Section II. SAFETY

7-7. General

The safety of the bridge inspector is of the utmost importance. While the work may be hazardous, the accident probability may be limited by proceeding cautiously. Always be careful and use good judgment and prudence in conducting your activities both for your own safety and that of others. The safety rules must be practiced at all times to be effective.

7-8. Bridge site organization

a. General. The safety of personnel and equipment and the efficiency of the bridge inspection operation depend upon proper site organization.

b. Personnel. All individuals who are assigned to work aloft should be thoroughly trained in the rigging and use of their equipment, i.e., scaffolds, working platforms, ladders, and safety belts. The plans for inspection should give first consideration to safeguarding personnel from possible injuries.

c. Equipment. Inspection equipment, highway traffic barricades, and signs should be arranged according to the plan of inspection to accomplish as little handling, unnecessary movement, and prepositioning as possible. Vehicles not directly involved in the inspection process should be parked to prevent congestion and avoid interference in the areas of inspection.

d. Orderliness. Individuals should develop orderly habits in working and housekeeping on the job.

7-9. Personal protection

a. It is important to dress properly. Keep clothing and shoes free of grease. The following protective equipment is recommended for use at all times:

(1) Hard hat with a chin strap.

(2) Goggles, face masks, shields, or helmets, when around shot blasting, cutting, welding, etc.

(3) Reflective vests or belts when working in traffic.

(4) Life preservers or work vests when working over water.

(5) Shoes with cork, rubber, or some other nonslip soles.

b. If you wear glasses, wear them when climbing. The wearing of bifocals is an exception to this rule. Only regular single-lens glasses should be worn while climbing. Where work requiring close-up viewing is to be performed, a separate pair of glasses with lenses ground for this purpose should be worn.

c. Do not drink alcoholic beverages before or during working hours. They impair judgment, reflexes, and coordination.

7-10. Special safety equipment

a. A life line or belt must be worn when working at heights over 20 feet, above water, or above traffic.

b. A life-saving or safety skiff should be provided when working over large rivers or harbors; the skiff should have life preservers and life lines on board.

c. Warning signals, barricades, or flagmen are necessary when the deck is to be inspected or when scaffolding or platform trucks are used for access to the undersides or bridge seat of a structure.

7-11. Climbing of high steel

a. General. It is preferable to work from a traveler, catwalk, or platform truck, if possible. NOTE: On old ladders and catwalks, proceed with caution.

b. Scaffolding. When using scaffolding, the following precautions should be observed:

(1) Scaffolding and working platforms should be of ample strength and should be secure against slipping or overturning.

(2) Hanging scaffolds and other light scaffolds supported by ropes should be tested before using by hanging them 1 foot or so from the ground and loading them with a weight at least four times as great as their working load.

(3) Scaffolds should be inspected at least once each working day.

c. Ladders. Ladders should be used as working platforms only when it is absolutely necessary to do so. When using ladders, the following precautions should be observed:

(1) Make certain that the ladder to be used is soundly constructed. If made of wood, the material should be straight-grained and clear.

(2) Ladders should be tested to make sure they can carry the intended loads.

(3) Ladders should be blocked at the foot or tied at the top to prevent slipping.

(4) Personnel should be cautioned frequently about the danger of trying to reach too far from a single setting of a ladder.

d. Planks or platforms. Planks or platforms may be used where necessary. The following precautions should be observed:

(1) Planks should be large enough for the span.

(2) Never use a single plank. Two planks are a bare minimum; they should be attached by leads 18 inches apart.

e. Safety.

(1) Keep all catwalks, scaffolds, platforms, etc., free from ice, grease, or other slippery substances or materials.

(2) Catwalks, scaffolds, and platforms should have hand rails and toe boards to keep tools or other objects from being kicked off and become a hazard to anyone below.

(3) Always watch where you are stepping. Do not run or jump.

(4) Do not climb if you are tired or upset.

7-12. Confined spaces

a. General. In recent years there has been an increasing use of hollow structural members of the tubular or box-section types large enough to permit a man to enter the interior of the member. In bridge work, boxes are used both in large truss bridges and in girder bridges with rectangular or trapezoidal box sections. In these types of members, the interior is often closed off at both ends, forming a closed box. This protected interior is high in corrosion resistance even in the bare metal state. In some closed sections, a closable, watertight, and vapor tight access hole is provided to permit inspection of the interior. While the box section offers both structural and maintenance advantages over other types of sections, there are certain health hazards of which the maintenance inspectors, and others who may be involved with these types of sections, should be aware.

b. Hazards. No health hazard exists in confined space if there is proper ventilation. However, a hazardous atmosphere can develop because of a lack of sufficient oxygen or because of a concentration of toxic gases. Oxygen deficiency can be caused by the low oxidation of organic matter which can become moistened. Toxic gasses may seep into the confined space or may be generated by such work processes as painting, burning, or welding. The confined space may be of such small volume that air contaminants are produced more quickly than the limited ventilation of the space can overcome. Persons should not be allowed to work in confined spaces containing less than 19 percent oxygen, unless provided with air breathing apparatus. However, as noted, a space with sufficient oxygen content can become unfit for human occupancy if the work conducted therein produces toxic fumes or gases. Such space should be occupied by the inspector only after adequate ventilation.

c. Safety procedures.

(1) *Preentry air tests.*

(a) Tests for oxygen content should be conducted with an approved oxygen-detecting device. A minimum of two tests should be conducted.

(b) Where the presence of other gases is suspected, tests for such gases should be conducted using approved gas-detecting devices. The following gases should be considered: carbon dioxide, carbon monoxide, hydrogen sulfide, methane, or any combustible gas.

(c) If the oxygen content of the air in the space is below 19 percent or if noxious gases present are equal or in excess of 125 percent of the Threshold Limit Values established by the American Conference of Government Industrial Hygienists (reference 6), no person should be allowed to enter such space until the oxygen content and gas content meet these specified limits for a minimum period of 15 minutes.

(2) *Ventilation during occupancy.*

(a) All confined spaces should be mechanically ventilated continuously during occupancy regardless of the presence of gas, the depletion of oxygen, or the conduct of contaminant-producing work.

(b) Where contaminant-producing operations are to be conducted, the ventilation scheme should be approved by an industrial hygiene engineer, safety engineer, marine chemist, or others qualified to approve such operations.

(3) *Air tests during occupancy.*

(a) If toxic gas presence or oxygen depletion is detected or suspected, air tests similar to the preentry air tests should be conducted during occupancy at 15-minute intervals.

(b) Where contaminant-producing operations are conducted, air tests should be conducted to determine the adequacy of the ventilation scheme.

Section III. DOCUMENTATION OF THE BRIDGE INSPECTION

7-13. General

The field inspection of a bridge should be conducted in a systematic and organized procedure that will be efficient and minimize the possibility of any bridge item being overlooked. Notes must be clear and detailed to the extent that they can be fully interpreted at a later date when a complete report is made. Sketches and photographs should be included in an effort to minimize long descriptions.

7-14. Planning and documenting the inspection

Careful planning of the inspection and selection of appropriate record keeping formats are essential for a well-organized, complete, and efficient inspection. During the planning phase the following items should be considered:

a. The inspection schedule.

b. The inspection type.

c. The resources required: manpower, equipment, materials, and special tools and instruments.

d. A study of all pertinent available information on the structure such as plans, previous inspections, current inventory report, and previous repairs.

e. Optional documentation methods:

(1) *Notebook.* The inspection notebook is normally used as the sole documentation on structures that are complex or unique. It should be prepared prior to the inspection and formatted to best facilitate the systematic inspection and recording of the bridge.

(2) *Bridge inspections.* For small and simple bridges, it may be more convenient to prepare checklists. Suggested items for these inspections are provided in appendixes B and C. Sketches can be drawn and additional comments provided as required. If available, standard prepared sketches should be attached with the coding of all members clearly indicated. Where sketches and narrative descriptions cannot fully describe the deficiency or defect, photographs should be taken and should be referred appropriately in the narrative. Prior to the inspection, it should be determined which items are not applicable for the bridge to be inspected.

f. Coordination of resource requirements, particularly that of specialist personnel and special equipment.

g. The inspection procedure.

h. The existence of fracture critical members. As discussed in chapter 6, these members should be identified prior to the inspection so that they can be given special attention during the inspection. These members should be specifically denoted in the inspector's notebook prior to the inspection.

7-15. Structure evaluation

a. General. A bridge is typically divided into two main units, the substructure and the superstructure. For convenience the deck is sometimes considered as a separate unit. These basic units may be divided into structural members, which, in turn, may be further subdivided into elements or components. The general procedure for evaluating a structure is to assign a numerical rating to the condition of each element or component of the main units. A suggested numerical rating system is provided in appendix C. These ratings may be combined to obtain a numerical value for the overall condition of a member or of a unit.

b. Explanatory aids.

(1) *Narrative descriptions.* Descriptions of the condition should be as clear and concise as possible. Completeness, however, is essential. Therefore, narratives of moderate length will sometimes be required to adequately describe bridge conditions.

(2) *Photographs.* Photographs can be a great assistance. It is particularly recommended that pictures be taken of any problem areas that cannot be completely explained by a narrative description. It is better to take several photographs that may be unessential than to omit one that would preclude misinterpretation or misunderstanding of the report. At least two photographs of every structure should be taken. One of these should depict the structure from the roadway while the

other photo should be a view of the side elevation.

(3) *Summary.* An inspection is not complete until a narrative summary of the condition of the structure has been written.

(4) *Recommendations.* The inspector should list according to urgency any repairs that are necessary to maintain structural integrity and public safety.

Section IV. INSPECTION PROCEDURE

7-16. General

The development of a sequence for the inspection of a bridge is important since it actually outlines the plan for inspection. A well constructed sequence will provide a working guide for the inspector and ensure a systematic and thorough inspection.

a. Factors. Some of the factors that influence the procedure or sequence of a bridge inspection are:

(1) Size of the bridge.
(2) Complexity of the bridge.
(3) Existence of fracture critical members.
(4) Traffic density.
(5) Availability of special equipment.
(6) Availability of specialists.

b. Thoroughness of inspection. Thoroughness is as important as the sequence of the inspection. Particular attention should be given to:

(1) Structurally important members.
(2) Members most susceptible to deterioration or damage.

c. Visual inspection. Dirt and debris must be removed to permit visual observation and precise measurement. Careful visual inspection should be supplemented by appropriate special devices and techniques. If necessary, use of closed circuit television, photography, and mirrors will increase visual access to many components.

7-17. Inspection sequence

a. Average bridges. For bridges of average length and complexity, it is convenient to conduct the inspection in the following sequence:

(1) *Substructure units.*
(a) Piles.
(b) Fenders.
(c) Scour protection.
(d) Piers.
(e) Abutments.
(f) Skewbacks.
(g) Anchorages.
(h) Footings.

(2) *Superstructure units.*
(a) Main supporting members.
(b) Bearings.
(c) Secondary members and bracing.
(d) Utilities.
(e) Deck, including roadway and joints.
(f) End dams.
(g) Sidewalks and railings.

(3) *Miscellaneous.*
(a) Approaches.
(b) Lighting.
(c) Signing.
(d) Electrical.
(e) Barriers, gates, and other traffic control devices.

b. Large bridges. While the sequence of inspection for large bridges will generally be the same as for smaller bridges, exceptions may occur in the following situations:

(1) *Hazards.* Climbing and other hazardous tasks should be accomplished while the inspector is fully alert.

(2) *Weather.* Wind, extreme temperatures, rain, or snow may force the postponement of hazardous activities such as climbing, diving, or water-borne operations.

(3) *Traffic.* Median barriers, decks, deck joints, traffic control devices, and approaches should be inspected in daylight during periods of relatively light traffic to ensure inspector safety and to avoid the disruption of traffic.

(4) *Inspection party size.* When the inspection party is large, several different tasks may be performed simultaneously by different inspectors or groups of inspectors.

CHAPTER 8

BRIDGE COMPONENT INSPECTION

Section I. SUBSTRUCTURES

8-1. General

All bridge components are defined and discussed in chapter 3 of this manual. Bridge construction materials, their characteristics, and their associated deterioration problems are discussed in chapter 5 of this manual. This chapter presents a detailed, systematic guide to the inspection of each bridge component. Note that especially detailed instructions will be given for the inspection of FCMs. The guidelines provided in chapter 5 should be used as a supplement to this chapter to help recognize, describe, and assess problems with the various components.

8-2. Abutments

a. Check for scour or erosion around the abutment and for evidence of any movement (sliding, rotation, etc.) or settlement. Open cracks between adjoining wing walls or in the abutment stem, off-centered bearings, or inadequate or abnormal clearances between the back wall and the end beams are indications of probable movement (figure 8-1). If substructure cracking or movement is evidenced, a thorough subaqueous investigation or digging of test pits should be ordered to determine the cause of the problems.

b. Determine whether drains and weepholes are clear and functioning properly. Seepage of water through joints and cracks may indicate accumulation of water behind the abutment. Report any frozen or plugged weepholes. Mounds of earth immediately adjacent to weepers may indicate the presence of burrowing animals.

c. Check bearing seats for cracking and spalling, especially near the edges. This is particularly critical where concrete beams bear directly on the abutment. Check bearing seats for presence of debris and standing water.

d. Check for deterioration concrete in areas that are exposed to roadway drainage. This is especially important in areas where deicing chemicals are used.

e. Check backwalls for cracking and possible movement. Check particularly the construction joint between the backwall and the abutment.

f. Check stone masonry for mortar cracks, vegetation, water seepage, loose or missing stones, weathering, and spalled or split blocks.

8-3. Retaining walls

Inspection of most retaining walls should be similar to that of an abutment. Crib walls are subject to the same types of deterioration as other structures of wood, concrete, and steel:

a. Timber cribs may decay or be attacked by termites. However, the creosote treatment is usually very effective in protecting the wood.

b. Concrete cribs are subject to shipping and spalling. In addition, the locking keys or flanges at the ends of the crib pieces are sometimes broken off by vandals or inadvertently damaged by casual passersby.

c. Settlement of soil under the embankment will lead to distortion and possible damage to a crib wall. If sufficient movement occurs, the wall may fail.

8-4. Piers and bents

a. Check for erosion or undermining of the foundation by scour and for exposed piles (figure 8-2). Check for evidence of tilt or settlement as discussed in section VII of chapter 5. If problems of this type are evidenced, a thorough subaqueous investigation should be ordered to determine the cause of the problems.

b. Check for disintegration of the concrete, especially in the splash zone, at the waterline, at the groundline, and wherever concrete is exposed to roadway drainage (figure 8-3).

c. Check the pier columns and the pier caps for cracks.

d. Check the bearing seats for cracking and spalling.

e. Check stone masonry piers and bents for mortar cracks, water and vegetation in the cracks, and for spalled, split, loose, or missing stones.

f. Check steel piers and bents for corrosion (rust, especially at joints and splices). Bolt heads, rivet heads, and nuts are very vulnerable to rust, especially if located underwater or in the base of a column.

g. Examine grout pads and pedestals for cracks, spall, or deterioration.

h. Examine steel piles both in the splash zone and below water surface.

i. Investigate any significant changes in clearance for pier movement.

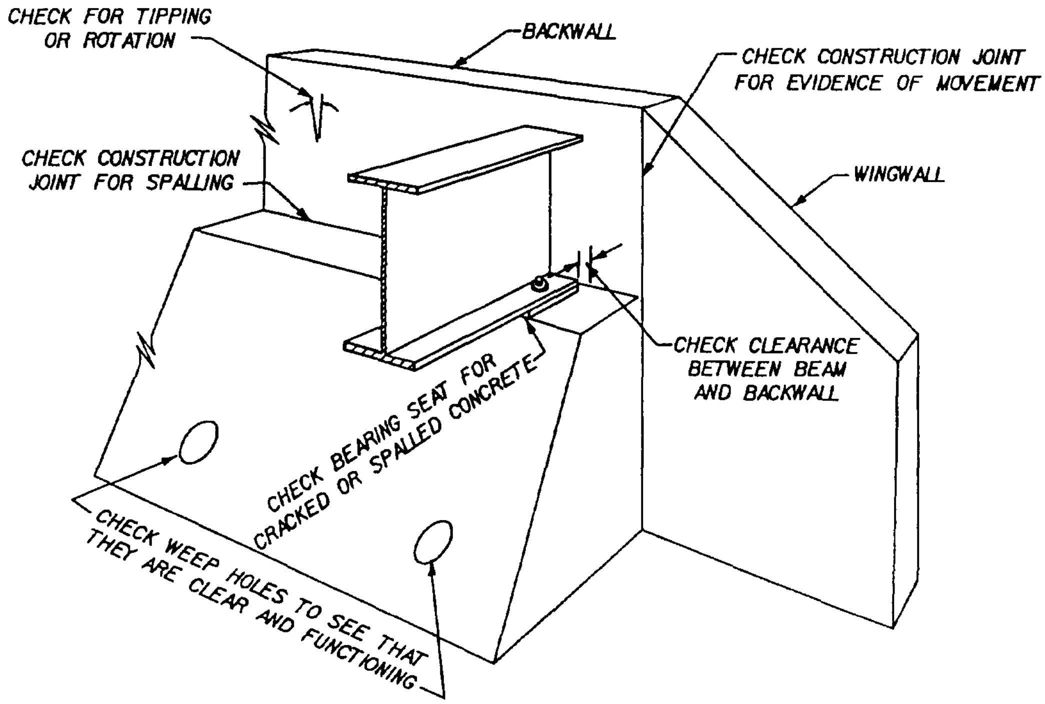


Figure 8-1. Abutment checklist items.

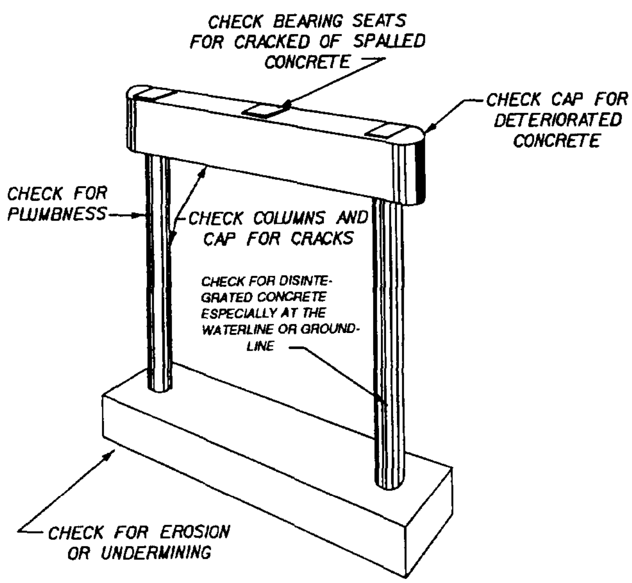


Figure 8-2. Concrete pier and bent checklist items.

j. Check all pier and bent members for structural damage caused by collision or overstress.

k. Observe and determine whether unusual movement occurs in any of the bent members during passage of heavy loads.

l. Where rocker bents (figure 8-4) are designed to rotate freely on pins and bearings, check to see that such movement is not restrained. Restraint can be caused by severe corrosion or the presence of foreign particles.

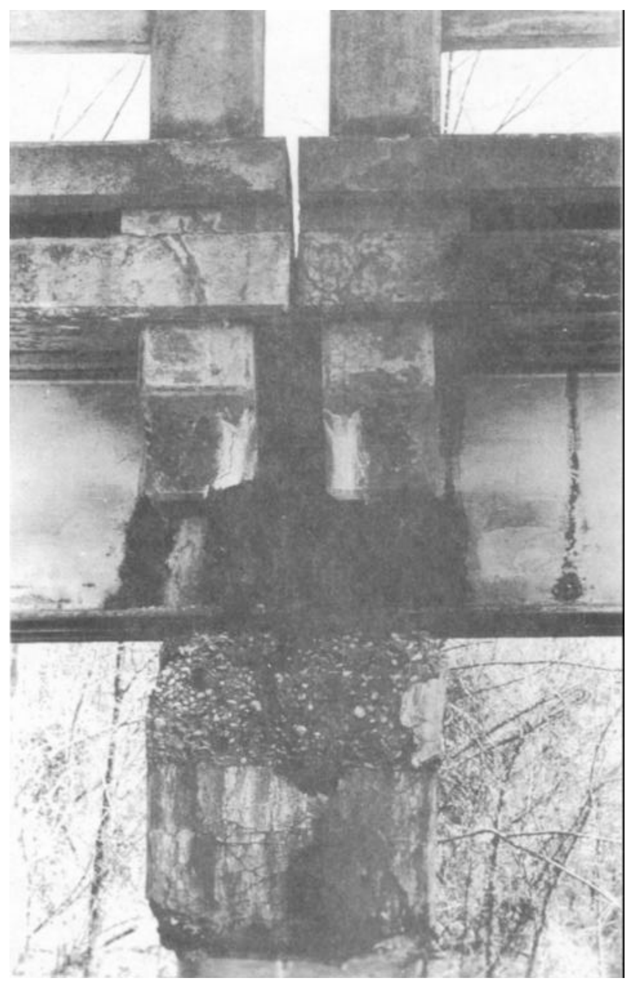


Figure 8-3. Pier cap disintegration due to roadway drainage.

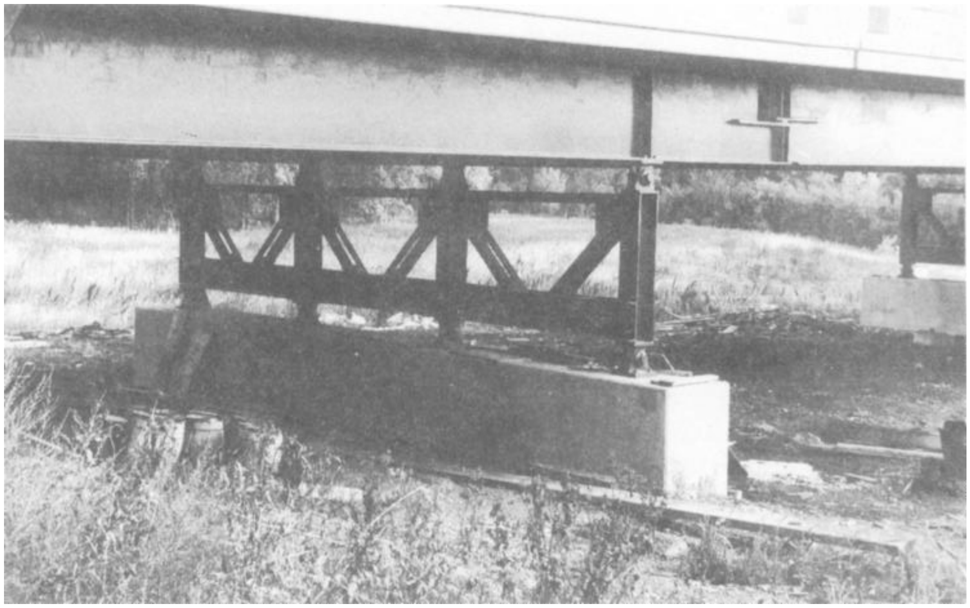


Figure 8-4. Steel rocker bent.

m. Determine whether any earth or rock fills have been piled against piers causing loads not provided for in the original design and producing unstable conditions.

n. Inspect cross girder pier caps (figure 6-5). Their failure will generally cause collapse of the unsupported span. Therefore, they are considered FCMs and should be closely inspected as follows:

(1) *Riveted.*

(a) Check all rivets and bolts to determine that they are tight and that the individual components are operating as one. Check for cracked or missing bolts, rivets, and rivet heads.

(b) Check the member for misplaced holes or repaired holes that have been filled with weld metal. These are possible sources of fatigue cracking.

(c) Check the area around the floorbeam and lateral bracing connections for cracking in the web due to out-of-plane bending.

(d) Check the entire length of the tension flanges and web for cracking which may have originated from corrosion, pitting or section loss, or defects in fabrication (e.g., nicks and gouges in the steel).

(e) Check entire length for temporary erection welds, tack welds, or welded connections not shown on the design drawings.

(2) *Welded.*

(a) Check all tranverse groove welds for indication of cracks, especially near backup bars.

(b) Check all tranverse stiffeners and connection plates at the connection to the web, particularly at floorbeams and lateral bracing where out-of-plane bending is introduced.

(c) If longitudinal stiffeners have been used, check any butt weld splices in the longitudinal stiffeners. The web at the termination of longitudinal stiffeners should also be checked carefully.

(d) If cover plates are present, check carefully at the terminus of each for cracks.

(e) Observe any area of heavy corrosion for pitting section loss or crack formation.

(f) If girders have been haunched by use of insert plates, observe the transverse groove welding between the web and insert plate.

(g) Check longitudinal fillet welds for possible poor quality or irregularities that may cause cracking to initiate. This is especially important during the first inspection of the member so that defects can be recorded and properly documented on follow-up inspections.

(h) Check for cracks at any intersecting fillet welds. If triaxial intersecting welds are found on an FCM, they should be reported and carefully examined in future inspections.

(i) Check any plug welds.

(j) Check bolted splices for any sign of cracks in girders or splice plates and look for missing or cracked bolts.

(k) Check the entire length of the tension flanges and web for cracking which may have originated from corrosion, pitting or section loss, or defects in fabrication.

(l) Check entire length for temporary erection, tack welds, or welded connections not shown on the design drawings.

8-5. Pile bents

a. Concrete. Check for the same items as discussed in paragraph 8-4.

b. Timber.

(1) Check for decay in the piles, caps, and bracing (figure 8-5). The presence of decay may be determined by tapping with a hammer or by test boring the timber. Check particularly at the groundline, or waterline, and at joints and splices, since decay usually begins in these areas.

(2) Check splices and connections for tightness and for loose bolts.

(3) Check the condition of the cap at those points where the beams bear directly upon it and at those points where the cap bears directly upon the piles. Note particularly any splitting or crushing of the timber in these areas.

(4) Observe caps that are under heavy loads for excessive deflections.

(5) Check for rotted or damaged timbers in the backwalls of end bents (abutments), especially where such conditions would allow earth to spill upon the caps or stringers. Approach fill settlement at end bents may expose short sections of piling to additional corrosion or deterioration.

(6) In marine evironments, check structures for the presence of marine borers and shipworms.

(7) Check timber piles in salt water to determine damage caused by marine borers.

(8) Check timber footing piles in salt water exposed by scour below the mudline for damage caused by marine borers.

(9) Check timber piles in salt water at checks in the wood, bolt holes, daps, or other connections for damage by marine borers.

c. Steel.

(1) Check the pile bents for the presence of rust, especially at the ground level line. Use a chipping hammer, if necessary, to determine the extent of the rust. Over water crossings, check the splash zone (2 feet above high tide or mean water level) and the submerged part of the piles for indications of rust.

(2) Check for debris around the pile bases. Debris will retain moisture and promote rust.

(3) Check the steel caps for rotation due to eccentric (off-center) connections.

(4) Check the bracing for broken connections and loose rivets or bolts.

(5) Check condition of web stiffeners.

8-6. Dolphins and fenders

a. Steel. Observe the "splash zone" carefully for severe rusting and pitting. The splash zone is the area from high tide to 2 feet above high tide. Where there are no tides, it is the area from the mean water level to 2 feet above it. Rusting is much more severe here than at midtide elevations.

b. Concrete. Look for spalling and cracking of concrete, and rusting of reinforcing steel. Be alert for hour-glass shaping of piles at the waterline.

c. Timber. Observe the upper portions lying between the high water- and mudline for marine

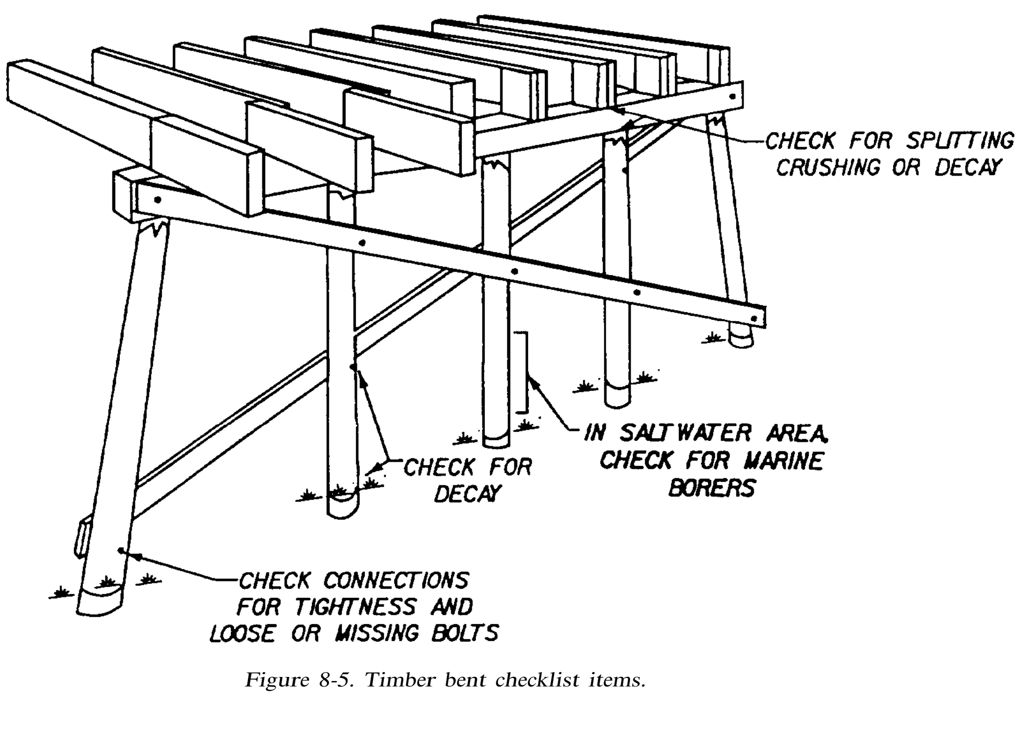


Figure 8-5. Timber bent checklist items.

insects and decay (figure 8-6). Check the fender pieces exposed to collision forces for signs of wear.

d. Structural damage. Check all dolphins or fenders for cracks, buckled or broken members, and any other signs of structural failures or damage from marine traffic.

(1) Piling and walers require particular attention, since these are areas most likely to be damaged by impact.

(2) Note any loose or broken cable which would tend to destroy the effectiveness of the cluster (figure 8-6). Note whether they should be rewrapped.

(3) Note missing walers, blocks, and bolts.

e. Protective treatment. Note any protective treatment that needs patching or replacing. This includes breaks in the surface of treated timbers, cracks in protective concrete layers, rust holes or tears in metal shields, and bare areas where epoxy or coal tar preservatives have been applied externally.

f. Catwalks. Note the condition of the catwalks for fender systems.

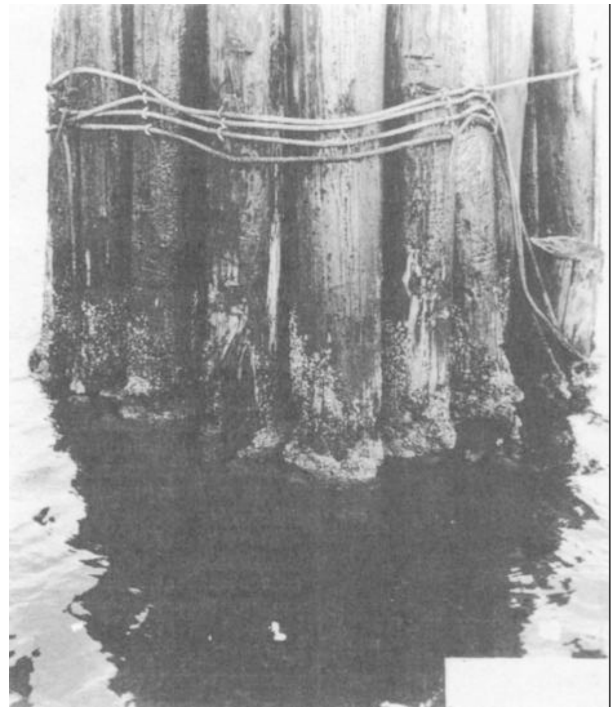


Figure 8-6. Deteriorated timber dolphins.

Section II. SUPERSTRUCTURES

8-7. Concrete beams and girders

a. All beams.

(1) Check for spalling concrete, giving special attention to points of bearing where friction from thermal movement and high edge pressure may cause spalling (figure 8-7).

(2) Check for diagonal cracking, especially near the supports. The presence of diagonal cracks on the side of the beam may indicate incipient shear failure. This is particularly important on the older prestressed bridges. Cantilever bridges, whether of prestressed or reinforced concrete, utilize a shiplapped joint in which the suspended span rests upon bearings located on the anchor span (figure 8-8). The shiplap cantilevers with reentrant corners are fracture critical details and should be inspected very carefully for signs of cracking or other deterioration.

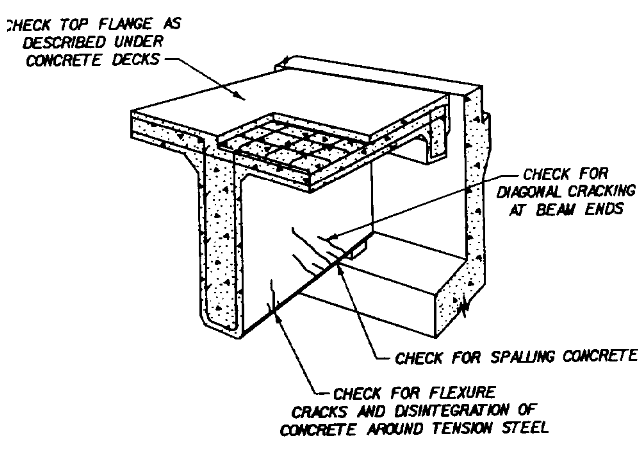


Figure 8-7. Concrete beam checklist.

(3) Check for flexure (vertical) cracks or disintegration of the concrete, especially in the area of the tension steel. Discoloration of the concrete surface may be an indication of concrete deterioration or the corrosion of the reinforcing steel. In severe cases, the reinforcing steel may become exposed.

(4) Observe areas that are exposed to roadway drainage for disintegrating concrete.

(5) Check for damage caused by collision or fire.

(6) Note any excessive vibration or deflection during passage of traffic.

b. Box girders.

(1) Examine the inside of box girders for cracks and to see that the drains are open and functioning properly.

(2) Check the soffit of the lower slab and the outside face of the girders for excessive cracking.

(3) Check diaphragms for cracks.

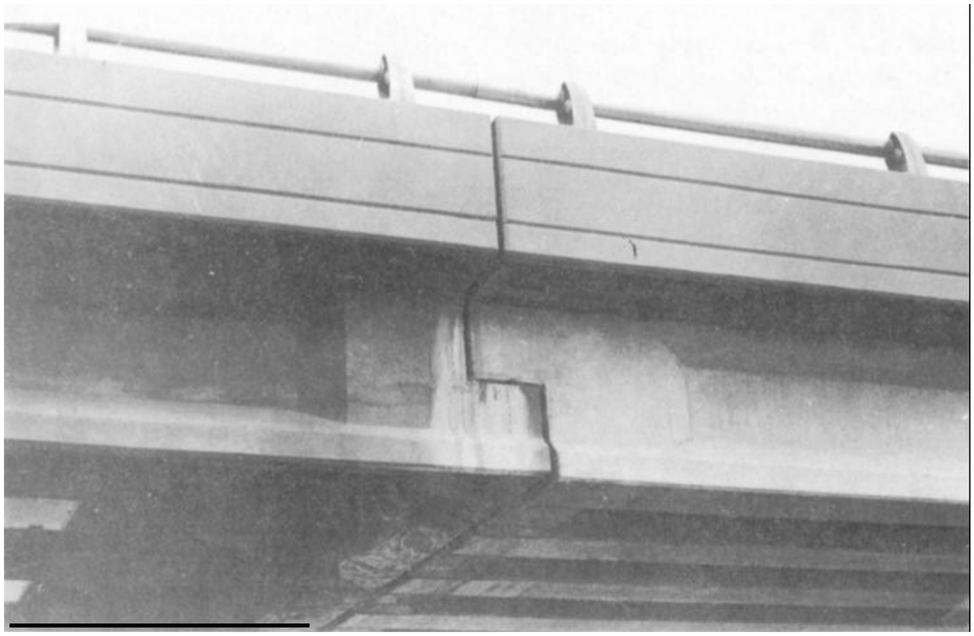


Figure 8-8. Shiplapped cantilever joint.

(4) Examine the underside of the slab and top flange for scaling, spalling, and cracking.

(5) Note any offset at the hinges which might indicate problems with the hinge bearing. An abnormal offset should be investigated further to determine the cause and the severity of the condition.

c. Prestressed concrete members.

(1) Check for longitudinal cracks on all flange surfaces. This may occur on older prestressed bridges where insufficient stirrups were provided.

(2) Examine the alignment of prestressed beams.

(3) Check for cracking and spalling in the area around the bearings and at the cast-in-place diaphragms where differential creep and humping of the beams may have some ill effects.

(4) On pretensioned deck units, either box-beams or voided units, check the underside during the passage of traffic to see whether any unit is acting independently of the others.

8-8. Steel beams and girders

It should be remembered that steel beams and girders may qualify as FCMs (chapter 6). Any serious problems found in an FCM should be addressed immediately since its failure could cause total collapse of the bridge. Immediate closure of the bridge may be warranted if the defect is deemed serious. Regardless of the member's FCM status, the following items should be inspected:

a. Check members for cleanliness and freedom from debris, especially on the top side of the bottom flange. Unclean members should be especially suspect since this indicates lack of maintenance and ideal conditions for deterioration. Cleaning may be necessary to properly inspect the members for cracks and corrosion.

b. Inspect steel for corrosion and deterioration (figure 8-9) especially at the following places:

(1) Along the upper flange.

(2) Around bolts and rivet heads.

(3) At gusset, diaphragm, and bracing connections.

(4) At cantilever hanger and pin connections.

(5) Under the deck joints and at any other points that may be exposed to roadway drainage.

(6) At any point where two plates are in face-to-face contact and water can enter (such as between a cover plate and a flange).

(7) At the fitted end of stiffeners.

(8) At the ends of beams where debris may have collected.

c. If rusting and deterioration are evident, check the members to determine the extent of reduced cross-sectional area, using calipers, rulers, corrosion meters, or section templates.

d. Check all rivets and bolts to determine that they are tight and that the individual components are operating as one. Check for cracked or missing bolts, rivets, and rivet heads.

e. Check the entire length of the tension flanges and web for cracking which may have originated from corrosion, pitting or section loss, or defects in fabrication (such as nicks and gouges in the steel).

f. Examine welds, weld terminations, and adjacent metal for cracks, particularly at:

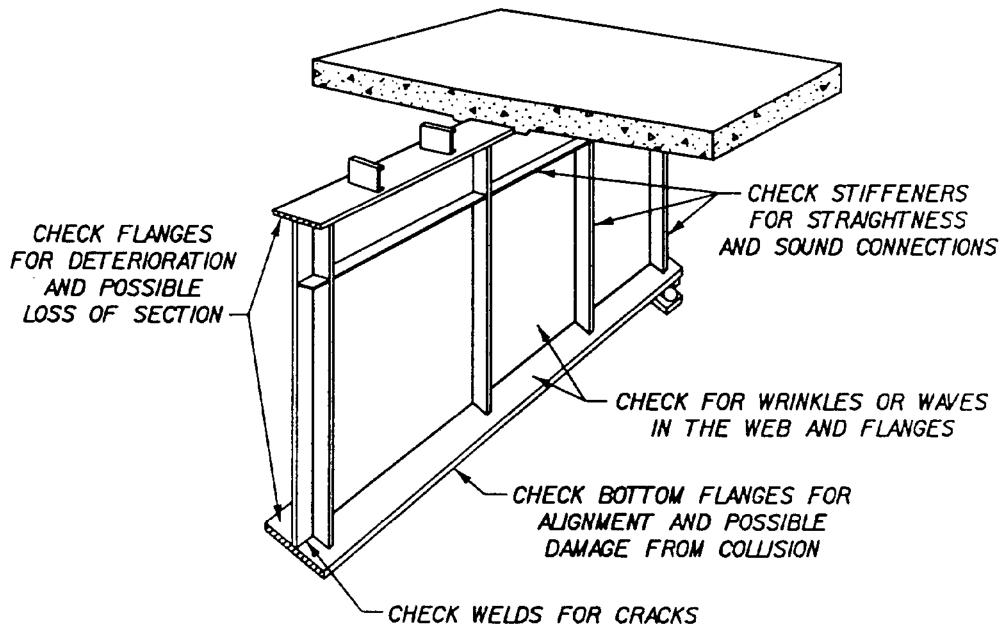


Figure 8-9. Steel girder checklist items.

(1) Unusual types of weld connections or connections to which access would have been difficult for the welder.

(2) Field welds, especially plug welds, often cause stress concentrations and are thus prone to fatigue cracking.

(3) Connections transmitting heavy torsional or in-plane moments to the members. Typical connections of this type are:

(a) Floorbeam-to-girder connections (see figure 8-10).

(b) Brackets cantilevered from the fascia beams (or any cantilever connection from a beam).

(c) Moment splices.

(d) Joints in rigid frames.

(4) Sudden changes in cross section or configuration or other locations subject to stress concentrations or fatigue loadings. Several specific areas in this category are:

(a) Termination points of welded cover plates (figure 8-11).

(b) Longitudinal welds along the length of cover plates, especially intermittent welds as shown in figure 8-12.

(c) Welds of insert plates in haunched girders (figure 8-13).

(5) The potential crack locations for longitudinal and transverse web stiffeners are summarized in figure 8-14. Note in figure 8-14 (sheet 3) that the crack is due to an improperly made butt weld.

(6) The intersection of horizontal and vertical fillet welds such as that shown in figure 8-15.

(7) Horizontal connection plates used to connect lateral bracing, as shown in figure 8-16.

(8) Areas where vibration and movement could produce fatigue stress.

(9) Coped sections/reentrant corners (figure 8-17).

(10) Connections of boxbeams to columns (figure 8-18).

g. Check the general alignment by sighting along the members. Misalignment or distortion may result from overstress, collision, or fire damage. If such a condition is present, its effect on structural safety of the bridge should be fully investigated.

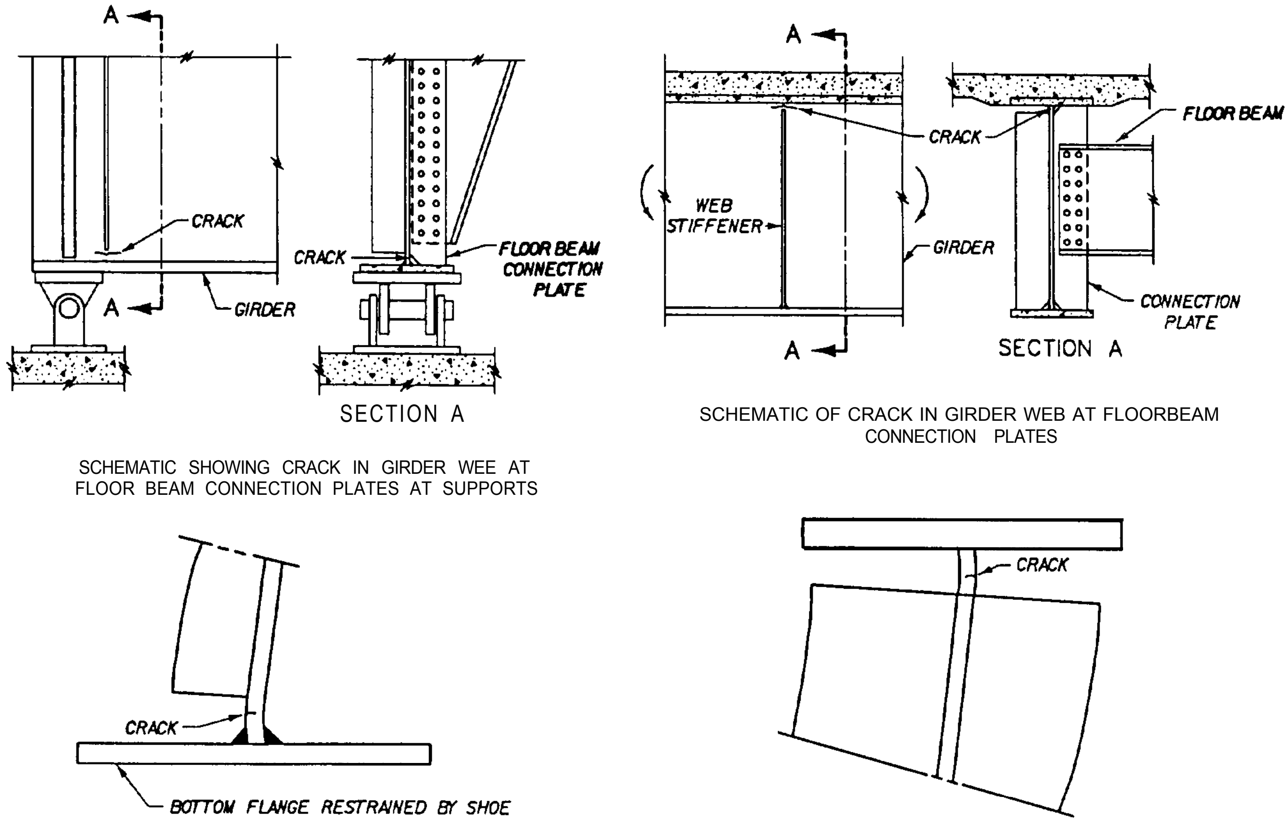
h. Check for wrinkles, waves, cracks, or damage in the web flanges of steel beams, particularly near points of bearing. This condition may indicate overstressing. Check the stiffeners for straightness and determine whether their connections are broken, buckled, or pulled from the web.

i. Determine whether any unusual vibration or excessive deflections occur under the passage of heavy loads.

j. Check the wind locks (figure 3-14) for binding, jamming, improper fit, or excessive movement before engaging.

k. Thoroughly check the inside of box girders for all of these problems.

l. In composite construction, stud type shear connectors are utilized between the upper flange of the beam or girder and the deck slab. In this case, the underside of the top girder flange should be checked for cracks as shown in figure 8-19. This is



SCHEMATIC SHOWING CRACK IN GIRDER WEE AT FLOOR BEAM CONNECTION PLATES AT SUPPORTS

SCHEMATIC OF CRACK IN GIRDER WEB AT FLOORBEAM CONNECTION PLATES

A. BOTTOM OF CONNECTION PLATE.

B. TOP OF CONNECTION PLATE.

Figure 8-10. Floorbeam connection plates.

only necessary in the areas spanning over pier supports; i.e., the negative moment region.

8-9. Pin and hanger connections

a. Hanger plates. These plates (figure 3-15) are as critical as the pin in a pin and hanger connection. It is, however, easier to inspect since it is exposed and readily accessible; and the following steps are required:

(1) Try to determine whether the hanger-pin connection is frozen, since this can induce large moments in the hanger plates. Check both sides of the plate for cracks due to bending of the plate from a frozen pin connection.

(2) Observe the amount of corrosion buildup between the webs of the girders and the back faces of the plates.

(3) Check the hanger plate for bowing or out-of-plane movement from the webs of the girders. If the plate is bowed, check carefully at the point of maximum bow for cracks which might be indicated by broken paint and corrosion.

(4) All welds should be checked for cracks.

b. Pin. Rarely is the pin directly exposed in a

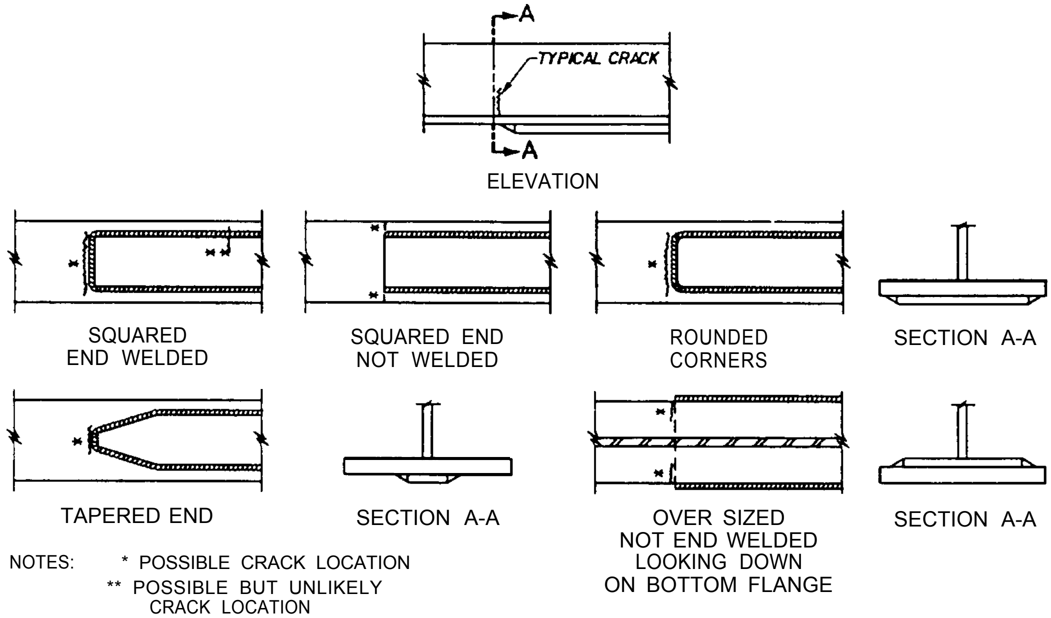


Figure 8-11. Cracks in ends of cover plates.

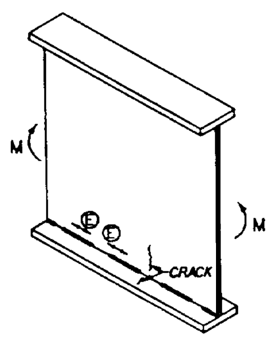


Figure 8-12. Intermittent welds.

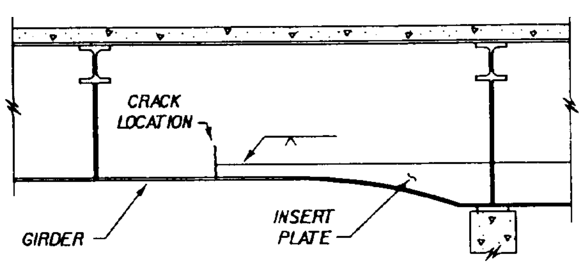


Figure 8-13. Insert plates in haunched girders.

pin and hanger connection, and as a result its inspection is difficult but not impossible. By carefully taking certain measurements, the apparent wear can be determined. If more than 1/8-inch net section loss has occurred, it should be considered critical and given immediate attention. Several types of pins and hangers and the manner for

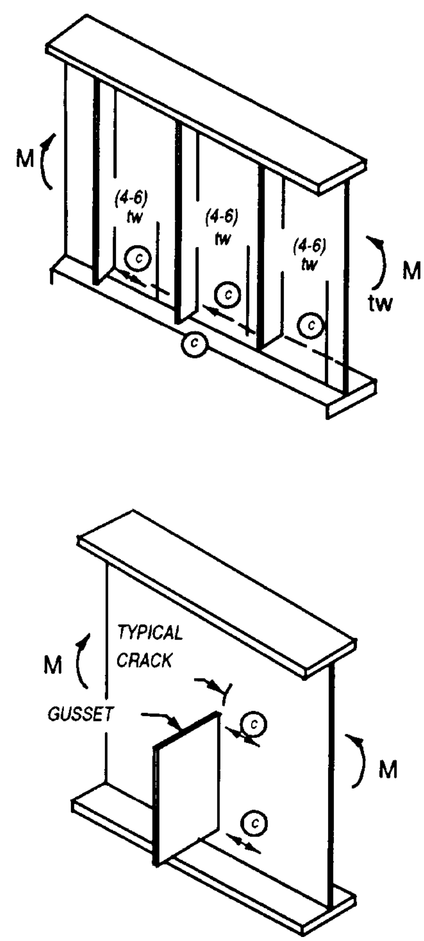


Figure 8-14. Attachments. (Sheet 1 of 3)

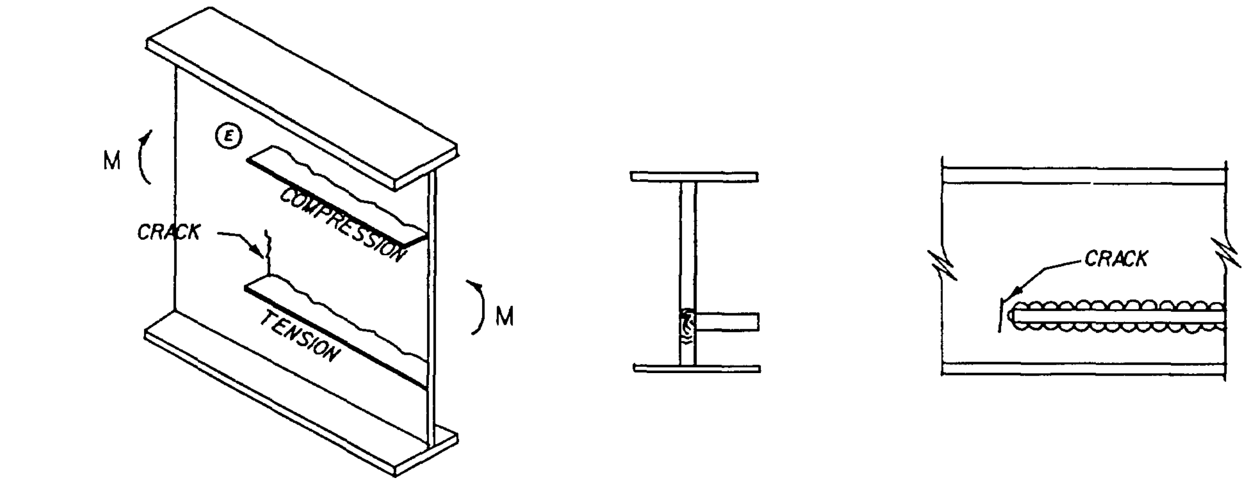
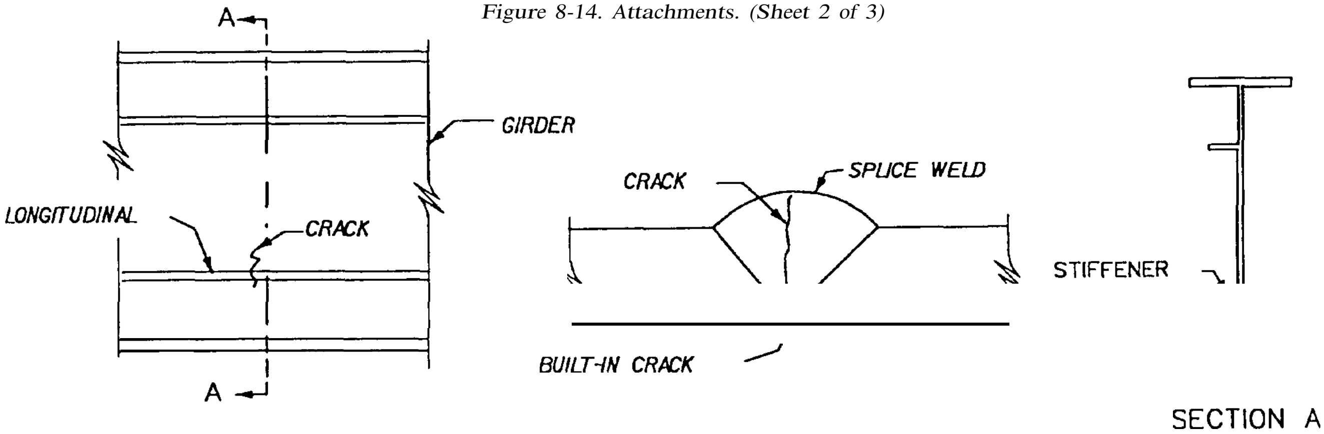


Figure 8-14. Attachments. (Sheet 2 of 3)



SCHEMATIC OF GIRDER SHOWING LONGITUDINAL STIFFENERS
IN TENSION STRESS REGION WIYH BUTT WELDED SPLICE

Figure 8-14. Attachments. (Sheet 3 of 3)

measuring wear on each are discussed in the following paragraphs:

(1) *Girder pin and hanger.* Wear to the pins and hangers will generally occur in two locations, at the top of the pin and top of the hanger on the cantilevered span, and the bottom of the pin and bottom of the hanger on the suspended span. Sometimes wear, loss of section, or lateral slippage may be indicated by misalignment of the deck expansion joints or surface over the hanger connection. The following inspection procedure should be used. Figure 3-16 can be used as a reference sketch.

(a) Locate the center of the pin.

(b) Measure the distance between the center of the pin and the end of the hanger.

(c) Compare to plan dimensions, if available. Remember to allow for any tolerances, since the pin was not machined to fit the hole exactly. Generally, this tolerance will be 1/32 inch. If plans are not available, compare to previous measurements. The reduction in this length will be the "apparent wear" on the pin.

(2) *Fixed pin and girder.* Wear will generally be on the top surface of the pin due to rotation from live load deflection and tractive forces. The following steps should be used with figure 3-16 as a reference:

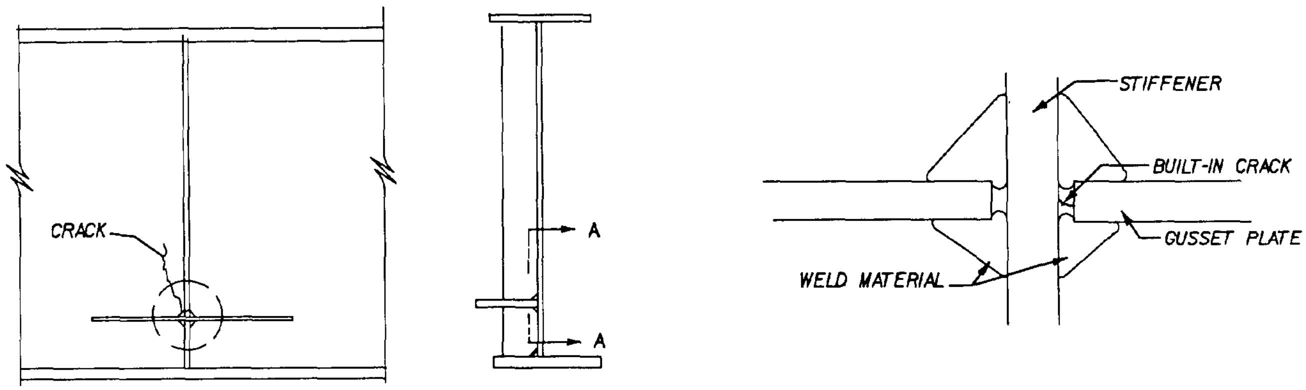


Figure 8-15. Intersecting welds.

Figure 8-16. Flange and web attachments.

(a) Locate the center of the pin.

(b) Measure the distance between the center of the pin and some convenient fixed point, usually the bottom of the top flange.

(c) Compare this distance to the plan dimensions and determine the amount of section loss.

(3) *Truss pin and hunger.* Pin and hanger arrangements are slightly different when used in trusses. Usually the hanger plates are compact members similar to a vertical or diagonal. The hanger then slips between gusset plates at both the upper and lower chords. It is more difficult to find a fixed reference point because the gusset plate dimensions are not usually given on design plans, but two recommended options are the intersection of the upper or lower chord and the nearest diagonal or the edge of the gusset plate along the axis of the hanger. Both these points will provide readily identifiable reference points which can be recreated easily by the next inspection team. For this reason, measurements should be carefully documented along with the temperature and weather conditions. The inspection procedure should include:

(a) Locate center of pin.

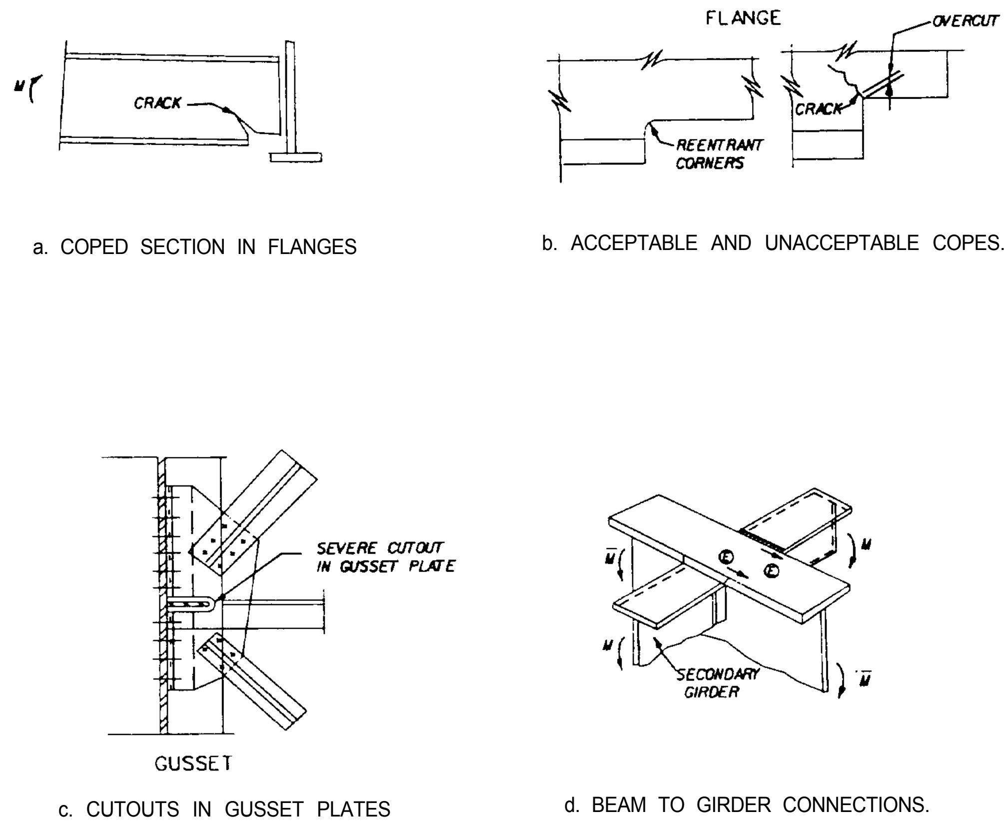


Figure 8-17. Copes and reentrant corners.

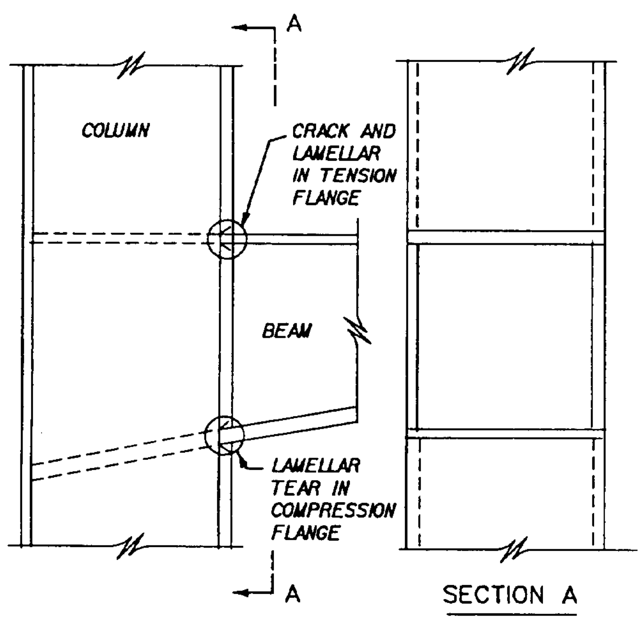


Figure 8-18. Boxbeam to column connections.

(*b*) Measure to reference point to determine section loss.

(*c*) Compare to plans or previous inspection notes.

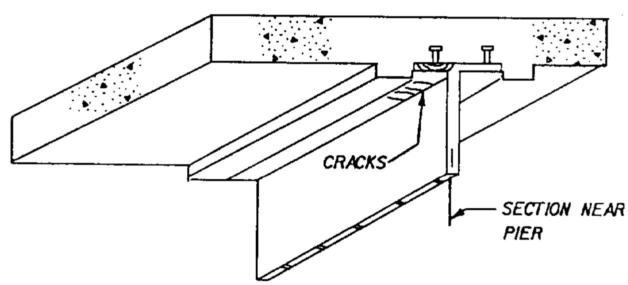


Figure 8-19. Cracks near shear studs.

8-10. Floor systems

a. Floorbeams. See figure 8-20.

(1) The end connections of floorbeams should be checked carefully for corrosion. This is particularly critical on truss bridges where the end connections are exposed to moisture and deicing chemicals from the roadway.

(2) The top flange of floorbeams should be checked for corrosion especially near the end connections and at points of bearing.

(3) The floorbeams should be checked to determine if they are twisted or swayed. This situation occasionally develops as a result of the longitudinal forces that are exerted by moving vehicles on

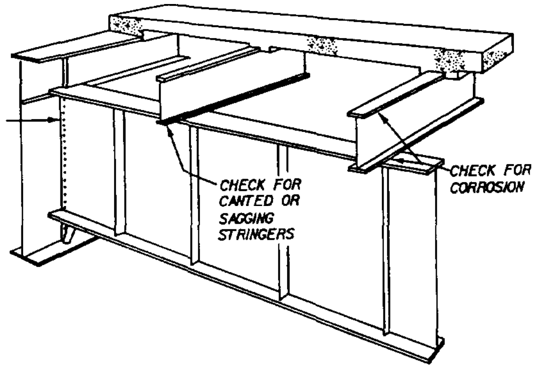


Figure 8-20. Steel floorbeam checklist items.

the floorbeams. It occurs primarily on older structures where the floorbeams are simply supported and where the stringers rest upon the floorbeams.

(4) The connections on the end floorbeams should be examined thoroughly for cracks in the welds and for slipped rivets or bolts.

b. Stringers.

(1) *Steel.*

(a) Check for rust or deterioration, especially around the top flange where moisture may accumulate from the floor above and at the end connections around rivets, bolts, and bearings.

(b) Check for sagging or canted stringers.

(c) Inspect all stringer connections for loose fasteners and clip angles (figure 8-21). Where stringers are seated on clip angles, check for cracks in the floorbeam web.

(2) *Timber.*

(a) Check for crushing and decay, especially along the top where the decking comes in contact with the stringer and at points at which the stringer bears directly upon the abutment and bent caps.

(b) Check for horizontal cracks and splitting, especially at the ends of stringers, where they are often notched.

(c) Check for sagging or canted stringers.

(d) Check the bridging between the stringers to determine whether it is tight and functioning properly.

(e) Check for accumulations of dirt and debris.

8-11. Diaphragms and cross frames

a. Steel.

(1) Check for loose or broken connections between the web of the beam or girder and the diaphragm (figure 8-22).

(2) Check for rust or other deterioration, especially around rivets and bolts, and those portions of the end of the diaphragms which come in contact with the bridge floor. These may be particularly susceptible to corrosion from roadway moisture and from deicing agents.

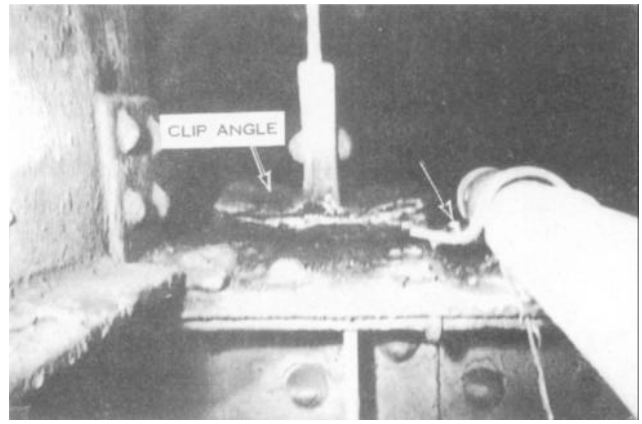


Figure 8-21. Clip angle stringer connection

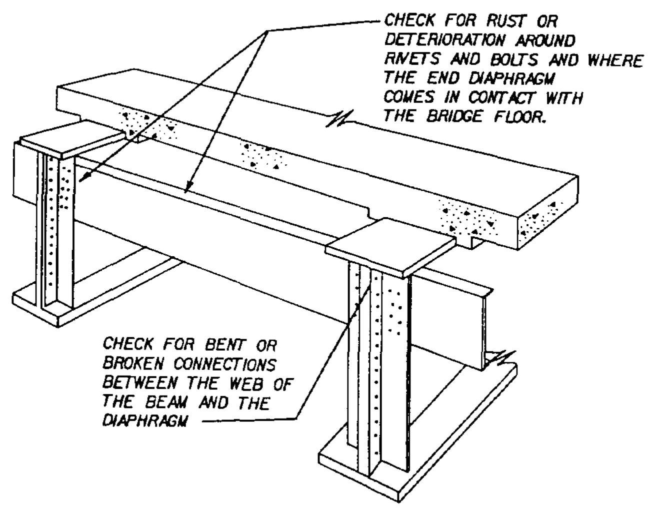


Figure 8-22. Diaphragm checklist items.

(3) Look for buckled or twisted cross frames. This situation may be an indication of overstress of the bracing.

b. Timber.

(1) Check for cracking or splitting, especially in end diaphragms that are supporting the floor.

(2) Check for decay along the top of the diaphragms where they may come in contact with the floor.

c. Concrete. Check for cracks, spalls, and for other forms of deterioration.

8-12. Trusses

a. Steel trusses.

(1) *Rust and deterioration.* On through trusses, moisture and deicing chemicals from the roadway are often splashed on the lower chord members and the member adjacent to the curb. The moisture and chemicals are retained at the

connection and between the adjacent faces of eyebars, pin plates, etc. leading to rapid deterioration of the member. On riveted trusses, the horizontal surfaces and connections of lower chord members (figure 8-23) are especially susceptible to corrosion. Debris tends to accumulate causing moisture and salt to be retained. Note any deformation caused by expanding rust on the inside surfaces of laminated or overlapping plates.

(2) *Alignment of truss members.* End posts and interior members are vulnerable to collision damage from passing vehicles. Buckled, torn, or misaligned members may severely reduce the load-carrying capacity of the truss. Misalignment can be detected by sighting along the roadway rail or curb and along the truss chord members. Investigate and report any abnormal deviation.

(3) *Over-stressed members.* Local buckling indicates overstress of a compression member. Wrinkles or waves in the flanges, webs, or cover plates are common forms of buckling. Overstress of a ductile tension member could result in localized contraction in the cross section area of the member. This is usually accompanied by flaking of the paint.

(4) *Loose connections.* Cracks in the paint or displaced paint scabs around the joints and seams of gusset plates and other riveted or bolted connections may indicate looseness or slippage in the joints. Check rivets and bolts that appear defective.

(5) *Pins.* Inspect pins for scouring and other signs of wear. Be sure that spacers, nuts, retaining

Figure 8-23. Lower chord of a riveted truss.

caps, and keys are in place. Refer to paragraph 8-9 for a detailed inspection procedure.

(6) *Noise.* Note clashing of metal with the passage of live loads.

(7) *Riveted or bolted tension members.*

(a) Check each component to see that the loads are being evenly distributed between them by attempting to vibrate the members by hand and that batten plates are tight. If the loads are being unevenly distributed, one component might be loose or not have the right ring to it when struck with a hammer.

(b) Check carefully along the first row of bolts or rivets for cracking as the first row carries more load than succeeding rows. The first row is that closest to the edge of the gusset plate and perpendicular to the axis of the member.

(c) Check for nicks, gouges, and tears due to impact from passing vehicular traffic. This type of damage can initiate future cracks.

(d) Observe carefully any tack welding used either in construction or repair since this is a potential source of cracks. Any tack welds should be specially noted in the report for future observation and consideration in stress rating.

(e) If any misplaced holes or holes used for reconstruction have been plug welded, check carefully for fatigue cracks.

(8) *Welded tension members.*

(a) Check the full length of all longitudinal welds of each tension member for cracks.

(b) Check all joints at the ends of the members, including gussets.

(c) Check all transverse welding including internal diaphragms in box members.

(d) If connections are welded at gusset plates, carefully check these welds, particularly if any eccentricities observable by eye are involved.

(e) As with bolted or riveted members, check carefully for nicks, gouges, and tears due to impact damage and for any repairs made using tack welding.

(f) Box sections or other sections welded with backup bars should be checked carefully for discontinuity in the backup bars.

(g) Portions of fracture critical tension members which are difficult to access must be checked for corrosion using mirrors, fiberscopes, or boroscopes.

(h) Members should be examined carefully for any sites of arc strikes.

(i) Check carefully any holes that have been filled with weld metal since those are a source of fatigue cracking.

(9) *Eyebar members.* Whether or not these bars are fracture critical is dependent upon the

number of eyebars per member. During the inspection process, the inspector should:

(a) Inspect carefully the area around the eye and the shank for cracks (figure 8-24). This is where most failures occur in eyebars.

(b) Examine the spacers on the pins to be sure they are holding the eyebars in their proper position.

(c) Examine closely spaced eyebars at the pin for corrosion buildup (pack rust). These areas do not always receive proper maintenance due to their inaccessibility.

(d) Evaluate weld repairs closely.

(e) Check to determine if any eyebars are loose (unequal load distribution) or if they are frozen at the ends (no rotation).

(f) Check for any unauthorized welds and include their locations in the report so that the severity of their effect on the member may be assessed.

(10) Counters.

(a) Check the looped rod for cracks where the loop is formed.

(b) Observe the counters under live load for abnormal rubbing where the counters cross, and check this area carefully for wear (figure 8-25).

(c) Examine the threaded rods in the area of the turnbuckle for corrosion and wear.

(d) Test the tension in each rod to be sure they are not over-tightened or undertightened. The relative tension can be checked by pulling transversely by hand. The inspector should not adjust the turnbuckle but report the problem.

b. Timber trusses.

(1) Check for weathering, checking, splitting, and decay. Decay is often found at joints, caps, and around bolts holes. Decay is also common on the bridge seat.

(2) Check for crushing at the ends of compression chord and diagonal members.

(3) Examine splices carefully for decay. Note whether bolts and connections are tight.

(4) Check for decay at joints where there are contact surfaces, caps, where moisture can enter, and around holes through which truss bolts are fitted.

(5) Check end panel joints for decay.

(6) Check for dirt or debris accumulation on the bridge seat.

(7) Investigate the roof and sides of covered bridges for adequacy of protection afforded the structure members from the elements of weather.

(8) Check the alignment of the truss. Sagging of the truss may be due to the partial failure of joints or improper adjustment of steel vertical rods.

(9) Be particularly aware of fire hazards under the bridge, such as:

(a) Brush or drift accumulating.

(b) Storage of combustible material.

(c) Parking of vehicles.

(d) Signs of fires built.

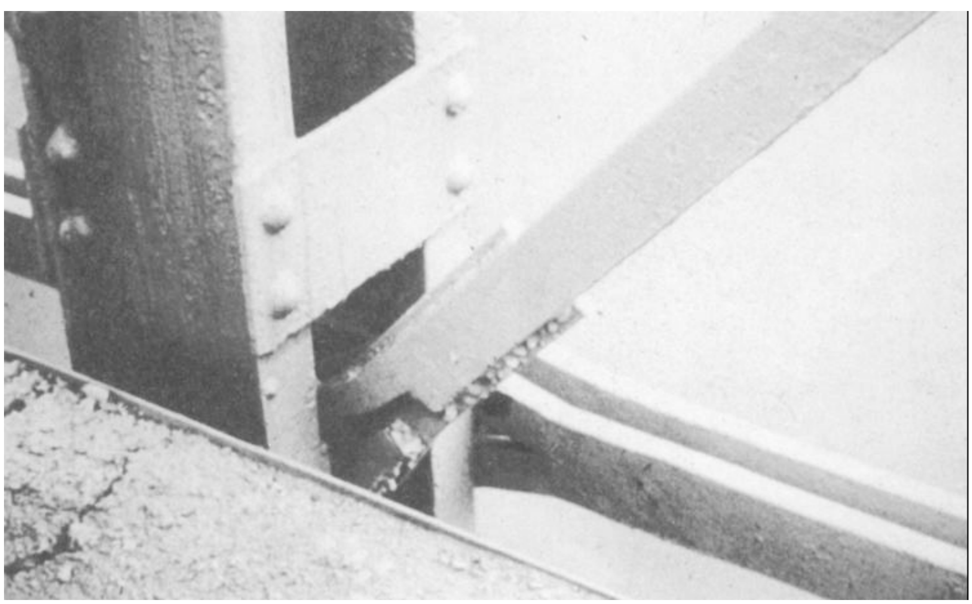


Figure 8-24. Broken eyebar.

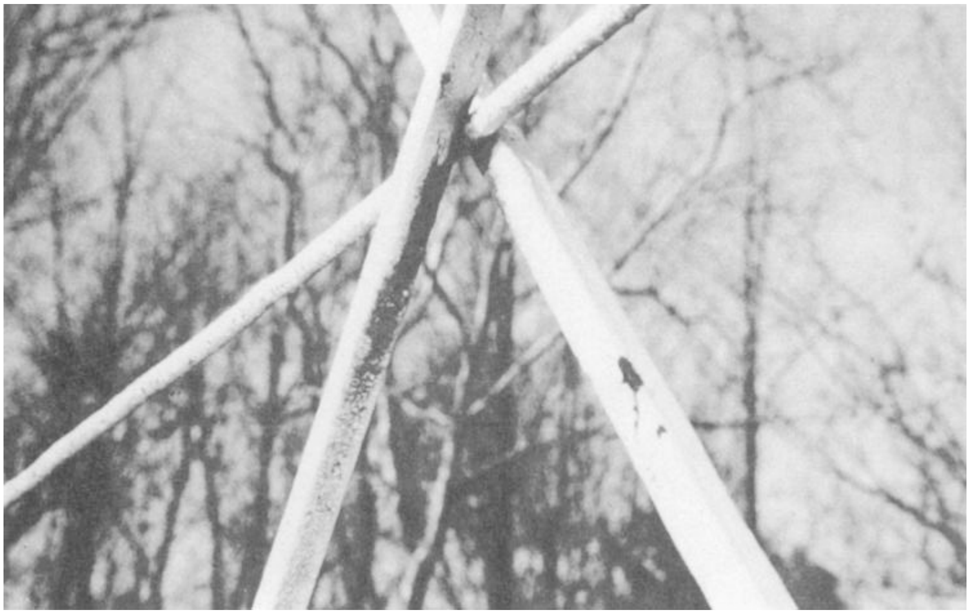


Figure 8-25. Worn counters due to rubbing.

8-13. lateral bracing portals and sway frames

a. Check all bracing members for rust, especially on horizontal surfaces such as those of lateral gusset plates and pockets without drains or with clogged drains.

b. Check for rust around bolts and rivet heads.

c. Look for loose or broken connections.

d. Check all upper and lower bracing members to observe whether they are properly adjusted and functioning satisfactorily.

e. Check for bent or twisted members. Since most of these bracing members work in compression, bends or kinks could significantly reduce their effectiveness. Since portals and sway braces necessarily restrict clearances, they are particularly vulnerable to damage from high loads.

f. Where lateral bracing is welded to girder flanges, inspect the weld and flanges for cracking.

g. Observe transverse vibration or movement of the structure under traffic to determine adequacy of lateral and sway bracing.

8-14. Tied arches

The stability of these types of arches is dependent upon the structural tie which is in tension. Therefore, the tie is always classified as a fracture critical member. The tie is the box member stretching horizontally between bearings. The majority of tied arch bridges built in the last decade have experienced some problems in the tie.

a. Riveted or bolted members. As with any FCM, the advantage of a riveted or bolted member is that they are internally redundant. Inspection should include:

(1) Observe built-up members to assure that the load is being evenly distributed to all components and that batten plates, lacing, and ties are tight. If members are loose or do not ring properly when struck with a hammer, loads may be distributed unevenly.

(2) Check the bolts or rivets at all connections (hangers, floorbeams, and end reactions) for cracks. All tack welds and/or strikes should be brought to the attention of the engineer for proper evaluation.

(3) Observe if any repairs or construction techniques have made use of tack welding and check carefully for cracks. All tack welds and/or strikes should be brought to the attention of the engineer for proper evaluation.

(4) Check the area around the floorbeam connection for cracks due to out-of-plane bending of the floorbeam and for cracks in rivet and bolt heads due to prying action.

(5) Check for corrosion sites with potential loss of section. This is particularly important in the inside of box-shaped members.

b. Welded members. These members must be thoroughly inspected from the inside as well as the outside. The key locations in the tie girder are the floorbeam connections, the hanger connections, and the knuckle area (area at the intersection of the tie girder and the arch rib). The inspection steps should include the following:

(1) Check all welds carefully for the entire length of the member. This applies primarily to the corner welds where the web and flange plates

are joined. Depending on the results of the corner weld inspection, it may be desirable to remove the backing bars and reexamine the welds. All fillet welds inside the girder should be inspected visually as accessible. Wire brushes should be used to clean the welds as necessary. The inspector should look for triaxial intersecting welds, irregular weld profiles, and possible intermittent fillet welds along the backup bars.

(2) Locate and inspect all the internal diaphragms and transverse butt welds. It may be necessary to clean the welds using a power wire brush.

(3) Check transverse connections at floorbeam with particular care. The usual location of the crack is near the corners, particularly if there is any gap between the floorbeam diaphragm and the web plates. This is a good place to clean with a power wire brush and use a dye penetrant test to ascertain the presence of cracks.

(4) If the box section has been welded with backup bars in the corners, as is often the case, the backup bars should be carefully examined for any breaks or poor splices.

(5) Portions of members that are difficult to access must be checked for corrosion using mirror, fiberscopes, or boroscopes.

(6) Hanger connections should each receive a thorough and detailed check. The purpose is to locate cracks or local distortions and to evaluate the extent of rusting or deterioration. These connections are where the support from the arch rib connects to the tie and, ordinarily, the floorbeams at the same location.

(7) The knuckle area at the intersection of the arch tie and arch rib is extremely complicated structurally and physically. Considerable study may be necessary to determine how to inspect all of the necessary locations in this area. Again, it may be necessary to use mirrors or devices. Also, dye penetrant testing should be used in this area if any suspicious crack-like formations are observed.

(8) At floorbeam connections and any splice points where the splices have been made with bolts, all of the bolts should be checked for tightness.

8-15. Metal bearings

In examining these types of bearings, determine initially whether they are actually performing the functions for which they have been designed. Bearings should be carefully examined after unusual occurrences such as heavy traffic damage, earthquakes, or batterings from debris in flood periods. Bearings should be inspected for the following (refer to figure 8-26):

a. Check to ensure that rockers, pins, and rollers are free of corrosion and debris. Excessive corrosion may cause the bearing to “freeze” or lock and become incapable of movement. When movement of expansion bearings is inhibited, temperature forces can reach enormous values.

b. Check rocker bearings where slots are provided for anchor bolts to ensure that the bolt is not frozen to the bearing.

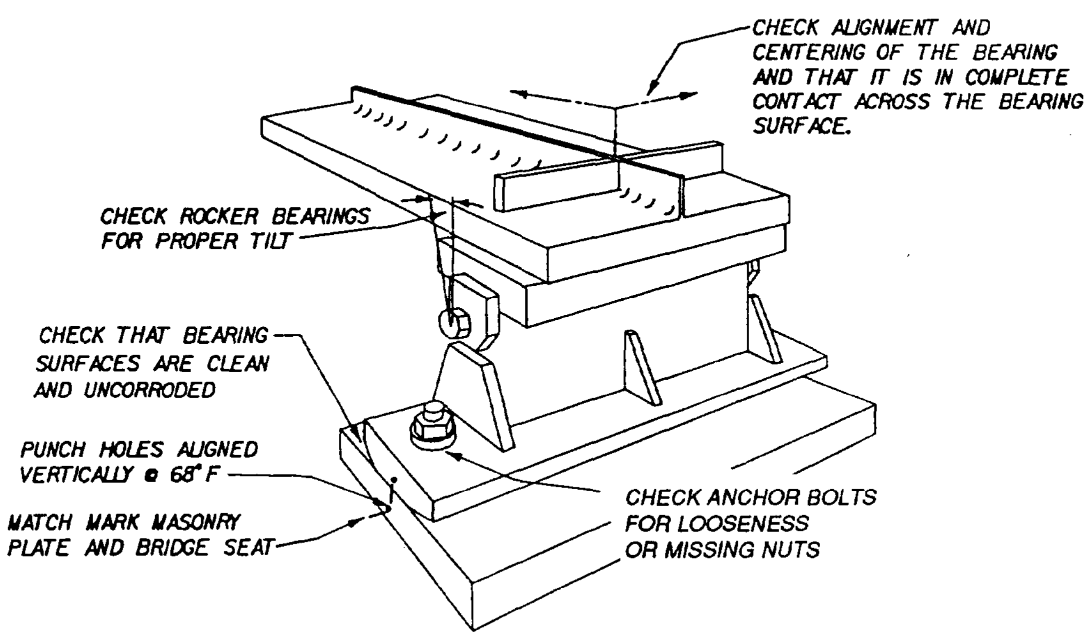


Figure 8-26. Metal bearing checklist items,

c. Check for dirt and corrosion on the bearing surfaces of rockers and rollers and the deflection slots around pins.

d. Determine whether the bearings are in proper alignment, in complete contact across the bearings surface, and that the bearing surfaces are clean.

e. Check barriers that require lubricants for proper functioning to ensure adequate and proper lubrication.

f. In those cases where bronze sliding plates are used, look for signs of electrolytic corrosion between the bronze and steel plates. This condition is common on bridges that are located in salt-air environments.

g. Detection of bearing rattles under live load conditions usually indicates that the bearings are loose. Determine the cause of this condition.

h. Check anchor bolts for looseness or missing nuts.

i. Measure the rocker tilt to the nearest 1/8-inch offset from the reference line as shown in figure 8-26. The appropriate amount of rocker tilt depends upon the temperature at the time of observation. Most rockers are set to be vertical at 68°F for steel bridges. Record the temperature at the time of inspection.

j. Measure the horizontal travel of the sliding bearings to the nearest 1/8 inch from the reference point. The two punch holes are aligned vertically at the standard of temperature used (usually 68°F). Record the temperature at the time of inspection.

k. On skewed bridges, bearings and lateral shear keys should be checked to determine if either are binding or if they have suffered damage from the creep effect of the bridge.

8-16. Elastomeric bearings

a. Check for splitting or tearing either vertically or horizontally. This is often due to inferior quality pads (figure 8-27).

b. Check for bulging caused by excessive compression. This may be the result of poor material composition.

c. Check for variable thickness other than that which is due to the normal rotation of the bearing.

d. Note the physical condition of the bearing pads and any abnormal flattening which may indicate overloading or excessive unevenness of loading.

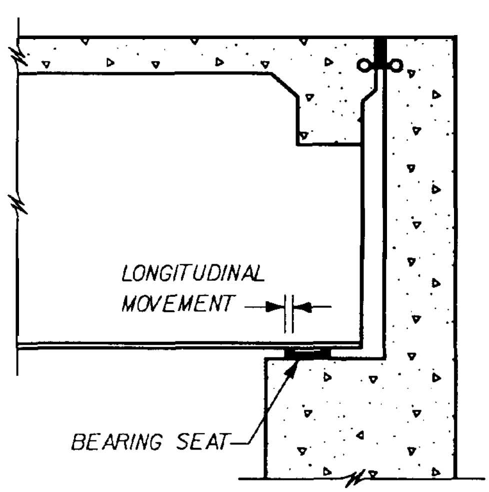
8-17. Decks

a. Concrete decks. Check for cracking, scaling, and spalling of the concrete and record the extent of the deterioration. Refer to chapter 5 for guidance in recognizing and describing concrete deterioration.

(1) *Deck surface.* Note the type, size, and location of any deck deterioration.

(2) *Deck underside.* Inspect the underside of the deck for deterioration and water leakage. The passage of water through the deck usually causes some leaching of the concrete which forms grayish-white deposits of calcium hydroxide in the area of the leak known as efflorescence (figure 8-28). Extensive water leakage may indicate segregated or porous concrete or a general deterioration of the deck. Areas of wet concrete are additional indications of defective concrete.

(3) *Wearing surface.* Examine the wearing surface covering the concrete deck for reflection crack-



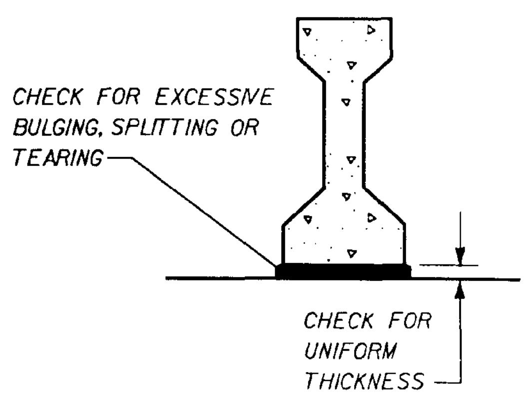


Figure 8-27. Elastomeric pad checklist items

ing and for poor adherence to the concrete. Deteriorated concrete beneath the wearing surface will often be reflected through the surface in the form of map cracking. Poor adherence leads to development of potholes. If deterioration is suspected, remove a small section of the wearing surface to check the condition of the concrete deck.

(4) *Wear.* Determine whether the concrete surface is worn or polished. When softer limestone aggregates are used in the concrete, fine aggregates and paste will be worn away, exposing the surface of the coarse aggregates to the polishing action of rubber tires. The resulting slippery surface becomes increasingly hazardous when the surface of the limestone is wet.

(5) *Stay-in-place forms.* If deterioration is suspected, remove several panels of the forms to permit examination of the underside of the deck. Rusty forms (figure 8-29), water dripping from pinholes in the form, or the separation of portions of the forms from the deck are reliable indications of deck cracking.

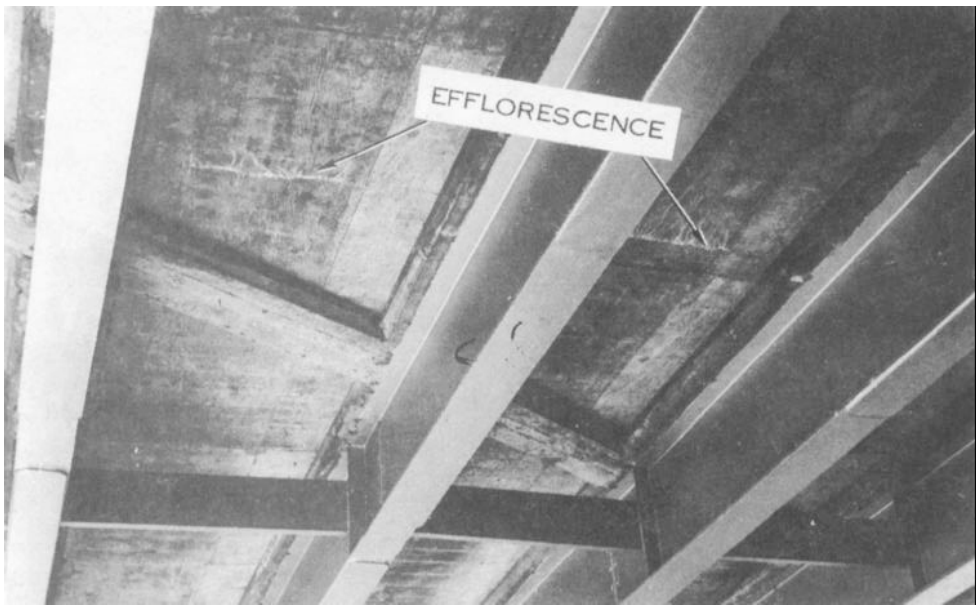


Figure 8-28. Efflorescence on the underside of a concrete deck.

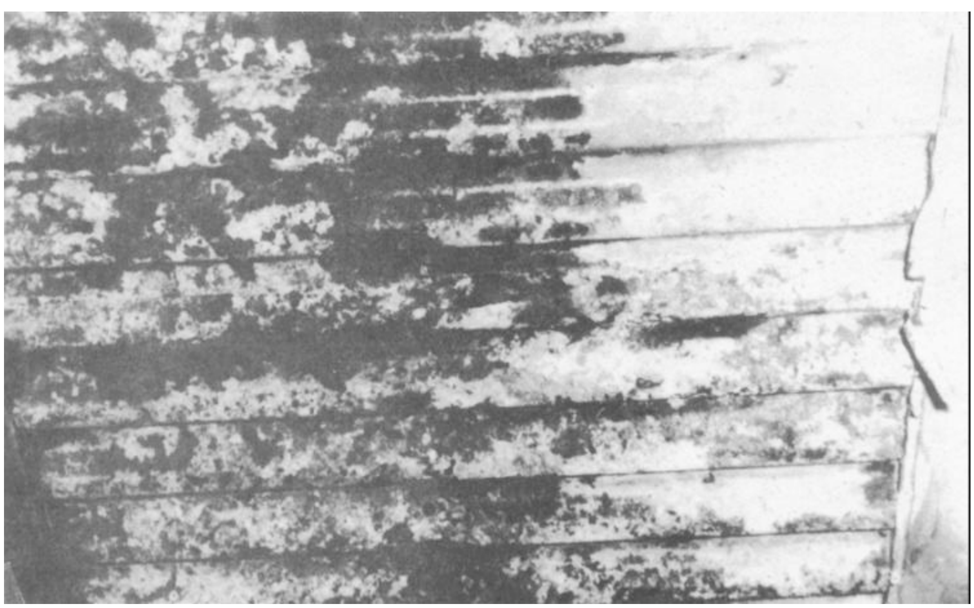


Figure 8-29. Rusted stay-in-place forms underneath a concrete deck.

(6) *Reinforcing steel.* Note whether there are any stains on the concrete which would indicate that the reinforcing steel is rusting. Note whether any of the reinforcing steel is exposed.

b. *Timber decks.*

(1) *Deterioration.* Check for loose, broken, or worn planks, for loose fasteners, and for presence of decay particularly at the contact point with the stringer where moisture accumulates. Check asphalt overlays for the presence of potholes and cracking as a result of weak areas in the deck.

(2) *Traffic response.* Observe the timber deck under passing traffic for looseness or excessive deflection of the members.

(3) *Slipperiness.* Timber decks are sometimes slippery, especially when wet. Observe the traction of vehicles using the bridge for signs of this condition.

(4) *Utilities.* If utilities are supported by the bridge, note the effects on the bridge.

c. Steel decks.

(1) *General.* Check for corrosion and cracked welds. Maintenance of an impervious surface over a steel deck is an important safeguard against corrosion of the steel. Check to determine if the deck is securely fastened. Note any broken welds or clips. Determine if there is any loss of section due to rust or wear.

(2) *Slipperiness.* Note whether decks are slippery when wet.

(3) *Utilities.* If utilities are supported by the bridge, note any effect on the bridge.

d. Open-grating decks.

(1) *Cracks.* Examine the grating, support brackets, and stringers for cracking or welds.

(2) *Slipperiness.* Note whether decks are slippery when wet. Small steel studs may be welded to the grating to improve traction.

8-18. Expansion joints

a. Check all expansion joints for freedom of movement, proper clearance, and proper vertical alignment (figure 8-30). There should be sufficient room for expansion, but the joint should not be unduly open. Closed or widely opened joints or a bump at the back wall can result from substructure movements. Joints should be cleaned, filled and sealed to prevent seepage of water into the subgrade. This seepage causes subgrade failure and allows earth or debris to plug the joints and prevent closing in hot weather. The crowding of abutments against the bridge ends is common and can cause severe damage to the bridge. Proper opening size depends on the season, the type of joint seals, the temperature range, and the amount of slab expansion that must be accommodated by the joints. Normal temperature is usually assumed to be 65 to 70°F. Table 8-1 lists some general data for various types of expansion joints. The expansion length in table 8-1 is the portion of deck or structure expansion that must be accommodated by the joints. This distance may extend from the end of the bridge to the nearest fixed bearing, or it may be the sum of the distance on both sides of the joint. Multiplying the expansion length by the differential between the temperature at the particular moment and 68°F and this product by 0.0000065 will give the approximate change in joint opening from the values listed. Very often, construction plans will give useful data concerning the setting of expansion devices.

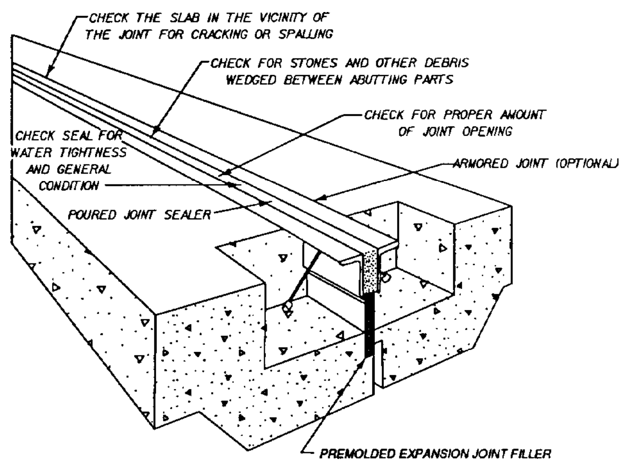


Figure 8-30. Expansion joint checklist items.

Table 8-1. Expansion joint data

Joints	*Expansion Lengths*	*Joint Openings at 69°F*
Steel finger dams	200-foot minimum	3 inches min.
Steel expansion plates	200-foot maximum	2 inches
Compression seals	135-foot maximum	1 5/8 inches
Poured sealants and joint fillers	120-foot maximum	1½ inches

b. Check seals for water tightness and general conditions. Look for:

(1) Seal or sealant pulling away from the edges of the joints.

(2) Abrasion, shriveling, or other physical deterioration of the seal.

(3) Stains and other signs of leakage underneath the deck. Leaking seals permit water and brine to flow onto the bridge seat and pier cap causing corrosion of the bearings, disintegration of the concrete, and staining. Joints not properly sealed should be cleaned and resealed.

c. Check to see that expansion joints are free of stones and other debris. Stones lodged in the joints can create localized stresses which may cause cracking and spalling of the deck. Large amounts of debris cause jamming, thus rendering the joints ineffective.

d. Examine steel finger-type joints and sliding plate joints for evidence of loose anchorages, cracking or breaking of welds, or other defective details. Sometimes the fingers may be damaged by traffic or by cracks which have developed at the base of the fingers.

e. Verify that surfacing material has not jammed the finger joints on bridges that have been resurfaced several times.

f. Examine specifically the underside of the expansion joint, regardless of accessibility, to detect any existing or potential problem.

g. Sound the concrete deck adjacent to all expansion devices for voids or laminations in the deck.

8-19. Railings, sidewalks, and curbs

a. Railings.

(1) Inspect all railings for damage caused by collision and for weakening caused by some form of deterioration.

(2) Check concrete railings for cracking, disintegration, and corrosion of rebars.

(3) Check steel and aluminum railings for loose posts or rails and for rust and other deterioration. In particular, check the condition of the connections of the posts to the decks, including the condition of the anchor bolts and the deck area around them.

(4) Check timber railings for decay, loose connections, and for missing or damaged rails.

(5) Check the vertical and horizontal alignment of all handrails for any indications of settlement in the substructure or any bearing deficiencies.

(6) Examine all handrail joints to see that they are open and functioning properly.

(7) Examine all handrails to see that they are of adequate height, secure, and relatively free of slivers or any projections which would be hazardous to pedestrians.

(8) Check for rust stains on the concrete around the perimeter of steel rail posts which are set in pockets. Remove grout from around the posts and determine severity of corrosion if rust stains indicate such action is warranted.

(9) Note whether barrier railings on the approaches to the bridge extend beyond the end of the bridge railing or parapet end and are anchored to the inside face (figure 8-31). This feature reduces the severity of vehicle collision. In situations where parapet ends are unprotected and no approach rail exists, a flared, tapered approach railing should be installed. On two-way bridges, this type of railing should be installed at both ends of the existing railings or parapet.

(10) Examine barrier railings for traffic damage and alignment.

(11) Check concrete barrier railings for cracks, spalls, and other deterioration.

(12) Check for corrosion in the metal portions of barrier railings and determine whether the anchor bolts and nuts are tight.

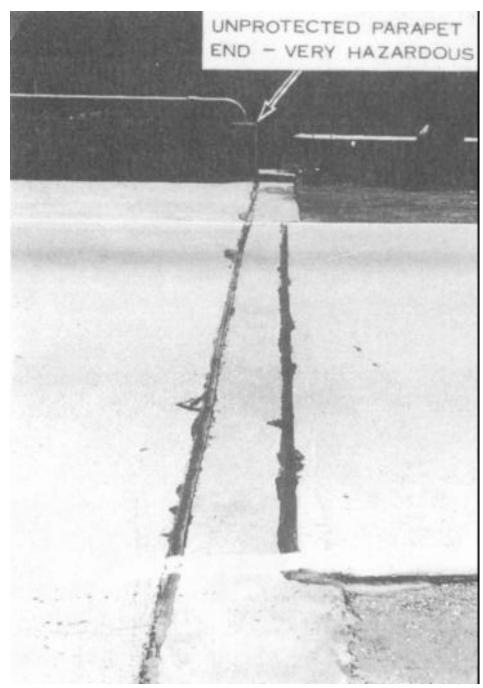


Figure 8-31. Unprotected parapet end of a bridge.

b. Sidewalks.

(1) Check concrete sidewalks and parapets in the same manner as the bridge decks for cracks, spalls, and other deteriorations.

(2) Examine the condition of concrete sidewalks at joints, especially at the abutments, for signs of differential movement which could open the joint.

(3) Check steel sidewalks for corrosion and to see that all connections are secure.

(4) Check timber sidewalks for soundness of the timber. Determine whether the floor planks are adequately supported.

(5) Check timber sidewalks for hazards to pedestrians such as loose or missing planks, large cracks, decay or warping of the planks, protruding nails, or other hazardous conditions.

(6) Check slickness of surfaced timber during wet or frosty weather conditions to determine whether any corrosive action is necessary.

(7) Check sidewalk drainage for adequate carryoff. Examine the sidewalk surface for roughness or other conditions that may make walking hazardous or difficult.

(8) Check structural integrity of sidewalk brackets.

c. Curbs.

(1) Check concrete curbs for cracks, spalls, and other deterioration.

(2) Check timber curbs for splitting, warping, and decay.

(3) Report any curbs or safety walks which project into the roadway or a narrow shoulder of the roadway, since they are safety hazards.

(4) Note any loss of curb height resulting from the buildup of the deck surface.

(5) Examine timber wheel guards including scupper blocks for splits, checks, and decay.

(6) Check timber wheel guards to see whether they are bolted securely in place.

(7) Note condition of the painting of timber wheel guards where paint is used to improve visibility.

8-20. Approaches

a. At the joint of the bridge backwall.

(1) *Vertical displacement.* Laying a straight edge across the joint will record any differences in elevation across the joint not caused by the grade. If the deck is lower than the approach, or if the straight edge indicates a rotation, then foundation settlement or movement may have occurred, and other indications of such action should be checked.

(2) *Joint width (horizontal displacement).*

(a) Incorrect opening. Measure the joint width for increased or decreased openings. Either condition indicates foundation movement. A decreased opening could also be caused by pavement thrust. Other parts of the bridge affected by such occurrences should also be investigated.

(b) Clogged joints. Where joints are clogged or jammed with stones and hard debris, the expansion joints will be unable to function properly, and pavement thrust will develop. Make particular note of this condition.

(c) Joint seal. The integrity of the joint sealant is critical to protecting the soil or portions of the bridge under the joint, particularly the bridge seat, from water. The seal may be damaged by either weathering, traffic abrasion, or movement of the seal itself.

b. Other transverse joints near the bridge. Examine these joints for closing or clogging, since they are liable to the same difficulties as the backwall joints. The inspector should note the relative movements (if any) of the joints, any clogging with stones or other debris, and any failure, deterioration, or slippage of the joint seal. The extent of these defects should be reported.

c. Approach slabs. Check for cracking or tipping of the approach slabs. These are indications of poor backfill compaction (although on a skewed bridge, it would not be unusual for an acute corner to crack).

d. Shoulders and drainage. Check the shoulders and determine whether they are maintained at the same height as the pavement. There should be adequate provisions to carry off drainage in the catch basins or ditches, especially if water is allowed to flow off the bridge deck (see figure 8-25).

e. Approach slopes. Check the approach slopes for adequacy and report any condition or other surface defects that make the approach unusually rough or indicate approach settlement.

f. Pavement approaches. Report any potholes, severe cracks, surface unevenness, or other surface defects that make the approach unusually rough or indicate approach settlement.

8-21. Bridge drainage

Almost all of the drainage problems encountered by an inspector are caused by the failure of the drainage system to carry water away. Poor deck drainage usually leads to deck disintegration. The following items should be checked:

a. Clogging or inadequate drainage openings. Check the deck and the deck inlets for signs of clogging or inadequate drainage openings. These deficiencies will be manifested by debris on or around the inlet after a storm. Scaling and concrete deterioration around the inlet are additional signs of an inadequate inlet.

b. Water stains. Observe the bridge beams, piers, and abutments for water stains. These may indicate leaky pipes, filled gutters, or scupper discharge pipes that are too short. However, stained abutments and piers could also mean leaky joints.

c. Drain outlets. Check to see that deckdrain outlets (scuppers) do not discharge water where it may be detrimental to other members of the structure, cause fill and bank erosion, or spill onto a roadway below.

d. Damaged pipes. Look for pipes damaged by freezing, corrosion, or collision. These will show cracks, holes, or stains.

e. Clogged pipes. Check pipes, if possible. Open the cleanout at bottom of pipes to see whether pipes are open all the way through.

f. Sand or soil accumulations. Check for layers of sand or soil on the bridge deck. Presence of either of these will retain moisture and brine and will accelerate deck scaling. Soil or sand deposits are clear indications of poor deck drainage (figure 8-32).

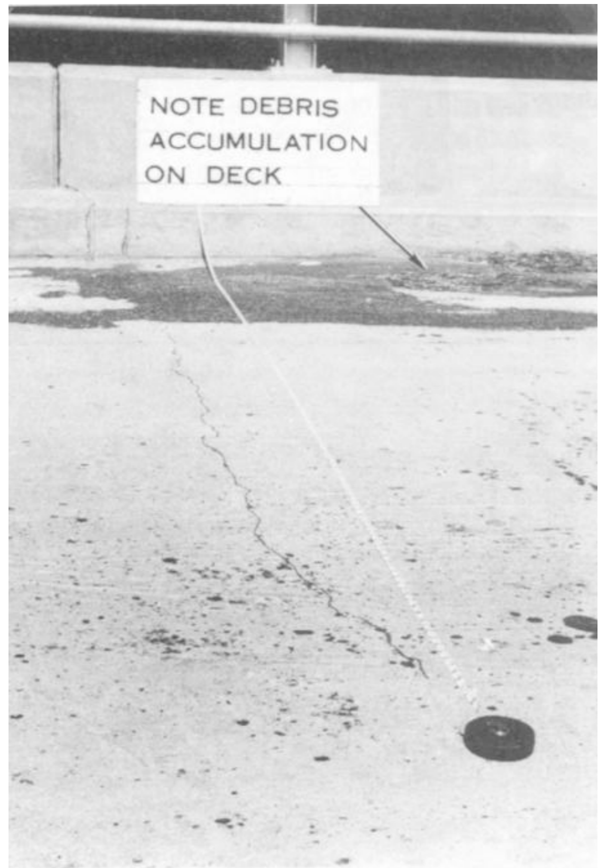


Figure 8-32. Debris accumulation on bridge deck indicating drainage problem.

Section III. MISCELLANEOUS INSPECTION ITEMS

8-22. Waterways

a. Maximum water level. Ideally, waterways should be inspected during and immediately following periods of flood, since the effects of high water will be most apparent at these times. Since this is not always possible, a knowledge of the heights of past major floods from stream gauging records or from other sources, together with observations made during or immediately following high water, are helpful in determining the adequacy of the waterway opening. Other sources are:

(1) High water marks or ice scars left on trees.

(2) Water marks on painted surfaces.

(3) Debris wedged beneath the deck of the bridge or on the bridge seats.

(4) Information from established local residents.

b. Insufficient freeboard. This is a prime characteristic of inadequate waterways. In addition to the signs mentioned previously, lateral displacement of old superstructures is a prime indication of insufficient freeboard.

c. Debris. Debris compounds the problems of a scanty freeboard. Check for debris deposits along the banks upstream and around the bridge.

d. Obstruction. Debris or vegetation in the waterways, both upstream and downstream, may reduce the width of the waterway, contribute to scour, and even become a fire hazard. Sand and gravel bars formed in the channel may increase stream velocity and lead to scour near piers and abutments.

e. Scour.

(1) *Channel profile.* In streambeds susceptible to scour and degradation, a channel profile should be taken periodically. Generally, 100-foot intervals, extending to a few hundred feet upstream and downstream, should be sufficient. This information, when compared with past records, will often reveal such problems as scour, shifts in the channel, and degradation.

(2) *Soundings.* Soundings for scour should be

taken in a radial pattern around the large river piers.

(3) *Shore and bank protection.*

(a) Examine the condition and adequacy of existing bank and shore protection.

(b) Check for bank or levee for erosion caused by improper location or skew of the bridge piers or abutments.

(c) Note whether channel changes are impairing or decreasing the effectiveness of the present protection.

(d) Determine whether it is advisable to add more channel protection or to revise the existing protection.

f. High backwater. Be particularly alert for locations where high fills and inadequate or debris-jammed culverts may create a very high backwater. The fill acts as a dam, and with the possibility of a washout during rainfall, a disastrous failure could result.

g. Wave *action.* Observe the effect of wave action on the bridge and its approaches.

h. Existing or potential problems. Observe the areas surrounding the bridge and its approaches for any existing or potential problems, such as ice jams.

i. Spur dikes. Observe the condition and functioning of existing spur dikes.

8-23. Paint

a. Examine all paint carefully for cracking or chipping, scaling, rust pimples, and chalking. Look for evidence of "alligatoring." If the paint film has disintegrated, note whether the prime coat or the surface of the metal is exposed. Note the extent and severity of the paint deterioration. If extensive "spot" painting will be required, probably the entire structure should be repainted; otherwise, spot painting will most likely be sufficient.

b. Look for paint failure on upper chord horizontal surfaces, or those surfaces which are most exposed to sunlight or moisture. Give particular attention to areas around rivets and bolts, the ends of beams, the seams of built-up members, the unwelded ends of stiffeners, and any other areas that are difficult to paint or that may retain moisture.

8-24. Signing

This section is concerned with the presence and effectiveness of bridge signing. Since some bridges on military installations must carry both military and civilian traffic, signing may be necessary for both types of traffic. The required regulatory signing for the bridge to be inspected should be determined prior to the inspection. The absence of required signing and the condition of the existing signs should be noted during the inspection. For civilian traffic, the AASHTO "Manual on Uniform Traffic Control Devices" should be consulted for specific information with regard to signing. Military signing should be inspected according to the following guidelines:

a. Type of signs. When inspecting a bridge for signing, not only should the presently posted signs be inspected, but it should also be determined whether additional signs are needed because of changed bridge or roadway conditions. The types of warning and regulatory signs normally required are:

(1) *Weight limit.* This is the most important inspection item, particularly for the older and deteriorated bridges. The weight limit should be determined by the bridge classification procedure outlined in chapter 9. Depending upon the bridge type and expected traffic, the bridge may need both military and civilian load classifications. Typical military load classification signs are shown in figure 8-33. Civilian load limit signs should be in accordance with the local legal requirements and with AASHTO "Manual on Uniform Traffic Control Devices."

(2) *Overhead clearance.* Minimum overhead clearances for military vehicles (as summarized in table 8-2) should be checked. When the overhead

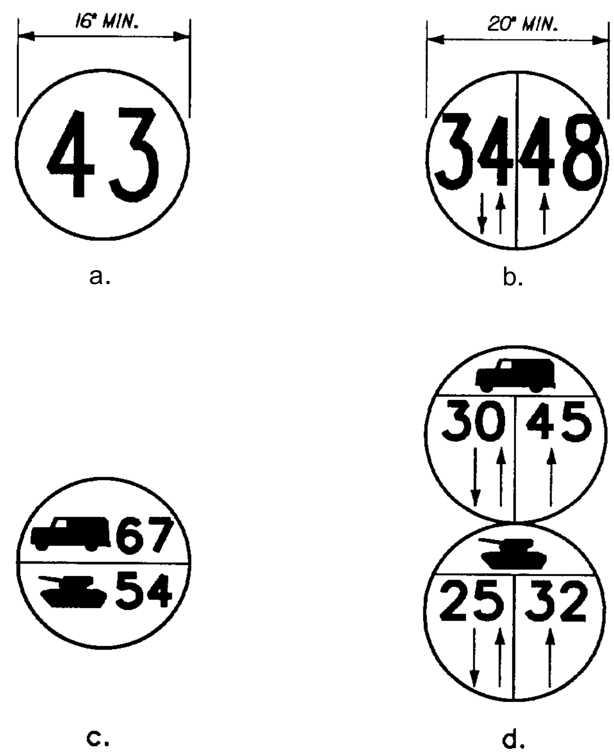


Figure 8-33. Typical military load-class signs.

Table 8-2. Minimum overhead clearances for bridges

Bridge Class	*Minimum Overhead Clearance*
4-70	14' 0"
71-over	15' 6"

clearance is less than the values prescribed in the table, the actual clearance must be indicated by the use of a telltale sign as shown in figure 8-34. Civilian traffic bridges with clearance restrictions should be marked as shown in figure 8-35. For civilian traffic, any clearance that is less than 1 foot higher than the local legal height and road limit should be posted with a "Low Clearance" sign. Where existing civilian signs are in place and are sufficiently clear, additional clearance signs (vertical or horizontal) for military vehicles are not required.

(3) *Roadway width.* Bridge width limitations often limit the maximum class of military vehicle for the bridge. Minimum lane widths for specific bridge classes are summarized in table 8-3 and should be checked during the inspection. Many new bridges are narrower than they should be. For civilian bridges, "Narrow Bridge" signs and striped paddleboards (figure 8-35) should be used when the bridge width is less than that of the approach roadway. If the superstructure or parapet end extends above the curb, it should be striped and a reflectorized hazard marker should be attached.

(4) *Narrow underpass.* Where the roadway narrows at an underpass or where there is a pier in the middle of the roadway, striped hazard markings should be placed on the abutment walls and on pier edges of civilian bridges. Reflective hazard markers should also be placed on the piers and abutments, and the approaching pavement should be appropriately marked to warn the approaching traffic of the hazard.

(5) *Speed and traffic markers.* These types of signs should be checked to ascertain whether they are appropriate. Speed restrictions should be carefully noted to determine whether such restrictions are consistent with bridge and traffic conditions. Additional traffic markers may be required to facilitate the safe and continuous flow of traffic.

b. Details of military signs.

(1) *Circular signs.* Both military and civil bridges should be marked with circular signs indicating the military load classification. They should have a yellow background with black inscriptions, as large as the diameter of the sign allows. These signs should be placed at both ends of the bridge in a position that is clearly visible to all oncoming traffic. The required sizes and appearance for these signs are summarized in figure 8-33.

(2) *Rectangular signs.* Additional instructions and technical information are inscribed on rectangular signs. These signs should be a minimum of 16 inches in height or width and have a yellow background upon which the appropriate letters, figures, or symbols are inscribed in black. These signs, other than those indicating height restrictions, should be placed immediately below the bridge classification signs. Height restriction signs should be placed centrally on the overhead obstruction.

c. Details of civilian signs.

(1) *Location.* The weight limit sign, being regulatory, should be located just ahead of the

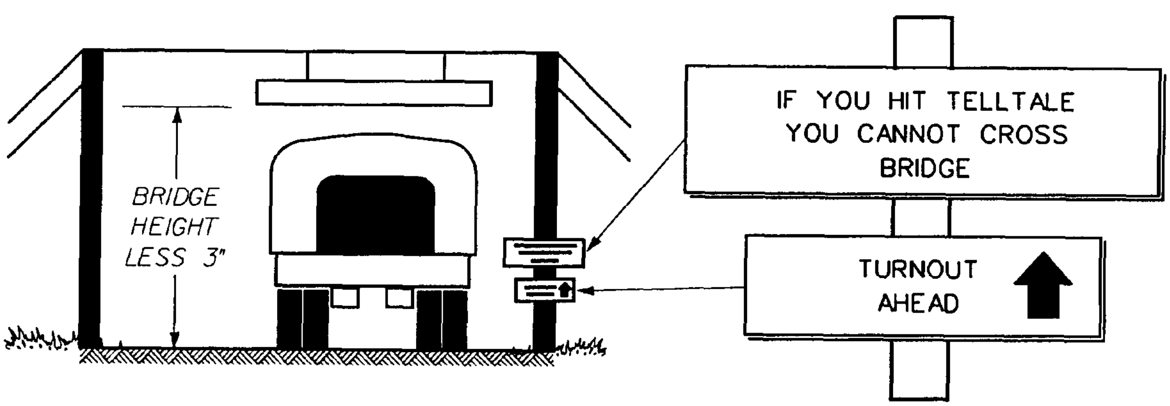


Figure 8-34. Typical telltale indicating overhead clearance of bridge.

Figure 8-35. Appropriate markings for clearances on civilian bridges.

Table 8-3. Minimum lane widths for bridges

Bridge	*Minimum Width Between Curbs*	
Class	One Lane	Two Lane
4-12	9' 0"	18' 0"
13-30	11' 0"	18' 0"
31-60	13' 2"	24' 0"
61-100	14' 9"	27' 0"

bridge. Lateral clearance of the sign should be determined by the requirements of the highway type. On heavily traveled roads (such as freeways), side-mounted signs should be:

(a) Positioned 30 feet from the edge of the travel way.

(b) Located behind a barrier, guardrail.

(c) Affixed to a breakaway installation.

On less traveled roads, signs should preferably be located behind a barrier guardrail or be affixed to a breakaway standard. Any sign support of sufficient mass to be a hazard, which does not meet the preceding criteria, should be noted and reported.

(2) Condition. It is important that all caution signs be in good condition. Evaluation of the condition and adequacy of the signing will depend upon the conditions prevailing in a given area. It is suggested that the AASHTO "Manual on Uniform Traffic Control Devices" be consulted for specific information with regard to signing. Signs should be checked for:

(a) Reflectorization. Adequate reflectorization and/or painting are required for night visibility.

(b) Legibility. Note whether the legend is difficult to read. This may be because of dirt encrustment, dulled paint, inadequate lettering, or inadequate sign size. Refer to the AASHTO "Manual on Uniform Traffic Control Devices" for guidelines as to criteria to be followed in evaluating sign legibility.

(c) Vandalism. Bullet holes, paint smears, campaign stickers, etc. should be noted.

(d) Minimum sizes. In general, most warning signs are diamond-shaped and measure at least 30 by 30 inches. "Low Clearance" signs are 36 by 36 inches. The "Weight Limit" signs are rectangular with minimum dimensions of 18 by 24 inches.

(e) Vegetation. On minor roads, heavy vegetation growth may obscure signs. Note the type and location of such vegetation so that it may be trimmed or removed entirely. If relocation of the sign(s) is necessary, include such remarks in the inspection report.

(f) Sign support damage. Note whether sign supports are bent, twisted, or otherwise damaged.

8-25. Utilities

a. Check pipe, ducts, etc., for leaks, breaks, cracks, and deteriorating coverings.

b. Check the supports for signs of corrosion, damage, loose connections, and general lack of rigidity. If utility mounts rattle during passage of traffic, especially on steel bridges, note need for padding.

c. Check the annual space between pipe and sleeve or between the pipe and the blocked-up area for leaks where utilities pass through abutments.

d. Check for leaky water or sewer pipes for damage.

e. Inspect the area under water or sewer pipes for damage.

f. Determine whether mutually hazardous transmittants, such as volatile fuels and electricity, are sufficiently isolated from each other. If such utilities are side-by-side or in the same bay, report this condition for auxiliary encasement or future relocation.

g. Check utilities that are located beneath the bridge for adequate roadway clearances.

h. Determine whether any utility obstructs the waterway area or is positioned so that it hinders drift removal during periods of high water.

i. Check the encasement of pipes carrying fluids under pressure for damage, and check vents or drains for leaks.

j. Check for the presence of shutoff valves on pipelines carrying hazardous pressurized fluids, unless the fluid supply is controlled by automatic devices.

k. Note whether any utility is located where there is a possibility that it may be struck and damaged by traffic or by ice and debris carried by high water.

l. Determine whether utilities are adequately supported and whether they present a hazard to any traffic which may use or pass under the bridge.

m. Check for wear or deteriorated shielding and insulation on power cables.

n. Check for adverse effect utilities may have on the bridge, e.g., interferences with bridge maintenance operations or an impairing of structural integrity.

o. Check whether vibration or expansion movements are causing cracking in the support members.

p. Check supporting members of the bridge for paint damage.

q. Note any adverse aesthetic effect utilities may have on the bridge.

8-26. Lighting

a. Whitewuy lighting.

(1) *Collision.* Note any light poles that are dented, scraped, cracked, inclined, or otherwise damaged.

(2) *Fatigue.* Aluminum light standards and castings are most likely to suffer from fatigue. Check for cracking in:

(a) Mast arms and cast fitting on standards.

(b) At the base of standards, especially the cast elements.

(3) *Corrosion.* Check steel standards for rusting and concrete standards for cracking and spalling.

b. Electrical systems. This part of the inspection should be made by or with the assistance of a qualified electrician.

(1) *Wiring.* Observe any exposed wiring for signs of faulty, worn, or damaged insulations. Note and report the following:

(a) Bad wiring practices.

(b) Bunches of excess wires.

(c) Loose wires.

(d) Poor wire splices.

(e) Inadequate securing of groundlines.

(2) *Junction boxes.* Check inside junction boxes for excessive moisture, drain hole, poor wire splices, and loose connections. Note the condition of wiring and insulation. Where the base of the light standards contains a junction box, examine this as well. Note whether the junction box, outlet box, or switch box covers are in place.

(3) *Conduit.* Check conduits for rust or missing sections. Check the curbs and sidewalks for large cracks that might have fractured the conduit imbedded in them. Note whether the conduit braces and boxes are properly secured.

(4) *Whiteway current.* On those structures where the whiteway current is carried over an open line above the sidewalks, check for hanging objects such as fishing lines and moss.

c. Lamps or damaged standards. Note any missing or damaged standards. A cover placed over the electric eye controller will turn on the lights. Note the number and the locations of those lights that do not illuminate.

d. Sign lighting. Inspect sign lighting for the same defect as conventional lighting.

e. Navigation lights.

(1) *Lights.* Check to determine whether all of the required navigation lights are present and properly located. For fixed bridges, a green navigation light is suspended from the superstructure over the channel centerline and red lights are placed to make the channel edges. When piers are situated at the channel edges, the red lights are positioned on the piers or fenders. For movable spans, navigation lighting requirements vary according to the bridge type. When in doubt as to the requirements, refer to Section 68 of the Coast Guard Pamphlet CG204, "Aids to Navigation."

(2) *Lighting devices.* Check the overall condition of lighting and devices to determine whether they are rusted, whether any of the lenses are

broken or missing, and whether the lights are functioning correctly.

(3) *Wiring.* Check the condition of wiring, conduits, and securing devices to determine whether they are loose or corroded.

f. Aerial obstruction lights. For short bridges (less than 150 feet), there should be at least two continuous glow red lights mounted at the high points of the superstructure. For longer structures, the red lights should be placed at 150- to 600-foot intervals, while sets of at least three flashing red beacons should be mounted atop the peaks of widely separated high points such as suspension bridge towers, truss cusps, etc. Check these lights for proper maintenance and functioning.

Section IV. INSPECTION OF RAILROAD BRIDGES

8-27. General

a. The construction of railroad bridges is the same as that for all of the previously discussed roadway bridges. Their construction may also be from steel, concrete, masonry, or wood. As a result, most aspects of their inspection are the same, including inspector qualifications, frequency of inspection, and the required thoroughness of inspection.

b. Thorough inspection of the track portion of railroad bridges is usually conducted separately and by different personnel and inspection standards. Therefore, track inspection is only briefly covered in this manual. The primary emphasis for the bridge inspector should be on the supporting bridge structure itself.

c. If, during the inspection, the inspector finds any condition that he considers serious enough to possibly result in collapse of the bridge, he should immediately close the bridge and notify the proper authorities.

8-28. Railroad deck types

Railroad bridge decks are generally of two different types: open deck and ballast deck. An open deck bridge has bolts securing the ties to stringers which in turn are attached to a pile bent or pier cap. On a ballast deck bridge, the deck is a solid floor with a regular ballast section placed on top of the floor.

8-29. Track inspection

As previously noted, a thorough track inspection is generally performed separately from the bridge inspection. However, a thorough bridge inspection should include a minimal inspection of the track since track defects can adversely affect the integrity of the bridge structure itself. The following items relating to the track should be inspected as a minimum:

a. Check the alignment of the track, both vertically and horizontally. State whether the track is level or on grade and if alignment is tangent or curved. If on a curve, note how the superelevation is provided, whether by cutoff in the bents or by taper in the caps or in the ballast section. Note the location of the track with reference to the chords for uniformity of loading.

b. Where track appears out of line or surface, note the location, degree of misalignment, and the probable cause.

c. Check the condition of the embankment at the bridge ends for fullness of crown, steepness of slopes, and depth of bulkheads. Note whether the track ties are fully ballasted and well bedded.

d. Record the weight and condition of the track rails and inside guardrails. Check the condition of any rail joints, fastenings, and tie plates.

e. Any rail anchors found on track over open deck bridges are to be removed immediately. Anchors on open deck bridges are particularly dangerous because the ties form an integral part of the bridge structure. Should the rail start to run, the rail anchors will put longitudinal forces into the ties which will be transferred to the remainder of the bridge structure, possibly causing structural damage. Where anchors are used on track approaching open deck bridges, every third tie should be box anchored (four anchors per tie) for at least two rail lengths off each end of the bridge. Very importantly, no anchors are to be applied on the bridge itself.

8-30. Deck inspection

a. Guardrails are installed to guide derailed equipment and prevent it from leaving the track. All bridges and their approaches should be equipped with guardrails which extend at least 50 feet past the ends of the structure. The condition of the guardrails should also be closely inspected. Look for loose or missing spikes, joint bars, track bolts, or tie plates.

b. On ballast deck bridges, check the ballast to see if it is clean and in full section. The ballast should be measured from the base of the rail at each end of bridge. The ballast section should be clean, free-draining, and free of vegetation, soil (mud), and other foreign materials. The ballast materials should not be at a level above the top of the ties.

c. Ballast deck bridges are normally equipped with drainholes to allow water to drain from the bridge deck. Check these holes to make sure they are open and free draining.

d. Walkways or walkboards along an open deck bridge should be maintained to allow for safe walking over the structure. Check for loose, broken, deteriorated, or missing boards.

e. The ties should be inspected as follows:

(1) Note the size, spacing, and uniformity of bearing of all ties. In a ballast deck bridge, make sure all of the ties are fully ballasted and well bedded. Bolts that secure the ties to the bridge stringers in open deck bridges should be checked for deterioration and sufficient tightness. Any tie that is not materially defective (paragraph 8-30e(2)), but does not fully support both rails, should be noted and recommended for tamping up and respiking.

(2) Typical tie defects are shown in figure 8-36 and a tie should be considered defective (and noted) if it is:

(a) Broken through.

(b) Split or otherwise impaired to the extent that it will not hold spikes or other rail fasteners.

(c) So deteriorated that the tie plate can move laterally more than ½ inch relative to the crosstie.

(d) Cut by the tie plate more than 2 inches.

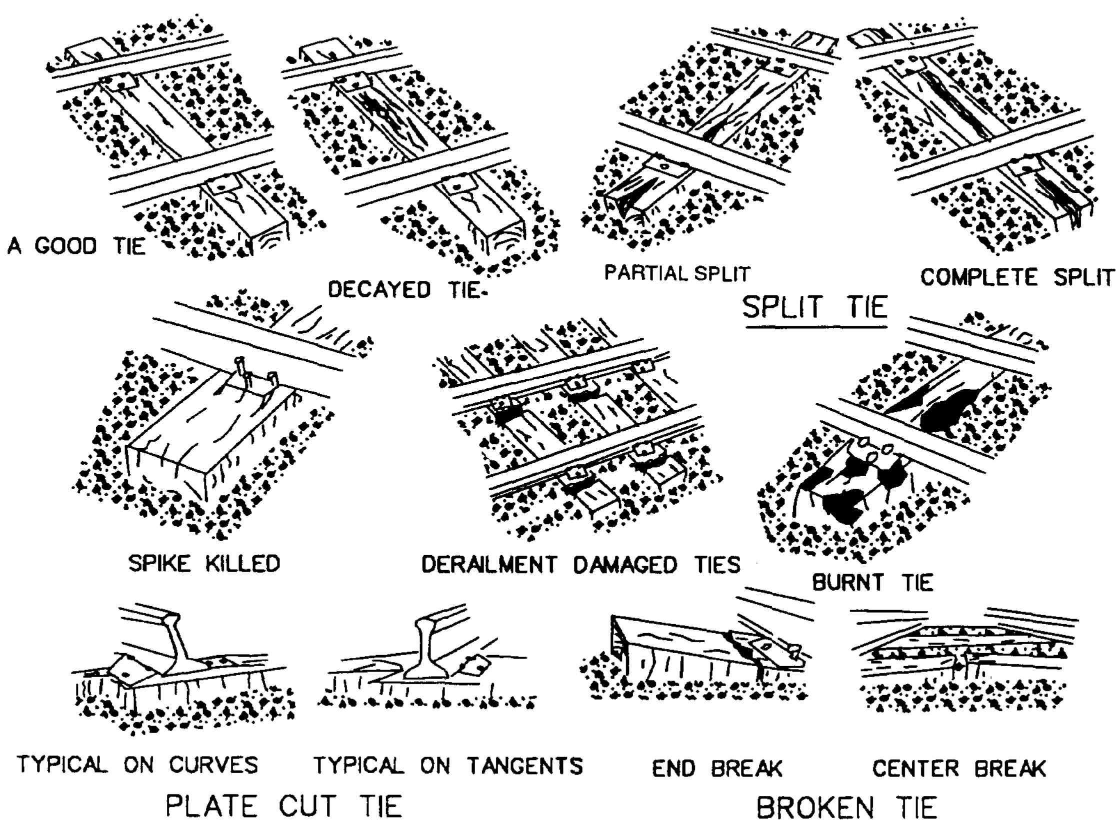


Figure 6-36. Examples of good and defective cross-ties.

(e) Cut by wheel flanges, dragging equipment, fire, etc. to a depth of more than 2 inches within 12 inches of the base of the rail, frog, or load-bearing area.

(f) Rotted, hollow, or generally deteriorated to a point where a substantial amount of the material is decayed or missing.

(3) The occurrence of consecutive defective ties in categories 1 and/or 2 requires operating restrictions as specified in table 8-4.

(4) All track joints should be supported by at least one nondefective tie whose centerline is within 18 inches of the rail ends as shown in figure 8-37. At any location where a rail joint is not supported by at least one nondefective tie, operations should not exceed 10 miles per hour (mph).

(5) If the existing tie spacing averages greater than 22 inches within the distance of a rail length, the desired spacing should be established during the next major maintenance cycle. For track constructed with an average tie spacing greater than 22 inches, the desired spacing should be established during the next track rehabilitation.

(6) Missing or skewed (crooked) ties are undesirable in track. At any location where the center-to-center tie spacing measured along either rail exceeds 48 inches, operations shall not exceed 10 mph until additional tie support is provided, or skewed ties should be straightened during the next track rehabilitation.

8-31. Superstructure inspection

The inspection procedures for the superstructure portion of railroad bridges are the same as those previously discussed for roadway bridges with the following exceptions:

Table 8-4. Operating restrictions

Number of Consecutive Defective Ties	Operating Restrictions
0 to 2	None
3	Limit maximum speed to 10 mph
4	Limit maximum speed to 5 mph
5 or more	No operation

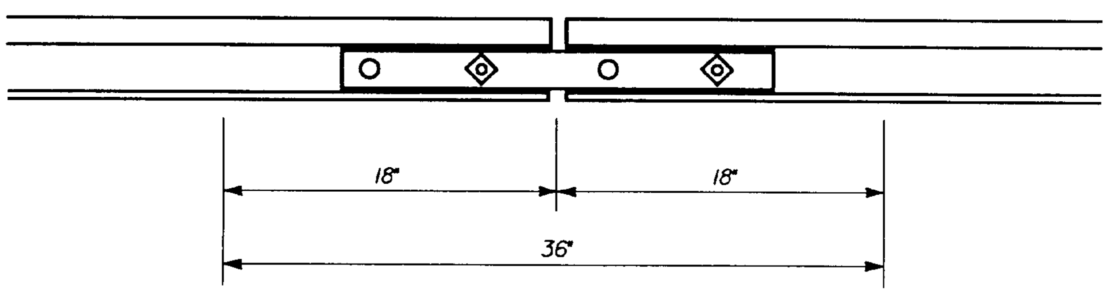
a. When possible, the movement of the superstructure during passage of a train should be observed. Note excessive movements, rattles, and vibrations.

b. Observe all members to determine if any are broken or moved out of proper position and whether all fastening devices are functioning properly.

c. Check all stringers for soundness and surface defects. Note their size and type and the number used in each panel. Note if the bearing is sound and uniform, if all stringers are properly chorded and securely anchored, and if all shims and blocking are properly installed. Note whether packers or separators are used and the condition of all chord bolts.

d. With timber trestles, fire protection is very important. The following items should be inspected:

(1) Note whether the surface of the ground around and beneath the structure is kept clean of grass, weeds, drift, or other combustible material.



AT EACH JOINT. AT LEAST ONE TIE WITHIN THIS AREA MUST BE NON-DEFECTIVE.

Figure 8-37. Required tie support at track joints.

(2) Where rust-resisting sheet metal is used as a fire protection covering for deck members, note the condition of the metal and its fastenings.

(3) Note if any other method of fire protection has been used, such as fire retardant salts, external or surface protective coatings, or fire walls. Record such apparent observations as are pertinent to the physical condition and effectiveness of such protective applications.

(4) Where water barrels are provided, note the number, condition, if filled, and if buckets for bailing are on hand. If sand is used, note whether bins are full and in condition to keep the sand dry.

(5) Note if timber, particularly top surfaces of ties and stringers in open deck bridges, is free from frayed fiber, punk wood, or numerous checks.

8-32. Substructure inspection

The inspection procedures for the substructure portion of railroad bridges are the same as those previously discussed for roadway bridges with the following exceptions:

a. When possible, the movement of the substructure during passage of a train should be observed. Note excessive vibration, deflection, side sway, and movement at pier supports.

b. Examine all bents and towers for plumbness, settlement, sliding and churning, and give an accurate description of the nature and extent of any irregularities. Note particularly whether caps and sill have full and uniform bearing on the supports.

c. Note the number and kind of piles or posts in the bents or towers. Note the uniformity of spacing and the location of any stubbed or spliced members, especially if the bridge is on a curve or the bent is more than 15 feet in height.

d. Check all fastening devices for physical condition and tightness.

8-33. Recommended practices

The inspector's outline of repairs should be based on the following recommended practices. Refer to chapters 11 through 13 of this manual for specific details for these repairs:

a. Posting of the outside piles should not be permitted on bridges on curves where bents exceed 12 feet in height or on tangents where bents are over 20 feet in height.

b. On high-speed track where traffic is heavy, not more than two posted piles in any one bent shall be permitted. If more than two piles are poor, all piles should be cut off to sound wood below groundline and a framed bent installed or piles redriven.

c. All posts should be boxed, in addition to toe nailing, to prevent buckling.

d. When individual caps, sills, braces, or struts have become weakened beyond their ability to perform their intended function, renewal is the only remedy.

e. When only an individual stringer is materially deteriorated, an additional stringer may be installed, inside or outside of the chord, to aid the weakened member.

f. Where piles are decayed at the top they may be cut off and double capped; a single pile may be corbelled.

g. Shimming of stringer to provide proper surface and cross level should be done with a single shim under each chord. If possible, avoid multiple shimming.

Section V. BOX CULVERTS

8-34. Types of distress

A culvert is generally used where its construction would permit a fill to substitute for a bridge without any loss of vital waterway area. This combination of high earth loads, long pipe-like structures, and running water tends to produce the following types of distress:

a. The basic causes and actions of foundation movements are discussed in chapter 5. Here, they need only be listed:

(1) Settlement of the box. This may be either a smooth sag, or it may be differential settlement at the expansion joints.

(2) Tipping of wing walls.

(3) Lateral movements of sections of the box.

b. High embankments may impose very heavy loads on the top and bottom slabs. These earth pressures can cause either shear or flexural failures in the top slabs.

c. Construction defects can lead to structural distress.

d. Undermining is a form of scour attack on the upstream and downstream ends of box culverts. When sheeting or a concrete cut-off wall is not provided or is not deep enough, the stream may wash away the soil under the ends of the floor slab, the apron, or the wing wall footings, leading to settlements and culvert cracking.

e. Plugging may result from debris collecting over the mouth of the culvert. This can cause flooding and flotation and displacement of part, or all, of the box.

f. Water leaving the box at high velocities may cause downstream scour at the streambed.

8-35. Inspection

a. Check for sag of the culvert floor. In times of light flow, this may be noted by location of sediment. Where there are several feet of water in the box, a profile of the crown may be taken.

b. Check for sag in the profile of the roadway overhead.

c. Check for vertical differential settlement at the expansion joints.

d. Check for transverse and longitudinal differential settlements at the expansion joints.

e. Check for widely opened expansion joints. Water may be seeping through joints from soil outside.

f. Check for canted wingwalls. This condition may be due to settlement, slides, or scour.

g. Check for slide failures in the fill around the box. Such slides are likely to affect the box as well.

h. Check for cracks and spalls in the top slab. Longitudinal cracks indicate shear or flexure problems; transverse cracks indicate differential settlement. Cracks in the sides may be from settlement or from extremely high earth pressures. Note the size, length, and location of the crack. Look for exposed or rusty rebars.

i. Where there is no bottom slab, look for undermining of side footings.

j. Check for undermining at the ends of the box and under the wings.

k. Examine the inside of the box for large cracks and debris. This may indicate the need for a debris rack. Check the inlet end of the culvert for debris. Note whether vegetation is obstructing the ends of the culvert.

l. If the culvert floor is visible, check it for abrasion and wear.

m. Note any other signs of deterioration of the concrete box, especially those which suggest design error or construction omissions.

APPENDIX A

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American Concrete Institute Committee 201, "Guide to Durable Concrete," *Journal of the American Concrete Institute*, Number 12, Proceedings Volume 74, pages 573-609, December 1977.

APPENDIX B

SUGGESTED ITEMS FOR ARMY ANNUAL AND AIR FORCE BIANNUAL BRIDGE INSPECTIONS

BRIDGE INSPECTION ITEMS

Include the following items:

1. Installation.
2. Bridge number.
3. Location.
4. Date inspected.
5. Existing bridge classification (if applicable).

For the following components, address each appropriate inspection item and make notes of any observed deficiencies and recommendations:

A. Timber Abutments

1. Signs of settlement.
2. Rusting of steel rods.
3. Decay of end dam, wingpost, post, and/or cap.
4. Deterioration of block (bearing and anchor).
5. Decay of sill and footing.
6. Loose timbers.
7. Decay of breakage of piles (wing or bearing).

B. Steel Pile Abutments

1. Settlement.
2. Rusting of end dam, pile and/or cap.
3. Section loss of steel members.
4. Missing, loose, or rusting bolts.

C. Concrete Abutments, Wingwalls, and Retaining Walls

1. Settlement.
2. Proper function of weep holes.
3. Cracking or spalling of bearing seats.
4. Deterioration of cracking of concrete.
5. Exposed reinforcing steel.

D. Timber Piers and Bents

1. Settlement.
2. Decay of caps, bracing, scabbing, or corbels.
3. Missing posts or piles.
4. Decay of posts or piles.
5. Debris around or against piers.
6. Section loss of sills or footings.
7. Erosion around piers.
8. Rusting of wire-rope cross bracing.
9. Loose or missing bolts.
10. Splitting or crushing of the timber when:
    a. The cap bears directly upon the cap, or
    b. Beam bears directly upon the cap.
11. Excessive deflection or movement of members.

E. Steel Piers and Bents

1. Settlement or misalignment.
2. Rusting of steel members or bearings.

3. Debris.
4. Rotation of steel cap due to eccentric connection.
5. Braces with broken connections or loose rivets or bolts.
6. Member damage from collision.
7. Need for painting.
8. Signs of excessive deflection or movement of members.

F. Concrete Piers and Bents

1. Settlement.
2. Deterioration or spalling of concrete.
3. Cracking of pier columns and/or pier caps.
4. Cracking or spalling of bearing seats.
5. Exposed reinforcing steel.
6. Debris around piers or bents.
7. Section loss of footings.
8. Erosion around piers.
9. Collision damage.

G. Concrete (girders, beams, frames, etc.)

1. Spalling (give special attention to points of bearing).
2. Diagonal cracking, especially near supports.
3. Vertical cracks or disintegration of concrete, especially in the area of the tension steel.
4. Excessive vibration or deflection during vehicle passage.
5. Corrosion or exposure of reinforcing steel.
6. Corroded, misaligned, frozen, or loose metal bearings.
7. Tearing, splitting, bulging of elastomeric bearing pads.

H. Timber (trusses, beams, stringers, etc.)

1. Broken, deteriorated, or loose shear connectors.
2. Failure, bowing, or joint separation of individual members of trusses.
3. Loose, broken, or worn planks on the timber deck.
4. Improper functioning of members.
5. Rotting or deterioration of members.

I. Steel (girders, stringers, floor beams, diaphragms, cross frames, portals, sway frames, lateral bracing, truss members, bearing and anchorage, eyebars, cables, and fittings)

1. Corrosion and deterioration along:
   a. Web flange.
   b. Around bolts and rivets heads.
   c. Under deck joints.
   d. Any other points which may be exposed to roadway drainage.
   e. Eyebars, cables, and fittings.
2. Signs of misalignment or distortion due to overstress, collision, or fire.
3. Wrinkles, waves, cracks, or damage in the web and flange of steel beam, particularly near points of bearing.
4. Unusual vibration or excessive deflection occurring during the passage of heavy loads.
5. Frozen or loose bearings.
6. Splitting, tearing, or bulging in elastomeric bearing pads.

J. Concrete Appurtenances

1. Cracking, scaling, and spalling on the:
   a. Deck surface.
   b. Deck underside.
   c. Wearing surface (map cracking, potholes, etc.).

NOTE: If deterioration is suspected, remove a small section of the wearing surface in order to check the condition of the concrete deck.

2. Exposed and/or rusting reinforcing steel.
3. Loose or deteriorated joint sealant.

4. Adequacy of sidewalk drainage.
5. Effect of additional wearing surfaces on adequacy of curb height.

K. Timber Appurtenances

1. Loose, broken, or worn planks.
2. Evidence of decay, particularly at the contact point with the stringer where moisture accumulates.
3. Excessive deflection or loose members with the passing of traffic.
4. Effect of additional wearing surfaces on adequacy of curb height.

L. Steel Appurtenances (including but not limited to decks, gratings, curbs, and sidewalks)

1. Corroded or cracked welds.
2. Slipperiness when deck or steel sidewalk is wet.
3. Loose fasteners or loose connections.
4. Horizontal and vertical misalignment and/or collision damage.

M. Masonry Bridges

1. Settlement.
2. Proper function of weep holes.
3. Collision damage.
4. Spalling or splitting of rocks.
5. Loose or cracked mortar.
6. Plant growth, such as lichens and ivy, attaching to stone surfaces.
7. Marine borers attacking the rock and mortar.

N. Miscellaneous

1. Existence and appropriateness of bridge classification signs.
2. Condition of approachments.
3. Leaks, breaks, cracks, or deterioration of pipes, ducts, or other utilities.
4. Damaged or loose utility supports.
5. Wear or deterioration in the shielding and insulation of power cables.

APPENDIX C

SUGGESTED ITEMS FOR ARMY TRIENNIAL AND EVERY THIRD AIR FORCE BIANNUAL BRIDGE INSPECTIONS

BRIDGE INSPECTION ITEMS

Include the following items:

A. General Information to Include

1. Bridge name.
2. Location.
3. Date of inspection.
4. Design load (if known).
5. Military load classification (if known).
6. Date built.
7. Traffic lanes.
8. Transverse section (describe or sketch).
9. Structure length.
10. No. of spans.
11. Plans available.
12. Inspection records.
    - *a*. Year inspected.
    - *b*. Inspector.
    - *c*. Qualification.
13. Bridge description.
    - *a*. Floor system.
    - *b*. Beams.
    - *c*. Girders.
    - *d*. Stringers.
    - *e*. Trusses.
    - *f*. Suspension.
    - *g*. Piers.
    - *h*. Abutment A.
    - *i*. Abutment B.
    - *j*. Foundation.
    - *k*. Piers or bents.
        - (1) Caps.
        - (2) Posts or columns.
        - (3) Footings.
        - (4) Piles.
        - (5) Other.
    - *l*. Deck:
        - (1) Wearing surface.
        - (2) Curb.
        - (3) Railings.
        - (4) Sidewalk.
        - (5) Other.

B. Bridge Components Rating Information

The following items may be rated using the suggested ratings from part C of this appendix. Descriptive remarks may also be included.

1. Traffic safety features.
    - *a*. Bridge railing.

b. Transitions.
c. Approach guardrail.
d. Approach guardrail terminal.

2. Deck.
a. Wearing surface.
b. Deck structural condition.
c. Curbs.
d. Median.
e. Sidewalk.
f. Parapet.
g. Railings.
h. Drains.
i. Lighting.
j. Utilities.
k. Expansion joints.

3. Load bearing components.
a. Bearing devices.
b. Stringers.
c. Girders or beams.
(1) General.
(2) Cross frames.
(3) Bracing.
d. Floor beams.
e. Trusses.
(1) General.
(2) Portals.
(3) Bracing.
f. Paint.

4. Abutments.
a. Wings.
b. Backwall.
c. Bearing seats.
d. Breast wall.
e. Weep holes.
f. Footing.
g. Piles.
h. Bracing.
i. Erosion or scour.
j. Settlement.

5. Piers/bents or pile bents.
a. Caps.
b. Bearing seats.
c. Column, stem, or wall.
d. Footing.
e. Piles.
f. Bracing.
g. Erosion or scour.
h. Settlement.

6. Channel and channel protection.
a. Channel scour.
b. Embankment erosion.
c. Drift.
d. Vegetation.
e. Fender system.
f. Spur dikes and jetties.

g. Rip rap.
h. Adequacy of opening.

7. Approach.
   a. Alignment.
   b. Approach.
   c. Relief joints.
   d. Approach.
      (1) Guardrail.
      (2) Pavement.
      (3) Embankment.

C. Suggested Component Ratings

1. Traffic Safety Features.

Code	*Description*
0	Inspected feature DOES NOT currently meet acceptable standards or a safety feature is required and NONE IS PROVIDED.
1	Inspected feature MEETS currently acceptable standards.
N	NOT APPLICABLE

2. Superstructure, Substructure, Channel and Channel Protection, and Approach.

Code	*Description*
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION-no problems noted.
7	GOOD CONDITION-some minor problems.
6	SATISFACTORY CONDITION-structural elements show some minor deterioration.
5	FAIR CONDITION-all primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
4	POOR CONDITION-advanced section loss, deterioration, spalling or scour.
3	SERIOUS CONDITION-loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION-advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION-major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put back in light service.
0	FAILED CONDITION-out of service-beyond corrective action.

3. Supplemental for Channel and Channel Protection (Use in conjunction with part 2 above).

Code	*Description*
N	NOT APPLICABLE bridge is not over a waterway.
9	There are no noticeable or noteworthy deficiencies which affect the condition of the channel.
8	Banks are protected or well vegetated. River control devices such as spur dikes and embankment protection are not required or are in a stable condition.
7	Bank protection is in need of minor repairs. River control devices and embankment protection have little minor damage. Banks and/or channel have minor amounts of drift.
6	Bank is beginning to slump. River control devices and embankment protection have widespread minor damage. There is minor stream bed movement evident. Debris is restricting the waterway slightly.
5	Bank protection is being eroded. River control devices or embankment have major damage. Trees and brush restrict the channel.

Code	*Description*
4	Bank and embankment protection is severely undermined. River control devices have severe damage. Large deposits of debris are in the waterways.
3	Bank protection has failed. River control devices have been destroyed. Stream bed aggradation, degradation, or lateral movement has changed the waterway to now threaten the bridge or approach roadway.
2	The waterway has changed to the extent the bridge is near a state of collapse.
1	Bridge is closed because of channel failure. Corrective action may put it back in light service.
0	Bridge is closed because of channel failure. Replacement is necessary.

4. Supplemental for Approach Roadway Alignment (Use in conjunction with part 2 above):

Code	*Description*
8	Speed reduction is NOT required.
6	A VERY MINOR speed reduction is required.
3	A SUBSTANTIAL speed reduction is required.

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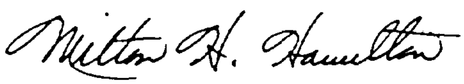

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Bridge Inspection, Maintenance and Repair Part III
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1. _________ are more critical to the overall safety of the bridge.

    a) Fracture critical members
    b) Beams
    c) Column
    d) none of the above

2. Fracture critical members are in _________.

    a) tension
    b) compression
    c) bending
    d) all of the above

3. Simple span single-box girder have their fracture critical members located in _________.

    a) the top of the box girder
    b) bottom of the box girder
    c) sides of box girder
    d) all members are considered fracture critical

4. In general, the fracture critical elements will be located near the center of the spans in the bottom of the girders and over the supports in the top of the girders.

    a) True
    b) False

5. The basic tool kit for a bridge inspection should include a _________.

    a) sketch pad
    b) camera
    c) keel marker
    d) all of the above

6. A life line or belt must be worn when working at heights over _________ above water or above traffic.

    a) 5 feet
    b) 10 feet
    c) 20 feet
    d) 50 feet

7. Persons should not be allowed to work in confined spaces containing less than _________ oxygen.

    a) 5%
    b) 15%
    c) 19%
    d) 32%

8. Bridge inspection explanatory aids include _________.

    a) narrative description
    b) photographs
    c) summary
    d) all of the above

9. As part of the substructure inspection, the bridge inspector must check _________.

    a) abutments
    b) retaining walls
    c) piers and bents
    d) all of the above

10. For steel dolphins and fenders check the _________ carefully for severe rusting and pitting.

    a) splash zone
    b) wet dry zone
    c) moisture zone
    d) all of the above

11. Check for spalling concrete, giving special attention to points of bearing where friction from thermal movement and high edge pressure may cause spalling.

    a) True
    b) False

12. Any serious problems found in an _________ should be addressed immediately since its failure could cause total collapse of the bridge.

   a) fracture critical members
   b) beams
   c) abutments
   d) none of the above

13. Check for wrinkles, waves, cracks, or damage in the _________ of steel beams, particularly near points of bearing. This condition may indicate over-stressing.

   a) stiffeners
   b) web flanges
   c) supports
   d) not an issue on multi-span beams

14. Local buckling indicates over-stressing of a _________ members.

   a) member under bending forces
   b) compression
   c) tension
   d) all of the above

15. For tied arches, the key locations in the tie girder are _________.

   a) floor beam connections
   b) hanger connections
   c) knuckle area
   d) all of the above

16. The appropriate amount of rocker tilt depends upon the _________ at the time of observation.

   a) traffic
   b) atmospheric moisture
   c) temperature
   d) none of the above

17. Stains on the concrete that would indicate that the reinforcement steel is _________.

   a) missing
   b) over-stressed
   c) bending
   d) rusting

18. Check all expansion joints for __________.

    a) proper clearance
    b) proper vertical alignment
    c) freedom of movement
    d) all of the above

19. Observe the bridge beams, piers, and abutments for water stains. These may indicate __________.

    a) leaky pipes
    b) filled gutters
    c) scupper discharge pipes are too short
    d) all of the above

20. __________ can effectively reduce the bearing of piles, undermine pier footings and abutments, and cut into the bank.

    a) Scour
    b) Drift
    c) Abutment instability
    d) Inadequate bank slope