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Section 8
Inspection and Evaluation of Common Steel Superstructures

Topic 8.3 Steel Two Girder Systems

8.3.1 Introduction

The steel two girder bridge, like the fabricated multi-girder bridge, can use either riveted or welded construction. The difference is that it has only two girders. Two girder bridges can also have features similar to those of fabricated multi-girder bridges, such as web insert plates, transverse web stiffeners, and longitudinal web stiffeners (see Figure 8.3.1).

However, unlike the fabricated multi-girder bridge, the two girder bridge has a floor system of smaller stringers and floorbeams. The floor system supports the deck while the girders support the floor system.

Two girders can be found in simple span and continuous span configurations. They can also be found on curved bridges, and pin and hanger connections are common details with this bridge type. Two girder bridges are either deck girder or through girder systems.

In a deck girder system, the deck is supported by the floor system and top flanges of the two girders (see Figure 8.3.1). In a through girder system, the deck is supported by the floor system between the two girders (see Figure 8.3.2).

Figure 8.3.1 General View of a Dual Deck Girder Bridge

While few through girders are constructed today, they were commonly used prior to the early 1950's. Since many through girder bridges were constructed in the 1940’s and 1950’s, they are commonly riveted. Their most common use was where vertical under-clearance was a concern, such as over railroads (see Figure 8.3.3).

Figure 8.3.2 Through Girder Bridge

Figure 8.3.3 Through Girder Bridge with Limited Underclearance

A rare type of through girder has three or more girders, with the main girders actually separating the traffic lanes (see Figure 8.3.4). These structures are most likely converted railroad or trolley bridges.

Figure 8.3.4 Through Girder Bridge with Three Girders

8.3.2 Design Characteristics

Floor System Arrangement

Floor systems are similar in deck girder and through girder systems.

The floor system supports the deck. There are two types of floor systems found on two girder bridges:

- Girder-floorbeam system
- Girder-floorbeam-stringer system

The girder-floorbeam (GF) system consists of floorbeams connected to the main girders. The floorbeams are considerably smaller than the girders and are perpendicular to traffic. The deck is supported by the floorbeams, which in turn transmit the loads to the main girders. The floorbeams can be either rolled beams, fabricated girders, or fabricated cross frames (see Figure 8.3.5).

Figure 8.3.5 Two Girder Bridge with Girder-Floorbeam System

The girder-floorbeam-stringer (GFS) system consists of floorbeams connected to the main girders, and longitudinal stringers, parallel to the main girders, connected to the floorbeams (see Figure 8.3.6). The stringers may either connect to the web of the floorbeams or be stacked on top of the floorbeams, in which case they may be continuous stringers. Stringers are usually rolled beams and are considerably smaller than the floorbeams. It is also possible to find floorbeams that are stacked on top of the main girders, and the floorbeams may extend or overhang from the girders (see Figure 8.3.7).

Figure 8.3.6 Two Girder Bridge with Girder-Floorbeam-Stringer System

Figure 8.3.7 Two Girder Bridge with GFS System with Stacked Floorbeam and Stringers

Primary and Secondary Members

The primary members of a two girder bridge are the girders, floorbeams, and stringers, if present. The secondary members are diaphragms and the lateral bracing members, if present. These secondary members usually consist of angles or tee shapes placed diagonally in horizontal planes between the two main girders. The lateral bracing is generally in the plane of the bottom flange. Lateral bracing serves to minimize any differential longitudinal movement between the two girders (see Figure 8.3.8). Not all two girder bridges will have a lateral bracing system. Diaphragms, if present, are usually placed between stringers.

Figure 8.3.8 Underside View of Deck Girder Bridge with Lateral Bracing System

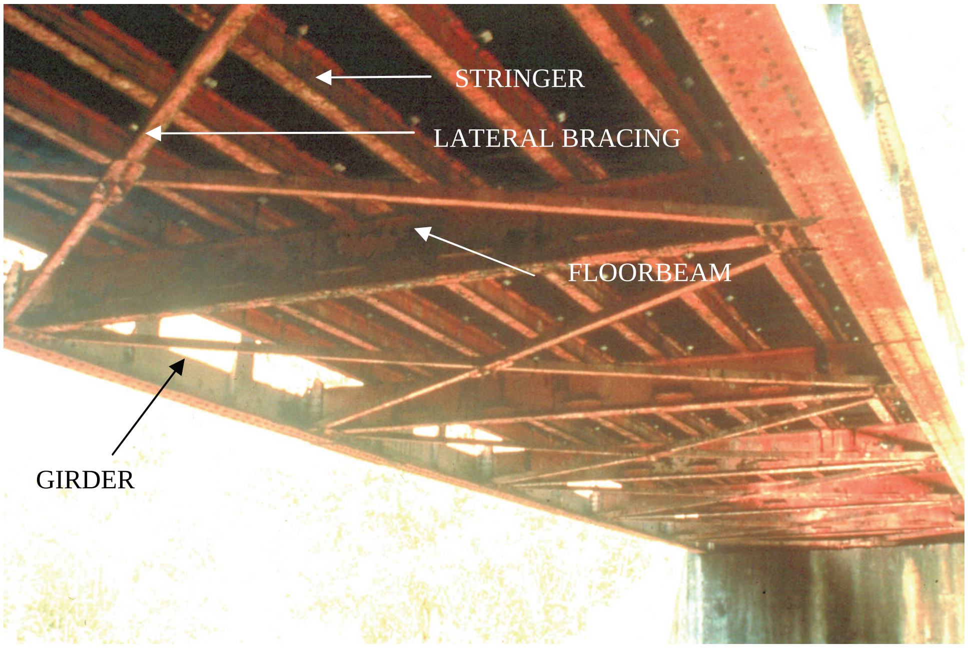

Figure 8.3.9 Underside View of Through Girder Bridge with Lateral Bracing

Fatigue Prone Details and Failure

Some common areas for fatigue prone details are:

- Fabrication welds
- Pin and hanger connections (if present)
- Welded cover plates
- Web stiffener welds

- Welded flange splices
- Intersecting welds
- Attachment welds located in the tension zone
- Web gaps
- Mechanical splices

Inspection of these areas is discussed further in Topic 8.3.4.

Fracture Critical Areas

Girders

Two girder bridges (deck girder and through girder) do not have load path redundancy. Both systems are therefore classified as fracture critical bridge types. The main girders are fracture critical members.

Pin and hanger assemblies in two girder bridges are fracture critical members (see Figure 8.3.10). Failure of one pin or one hanger will cause collapse of the suspended span since there is no alternate load path (e.g., Mianus River Bridge). Pins are considered "frozen" when corrosion restricts rotation. The pins and hangers experience additional bearing, torsion, bending and shear stresses when the pin and hanger assembly is frozen. This is a critical situation when it occurs on a (load path) nonredundant two girder bridge.

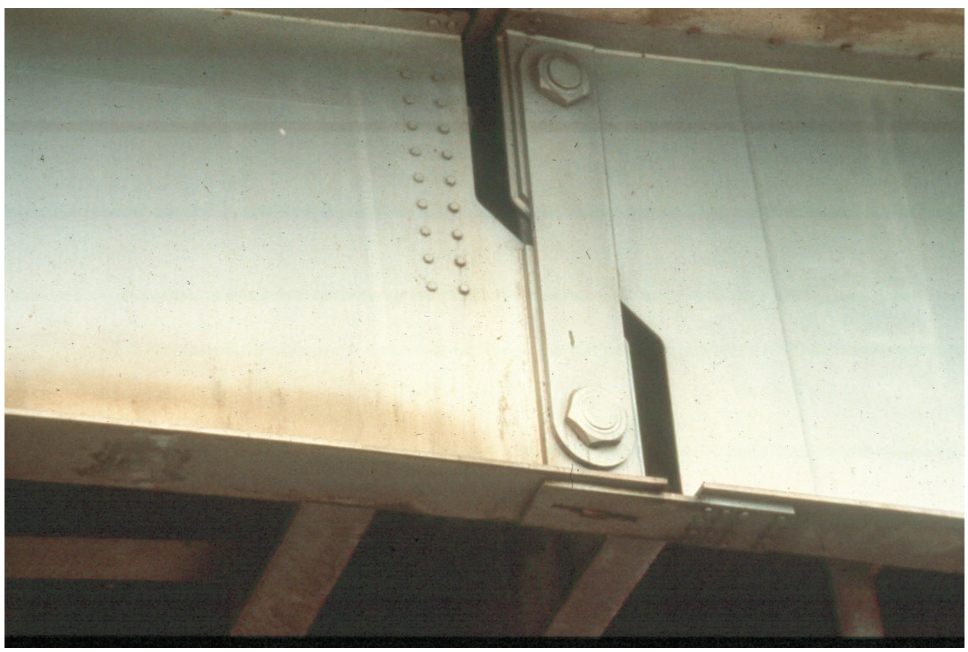

Figure 8.3.10 Two Girder Bridge with Pin and Hanger Connection

In the interest of conservatism, AASHTO chooses to neglect structural and internal redundancy and classify all two girder bridges as (load path) nonredundant.

Floorbeams

A floorbeam may be fracture critical if it satisfies one or more of the following conditions:

- Flexible or hinged connection to support at the girder/floorbeam connection
- Floorbeam spacing greater than 4 m (14'-0")
- No stringers supporting the deck
- Stringers are configured as simple beams

Several states consider floorbeams with spacing greater than 4 m (14'-0") to be fracture critical. A three dimensional finite element structural analysis may be performed to determine the exact consequences to the bridge if a floorbeam or floorbeam connection fails.

8.3.3 Overview of Common Defects

Common defects that occur on steel two girder and steel through girder bridges include:

- Paint failures
- Corrosion
- Fatigue cracking
- Collision damage
- Overloads
- Heat damage

See Topic 2.3 for a detailed presentation of the properties of steel, types and causes of steel deterioration, and the examination of steel. Refer to Topic 8.1 for Fatigue and Fracture in Steel Bridges.

8.3.4 Inspection Procedures and Locations

Inspection procedures to determine other causes of steel deterioration are discussed in detail in Topic 2.3.8.

Procedures

Visual

The inspection of steel bridge members for defects is primarily a visual activity.

Most defects in steel bridges are first detected by visual inspection. In order for this to occur, a hands-on inspection, or inspection where the inspector is close enough to touch the area being inspected, is typically required. More exact visual observations can also be employed using a magnifying unit after cleaning the paint from the suspect area.

Physical

Removal of paint can be done using a wire brush, grinding, or sand blasting, depending on the size of the suspected defect. Care should be taken in cleaning when the suspected defect is a crack. When cleaning steel surfaces, any type of cleaning process that would tend to close discontinuities, such as blasting, should be avoided. The use of degreasing spray before and after removal of the paint may help in revealing the defect.

When section loss occurs, use a wire brush, grinder or hammer to remove loose or flaked steel. After the flaked steel is removed, measure the remaining section and compare it to a similar section with no section loss.

The usual and most reliable sign of fatigue cracks is the oxide or rust stains that develop after the paint film has cracked. Experience has shown that cracks have generally propagated to a depth between one-fourth and one-half the plate thickness before the paint film is broken, permitting the oxide to form. This occurs because the paint is more flexible than the underlying steel.

Smaller cracks are not likely to be detected visually unless the paint, mill scale, and dirt are removed by carefully cleaning the suspect area. If the confirmation of a possible crack is to be conducted by another person, it is advisable not to disturb the suspected crack area so that re-examination of the actual conditions can be made.

Once the presence of a crack has been verified, the inspector should examine all other similar locations and details.

Advanced Inspection Techniques

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

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

Other methods, described in Topic 13.3.3, include:

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

Locations

Bearing Areas

Examine the web areas over the supports for cracks, section loss and buckling. If bearing stiffeners, jacking stiffeners and diaphragms are present at the supports inspect them for cracks, section loss and buckling also.

Examine the bearings at each support for corrosion. Check the alignment of each bearing and note any movement. Report any build up of debris surrounding the bearings that may limit the bearing from functioning properly. Check for any bearings that are frozen due to heavy corrosion. See Topic 9.1 for a detailed presentation on the inspection of bearings

Shear Zones

Examine the web areas of the girders, floorbeams, and stringers near their supports for section loss or buckling (see Figures 8.3.11 and 8.3.12). This is a critical area, especially if the web is coped or the flange is blocked.

Figure 8.3.11   Shear Zone on a Deck Girder Bridge

Figure 8.3.12 Web Area Near Support on a Through Girder Bridge

Flexure Zones

The flexure zone of each girder includes the entire length between the supports (see Figures 8.3.13 and 8.3.15). Investigate the tension and compression flanges for corrosion, loss of section, cracks, dings, and gouges. Check the flanges in high stress areas for bending or flexure- related damage. Examine the compression flange for local buckling and, although it is uncommon, for elongation or fracture of the tension flange. On continuous spans, the beams over the intermediate supports have high flexural stresses due to negative moment. Check flange splice welds and longitudinal stiffener splice welds in tension areas (see Figure 8.3.14).

Figure 8.3.13 Flexural Zone on a Two Girder Bridge

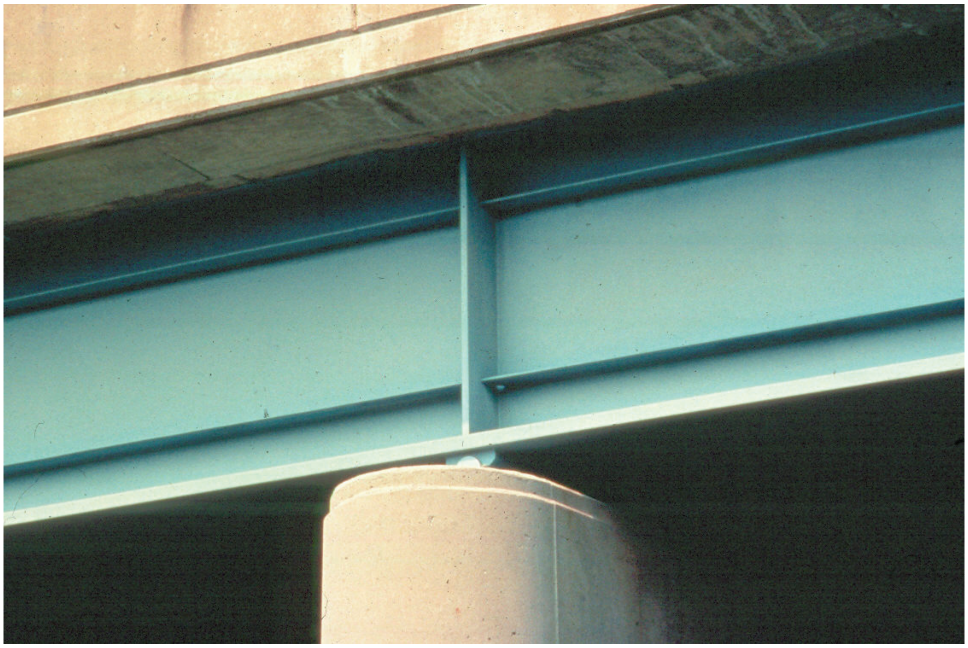

Figure 8.3.14 Longitudinal Stiffener in Tension Zone on a Two Girder Bridge

Figure 8.3.15 Flexural Zone on a Through Girder Bridge

Secondary Members

Investigate the diaphragms, if present, and the connection areas of the lateral bracing for cracked welds, fatigue cracks, and loose fasteners. Inspect the bracing members for any distortion or corrosion (see Figures 8.3.16 and 8.3.17). Distorted or cracked secondary members may be an indication the primary members may be overstressed or the substructure may be experiencing differential settlement.

Figure 8.3.16 Lateral Bracing Connection on a Deck Girder Bridge

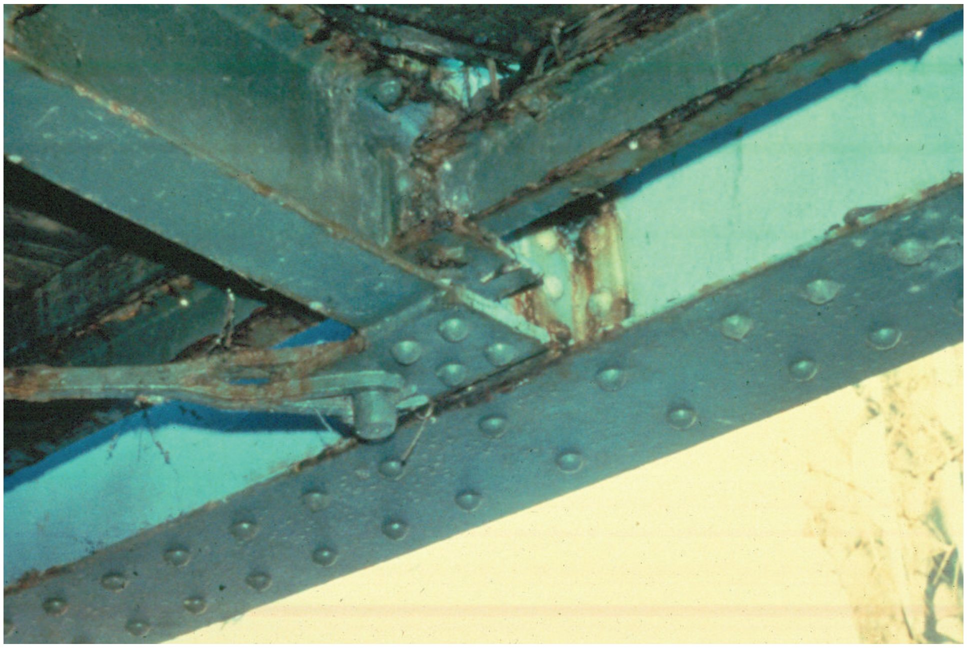

Figure 8.3.17 Lateral Bracing Connection on a Through Girder Bridge

Areas That Trap Water and Debris

Check horizontal surfaces that can trap debris and moisture and are susceptible to a high degree of corrosion and deterioration. Areas that trap water and debris can result in active corrosion cells and excessive loss in section. This can result in notches susceptible to fatigue or perforation and loss of section.

On two girder bridges check:

- Along the bottom flanges of the girders
- Pockets created by girder-floorbeams and floorbeam-stringer connections
- Lateral bracing gusset plates
- Areas exposed to drainage runoff
- Along the girder webs at the curb line (through girder system)

Areas Exposed to Traffic

Check underneath the bridge for collision damage to the main girders and bracing if the bridge crosses over a highway, railway, or navigable channel. Document any cracks, section loss, or distortion found (see Figures 8.3.18 and 8.3.19). On a through girder bridge, investigate the main girders along the curb lines and at the ends for collision damage.

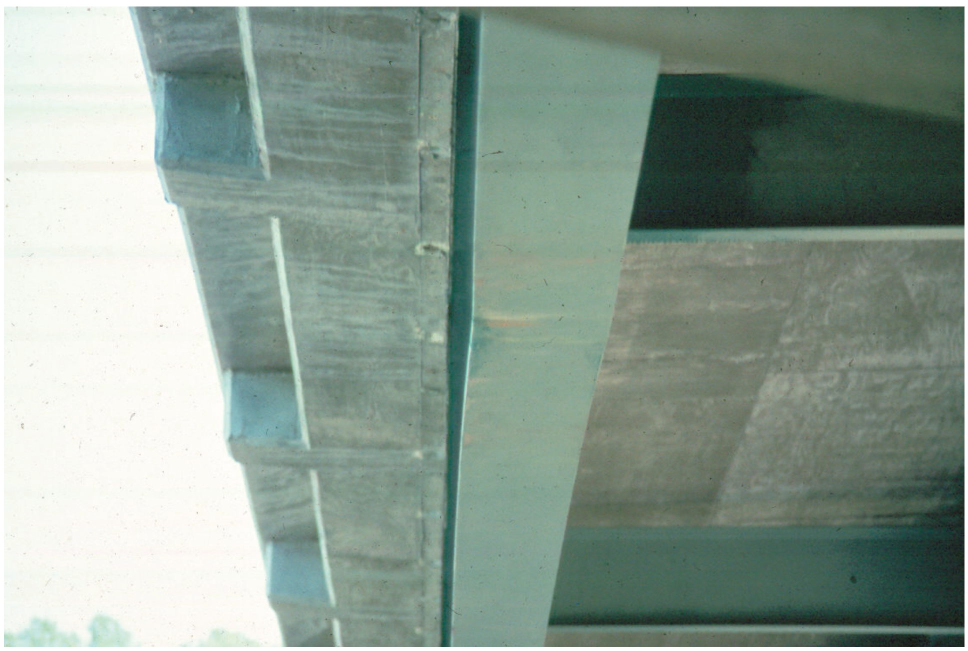

Figure 8.3.18 Collision Damage to a Two Girder Bridge

Figure 8.3.19 Collision Damage to a Through Girder Bridge

Fatigue Prone Details

Dirt and debris traps can result in active corrosion cells when water and salt are present. These corrosion cells can lead to excessive section loss. This corrosion can result in notches that are susceptible to fatigue or perforation.

Check web stiffener welds, welded web/flange splices, and intersecting welds (see Figures 8.3.20 and 8.3.21). Also inspect any attachment welds located in the tension zone of the girder and floorbeam bracket tie plate (see Figure 8.3.22), especially unplanned miscellaneous attachment welds, such as utility brackets.

If the structure has been painted, breaks in the paint accompanied by rust staining indicate the possible existence of a fatigue crack. Investigate the areas surrounding field splice cover plates on the tension flange. The suspected crack area should be cleaned to determine the existence of a crack and its extent. If a crack with rust staining exists in the paint, the fatigue cracks in the steel can already be up to 6 mm (1/4 inch) deep in the beam flange. Check any attachment welds located in the superstructure tension zones, such as traffic safety features, lighting brackets, utility attachments, catwalks and signs. Welds are considered to be intersecting if they are within 6 mm (1/4 inch) from each other (see Figure 8.3.21).

Figure 8.3.20 Web Stiffeners and Welded Flange Splice

Figure 8.3.21 Intersecting Welds

Check for fatigue cracks due to web-gap distortion. This is the major source of cracking in steel bridges.

If the girder or floorbeam is riveted or bolted, check all rivets and bolts to determine that they are tight and in good condition. Check for cracked or missing bolts, rivets and rivet heads. Check the base metal around the bolts and rivets for any signs of cracking.

Inspect the member for misplaced holes or repaired holes that have been filled with weld material. Check for plug welds which are possible sources of fatigue cracking.

Fracture Critical Members

Since two girder bridges have no load path redundancy and are fracture critical, it is important to inspect the main girders thoroughly. Floorbeams may also be fracture critical if they meet the requirements specified in Topic 8.3.2. Any defects such as cracks, section loss and out-of plane distortions should be measured and documented. All previous reports should be reviewed before performing the inspection to note any areas of particular concern. All reported deficiencies should be checked to ensure no further development has occurred.

Out-of-plane Distortion

Out-of-plane distortion can occur in several areas that can lead to web cracks near the flanges of steel bridges. The following are some common areas for out-of-plane distortion.

Girder Webs at Floorbeam Connections

Floorbeams between bridge girders exert out-of-plane forces to the girder webs through the vertical connection plates. The connection plates are usually sufficient to transmit the forces but the structural details at the ends of the connection plates sometimes are inadequate to accommodate the deflections and rotations.

Sometimes, floorbeam support brackets are welded to the tension flange of the girder (see Figure 8.3.22).

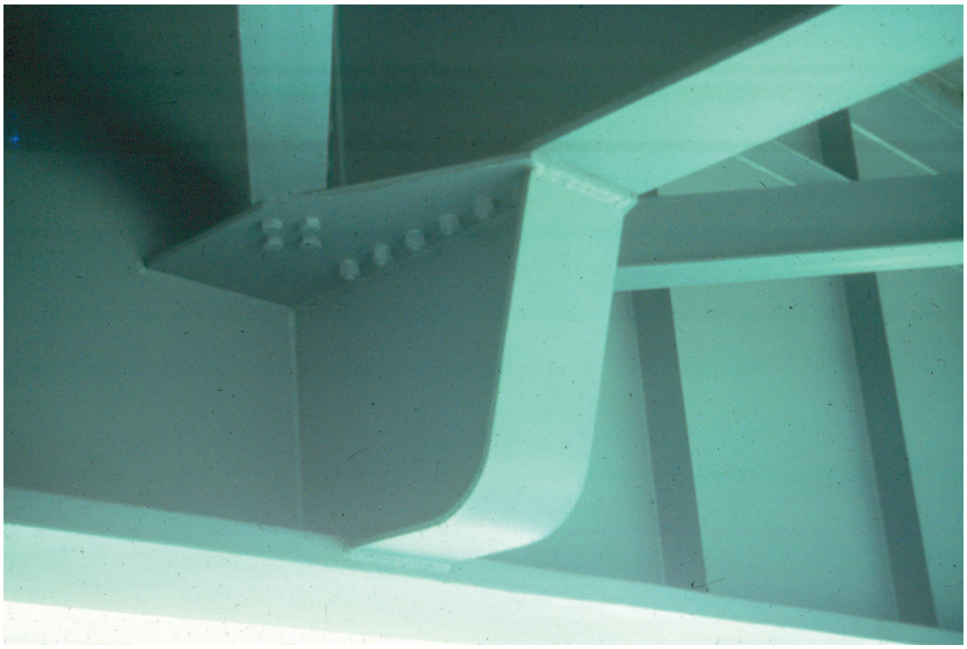

Figure 8.3.22 Floorbeam to Girder Connection

One type of connection detail that has incurred a large number of fatigue cracks is the end of floorbeam connection plates that are not attached to the top tension flange of continuous girder bridges. While the top flange is rigidly embedded in the bridge deck slab, and the connection plate itself is stiff enough to resist rotation and bending from the floorbeam, most of the out-of-plane distortions (perpendicular to the web) concentrate in the local region of the web above the upper end of the connection plate. Fatigue cracks develop in the region as a result of the web plate bending. The cracks are usually horizontal along the web-to-flange welds, and also propagate as an upside-down U along the upper ends of the fillet welds of the connection plate (see Figure 8.3.23). Movement at or near such small cracks often generates oxide powder that combines with moisture to cause apparent bleeding.

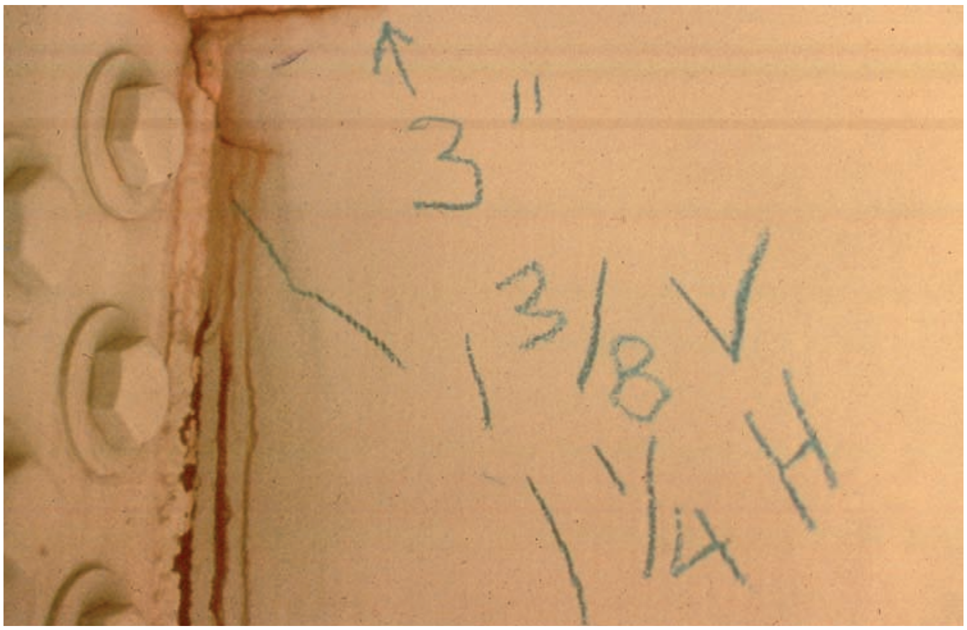

Figure 8.3.23 Crack Caused by Out-of-plane Distortion

Detection of cracks of fairly significant length is not difficult. Knowing that unattached ends of floor beam connection plates are likely locations of fatigue cracks increases the certainty of early detection of these cracks.

At the lower end of floorbeam connection plates that are not welded to the tension flange of girders, the condition of local out-of-plane distortion and bending of the web plate usually is less severe. This is because the tension flange is not restrained from lateral movement, which is sufficient to reduce the web plate bending. However, if the bottom flange is restrained from lateral deflection, fatigue cracks will develop along the web to flange weld.

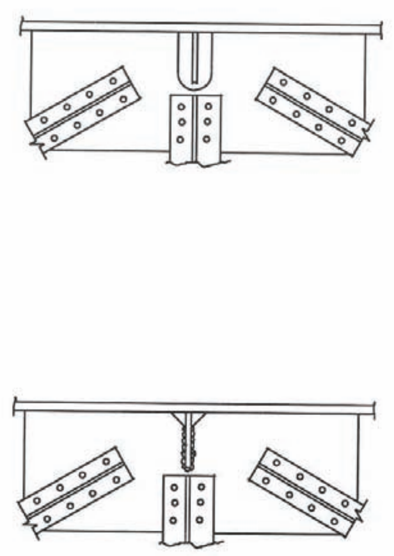

Figure 8.3.24 Lateral Bracing Gusset at Floorbeam or Diaphragm Connection Plate

Figure 8.3.25 Crack Caused by Out-of-plane Distortion

Lateral Gussets on Plate Girder Webs at Floorbeam Connection

The above figures show examples of potential for lateral gusset plate out-of-plane distortion problems. Vertical deflection of the lateral bracing causes stresses in the lateral bracing gusset plates. The welds connecting the lateral bracing gusset plate to the girder web may experience fatigue cracking. In addition to possible cracks at the internal gap, the ends of the gusset fillet weld should be equally suspect.

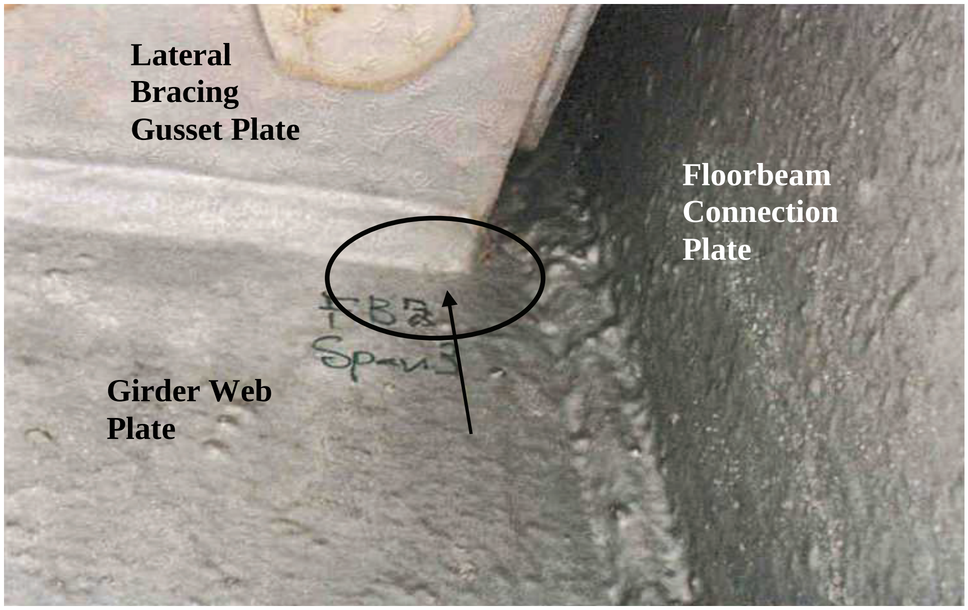

Figure 8.3.26 Crack Caused by Out-of-plane Distortion

Figure 8.3.26 shows another example of a crack in the gap between the lateral bracing gusset and the floorbeam connection plate. The crack was very small when detected and the photograph was taken. However, on the opposite side of the web plate, at the elevation of the gusset, a crack more than an inch long was detected along the weld toe of the vertical fillet weld that joins the web and the fascia transverse stiffener in alignment with the floorbeam. This situation of staggered cracks on opposite surfaces of a web plate in a small gap is typical of out-of-plane distortion induced cracks at lateral gusset to floorbeam connection details.

Fatigue cracks may also develop at the weld toe on the web surface at the far ends of a horizontal gusset attached to the web for lateral bracing members (the ends away from the floorbeam connection plate). With the out-of-plane distortion and twisting of the junction, the web is subjected to plate bending stresses that add to the primary stresses in the girder web (see Figure 8.3.27).

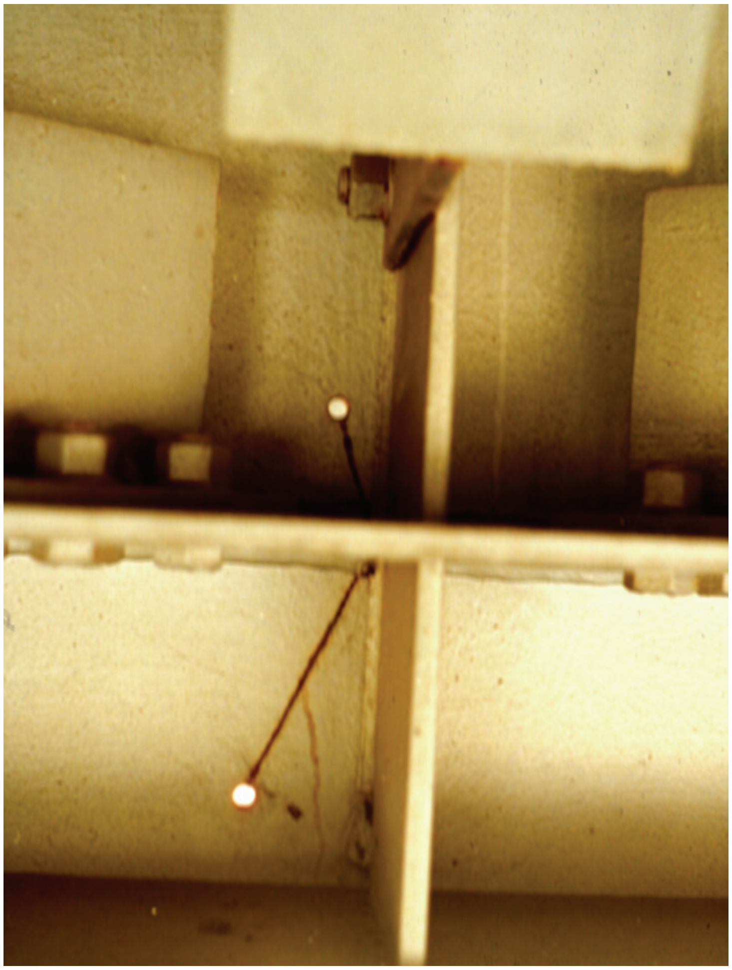

Figure 8.3.27 Cracking in Girder Web at the Intersection of Horizontal Gusset Plate for Lateral Bracing and Transverse Stiffener

Floorbeam and Cantilever Bracket Connection to Girders

In order to increase deck width, floorbeams are often cantilevered past the main longitudinal girders. The floorbeams may be stacked on top of the girders or framed into the girders.

The floorbeam may be connected to the girder web (see Figure 8.3.28). Inspect for cracks in the floorbeam and girder. A tie plate may be utilized to reduce the fatigue stresses in the floorbeam/girder connection (see Figure 8.3.29). Carefully inspect the tie plate for fatigue cracking.

Figure 8.3.28 Cracked Cantilever Floorbeam

In bridges with deep girders and floorbeams, such cracks have also been detected in small gaps at boundaries of floorbeam access holes at catwalks and at ends of stiffeners on web plate which stiffen the web plate and concentrate the out-of-plane distortion in the small gaps.

Figure 8.3.29 Tie Plate for Cantilever Floorbeam

8.3.5 Evaluation

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

NBI Rating Guidelines

Using the NBI rating guidelines, a 1-digit code on the Federal Structure Inventory and Appraisal (SI&A) sheet indicates the condition of the superstructure. Rating codes range from 9 to 0 where 9 is the best rating possible. See Topic 4.2 (Item 59) for additional details about NBI Rating Guidelines.

The previous inspection data should be used along with current inspection findings to determine the correct rating.

Element Level Condition State Assessment

In an element level condition state assessment of a steel two girder system, the AASHTO CoRe element is:

Element No.	Description
106	Unpainted Steel Girder/beam
107	Painted Steel Girder/beam
112	Unpainted Steel Stringer
113	Painted Steel Stringer
151	Unpainted Steel Floorbeam
152	Painted Steel Floorbeam
160	Unpainted Steel Pin and/or Pin & Hanger Assembly
161	Painted Steel Pin and/or Pin & Hanger Assembly

The unit quantity for the girder is meters or feet, and the total length must be distributed among the four available condition states for unpainted and five available condition states for painted structures depending on the extent and severity of deterioration. In both cases, Condition state 1 is the best possible rating. See the *AASHTO Guide for Commonly Recognized (CoRe) Structural Elements* for condition state descriptions. For pin and hanger assemblies, see Topic 8.4.

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

For damage to fatigue, the “Steel Fatigue” Smart Flag, Element No. 356, can be used and one of the three condition states assigned. For rust, the “Pack Rust” Smart Flag, Element No. 357, can be used and one of the four condition states assigned. For damage due to traffic impact, the “Traffic Impact” Smart Flag, Element No. 362, can be used and one of the three condition states assigned. For girders with section loss, the “Section Loss” Smart Flag, Element No. 363, can be used and one of the four condition states assigned.