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Chapter 8
Inspection and Evaluation of Common Steel Superstructures

Topic 8.5 Steel Box Girders

8.5.1 Introduction

A box girder bridge is supported by one or more welded steel box girders. The rectangular or trapezoidal cross section of the box girder consists of two or more web plates connected to a single bottom flange plate.

Box girder bridges are used in simple spans of 75 feet or more (see Figure 8.5.1) and in continuous spans of 100 feet or more. They are frequently used for curved bridges due to their high degree of torsional rigidity (see Figure 8.5.2).

Figure 8.5.1 Simple Span Box Girder Bridge

Figure 8.5.2 Curved Box Girder Bridge

8.5.2 Design Characteristics

Configuration

A box girder bridge can use a single box configuration (see Figure 8.5.3) or have multiple (spread) boxes in its cross section (see Figure 8.5.4). Several factors such as deck width, span length, terrain and even aesthetics can all play a role in determining which configuration will be used.

Figure 8.5.3 Box Girders With Cantilevered Supports for Deck

Figure 8.5.4 Spread Box Girders

Primary and Secondary Members

The primary members of a box girder bridge are the box girders (including all internal bracing) and, on a curved bridge, the diaphragms. On a straight bridge, the diaphragms are secondary members. Diaphragms can be solid plates, rolled shapes (e.g., I-beams and channels), or cross frames constructed with angles, tee shapes, and plates (see Figure 8.5.5). Diaphragms may be on the interior or exterior of the box.

Figure 8.5.5 Diaphragms – K Bracing and Plate

Function of an Internal Stiffener

The webs and bottom flange of large box shapes must be stiffened in areas of compressive stress. This is accomplished in part by stiffeners located inside the box member. The stiffeners are designed to help the box girder resist buckling due to torsional and shear forces. The stiffeners limit the unsupported length of the web and bottom flange, which result in increased stability of the box girder. Box girders may also incorporate both diaphragm and top flange lateral bracing systems. External diaphragms may be used between box girders (see Figure 8.5.6). Box girders typically have an opening or access door to allow the bridge inspector to examine the inside of the box (see Figure 8.5.7).

Figure 8.5.6 External Diaphragm

Figure 8.5.7 Box Girder Access Door

Fatigue Prone Details

Some common areas for fatigue prone details are:

- Welded attachments inside the box

- Attachment welds in the tension zone
- Butt welds in adjacent longitudinal stiffeners
- Intersecting welds between webs and flanges
- Field Splices
- Fatigue Cracks can also occur due to web-gap distortion and out-of-plane distortion

Inspection of these areas will be discussed in further detail later in this section.

Fracture Critical Areas

Box girder bridges may be fracture critical depending on the number of box girders in the span. If the span has two or less box girders, then the structure is nonredundant and the box girders are fracture critical members.

Deck Interaction

The top flange may consist of individual plates welded to the top of each web plate. If the top flange plates incorporate shear connectors, the superstructure is composite with the concrete deck. A composite deck is one in which the deck and the superstructure work together to carry the live load (see Figure 8.5.8). Alternatively, the top flange may consist of a single plate extending the width of the box. This configuration is classified as an orthotropic steel plate deck (see Figure 8.5.9). A wearing surface is then placed on the top flange as the riding surface.

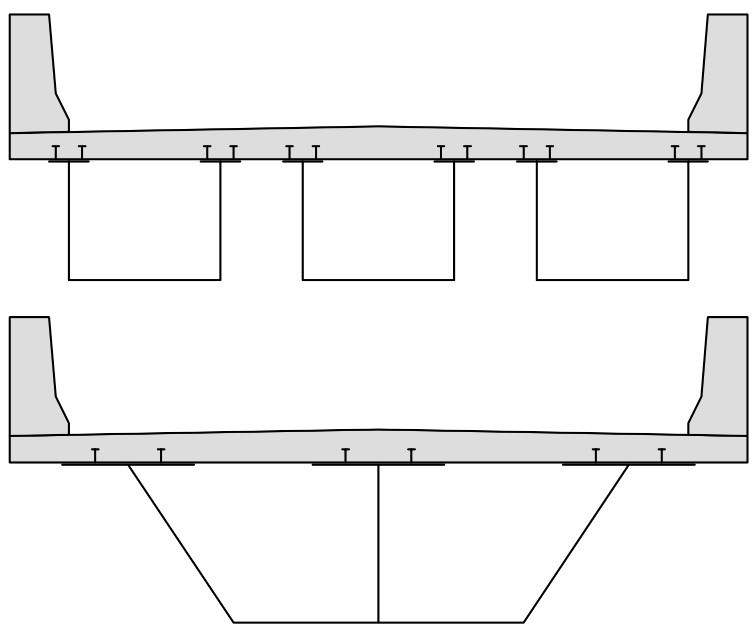

Figure 8.5.8 Box Girder Cross Section with Composite Deck

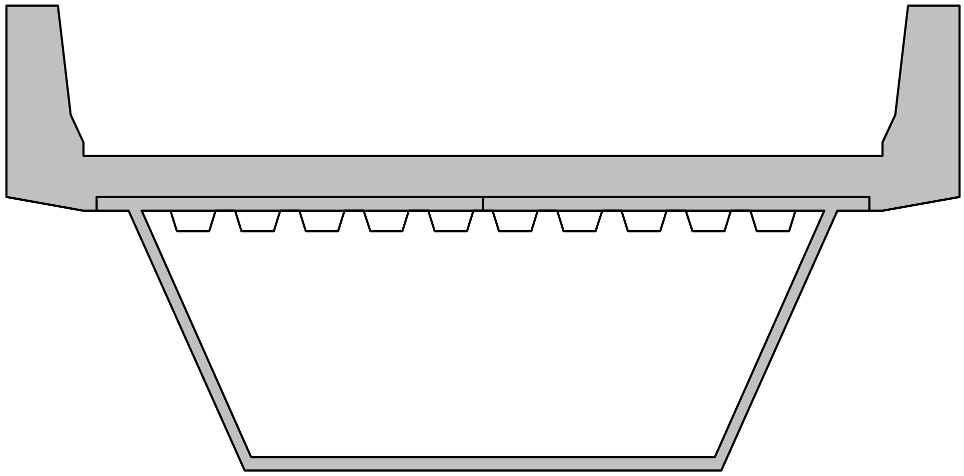

Figure 8.5.9 Box Girder Cross Section with Orthotropic Steel Plate Deck

8.5.3 Overview of Common Defects

Common defects that occur on steel box girder bridges are:

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

See to 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.

8.5.4 Inspection Procedures and Locations

Box girders must be inspected on both the interior and the exterior. When examining the interior, the inspector should proceed with caution. Major concerns involved with inspecting a confined space include lack of sufficient oxygen, the presence of toxic or explosive gases, unusual temperatures and poor ventilation. Also, the distance between access hatches frequently exceeds the limit that rescue crews can reach in the event of an emergency (refer to Topic 3.2 for a more detailed description of these safety concerns).

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 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 and location of the suspected defect. 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 programs
- Computer tomography
- Corrosion sensors
- Smart paint 1
- Smart paint 2
- Dye penetrant
- Magnetic particle
- Radiographic testing
- Robotic inspection
- Ultrasonic testing
- Eddy current

Other methods, described in Topic 13.3.3, include:

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

Locations

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 near substructure supports for cracks, section loss and buckling (see Figure 8.5.10). Be sure to include intermediate supports provided by piers (see Figure 8.5.11).

Figure 8.5.10 Box Girder Shear Zone

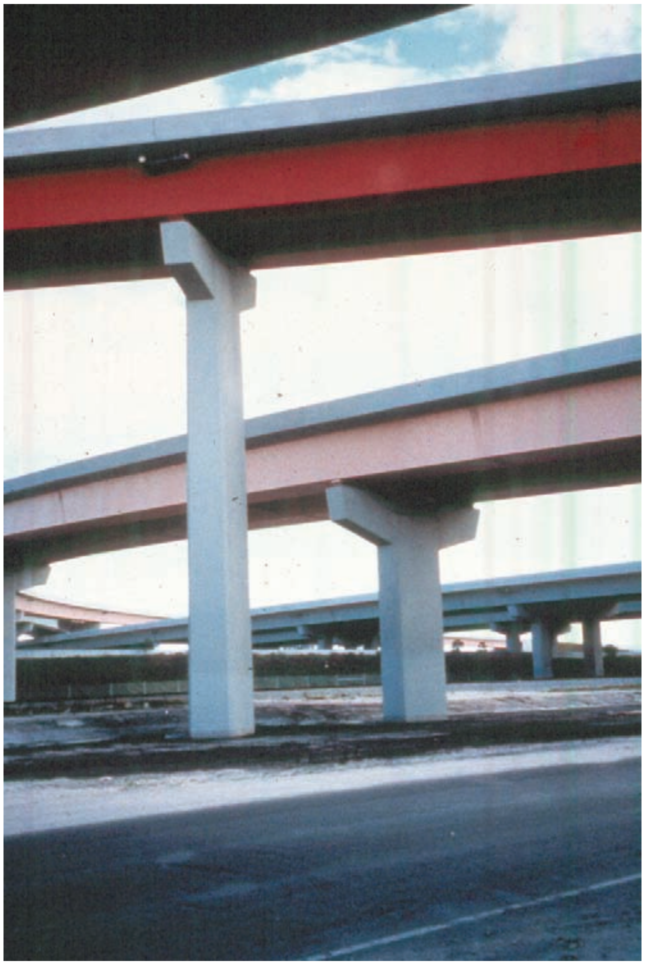

Figure 8.5.11 Continuous Box Girders

Flexure Zones

The flexure zone of each box girder includes the entire length between the supports (see Figure 8.5.11). 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 box girders over the intermediate supports have high flexural stresses due to negative moment. If welded cover plates are present, check carefully at the ends of the cover plates for cracks.

Secondary Members

Examine the diaphragm and bracing connections for loose fasteners or cracked welds. This problem is most common on skewed bridges, and it has also been observed on bridges with a high frequency of combination truck loads. Check horizontal connection plates, which can trap debris and moisture and are susceptible to a high degree of corrosion and deterioration. Check for distorted members. Distorted secondary members may be an indication the primary members may be overstressed or the substructure may be experiencing differential settlement.

Areas That Trap Water and Debris

The areas that trap water and debris result in active corrosion cells and excessive loss in section. Check horizontal connection plates that can trap debris and moisture and are susceptible to a high degree of corrosion and deterioration. Areas such as diaphragm to bottom flange connections can trap water, while external lateral bracing connection plates collect bird droppings and roadway debris. On box girder bridges, check the integrity of the drainage system. No water should be gaining access to the interior of the box(es).

Some steel box girders are designed or retrofitted with small drainage holes. If present, the drainage holes should be inspected for blockage and corrosion.

Areas Exposed to Traffic

For box girders over a highgway, railway or navigable channel, check the box girder for signs of collision damage. Document any loss of section, cracking, scrape marks or distortion.

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 all welds and welded attachments inside the box. This includes web stiffeners, flange stiffeners, diaphragms, lateral bracing, and stay-in-place deck panels. Stiffener weld terminations in tension zones are a special concern. Butt welds joining adjacent longitudinal stiffeners on the bottom flange serve as potential sources for cracks to propagate into the bottom flange. Check all intersecting welds between the webs and flanges, particularly in tension areas. Welds are considered to be intersecting if they are within 6 mm (1/4 inch) from each other. Check field splice areas, especially where stiffeners are welded to the web or bottom flange (see Figure 8.5.12).

Figure 8.5.12 Field Splice

Check back-up bars. These bars are sometimes used inside a box girder to help fabricate the corner welds between the web and the flange. A significant potential exists for cracking if these bars are discontinuous or are connected to the web or flange by tack welds or intermittent fillet welds. If such conditions exist, it should be brought to the attention of the bridge engineer.

Back-up bars were often spliced with non-NDT-inspected butt welds. These welds may be flawed and deserve special care in inspection if present in tension areas (see Figure 8.5.13).

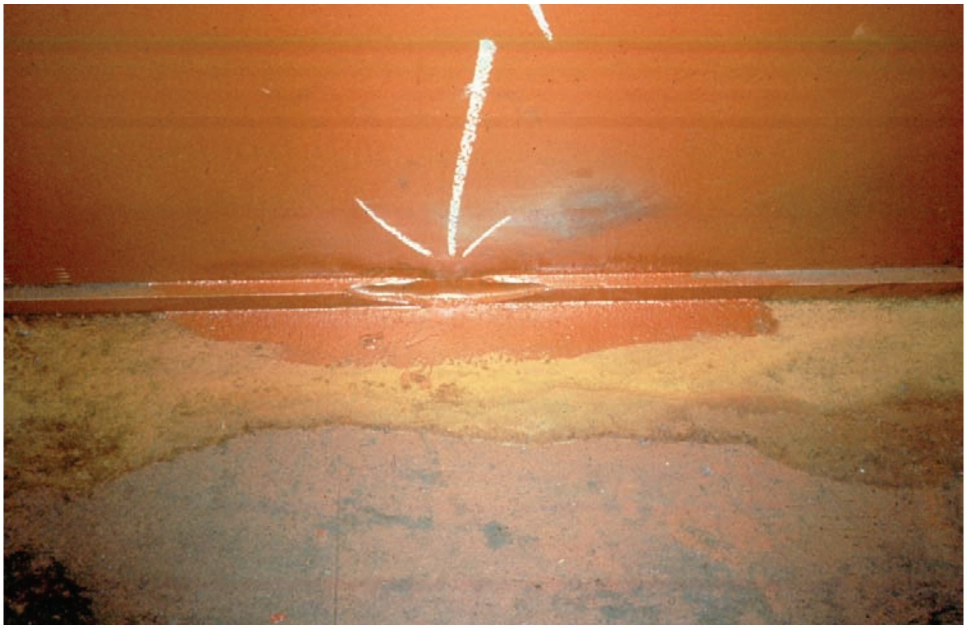

Figure 8.5.13 Butt Welds in Back-up Bars Ground Out as Retrofit

Fracture Critical Members

The redundant nature of a box girder bridge depends primarily on the number of box girders in the span. If two or less box girders are used, the structure is considered nonredundant and the box girders are fracture critical members (see Figure 8.5.14). All previous inspection 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.

If three or more box girders are used, the structure is generally considered redundant (see Figure 8.5.15). However, if the spacing of the box girders is large, the structure may not be redundant.

Figure 8.5.14 Non-redundant Box Girder Bridge

Figure 8.5.15 Redundant Box Girder Bridge

Out-of-Plane Distortions

Box girder members with diaphragm connection plates are susceptible to similar out-of-plane distortions and fatigue cracking experienced in steel two girder systems (see Topic 8.3).

Out-of-plane distortion and fatigue cracking has developed in box girders of rectangular or trapezoidal cross section with k-frame, or plate diaphragms. Curved boxes and box girders which are subjected to high torsional loads are more likely to develop this type of crack at diaphragm connection plates. Frequent inspection should be made if truck traffic volume is high.

The web gap detail between the web and the transverse stiffeners is another area that is prone to cracking (see Figure 8.5.16). Similar to a girder and floorbeam connection, the top flange is restrained from lateral movement and cracks may develop in the region as a result of web plate bending.

Figure 8.5.16 Box Girder Internal Diaphragm Not Attached to Flange

8.5.5 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 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 box girder bridge, the AASHTO CoRe element is:

Element No.	Description
101	Unpainted Closed Web / Box Girder
102	Painted Closed Web / Box Girder

The unit quantity for the steel box 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.

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 box girders with section loss, the “Section Loss” Smart Flag, Element No. 363, can be used and one of the four condition states assigned.