Table of Contents

Section 8

Inspection and Evaluation of Common Steel Superstructures

Topic 8.4 Pin and Hanger Assemblies

8.4.1 Introduction

Pin and hanger assemblies are devices put in bridges to permit expansion movement and rotation (see Figure 8.4.1). If only rotation of the joint is desired, one pin is used (see Figure 8.4.2). When expansion (longitudinal) movement is also required, a system consisting of two pins with hanger links between them is used.

Figure 8.4.1 Typical Pin and Hanger Assembly

Pin and hanger joints are usually found in multi-span bridges designed prior to 1970. Incorporating a hinge in a structure simplifies analysis. It also moves expansion joints (and drainage related damage) away from the abutments and piers (see Figure 8.4.3).

Modern design techniques and computer programs enable the engineer to design multi-span bridges without hinges. The problems associated with pin and hanger details far outweigh any advantages of placing expansion joints away from substructure units.

Although pin and hanger designs are no longer used, many bridges with these assemblies are still in service and will remain for the foreseeable future. Therefore, it is very important to pay special attention to these details during inspection.

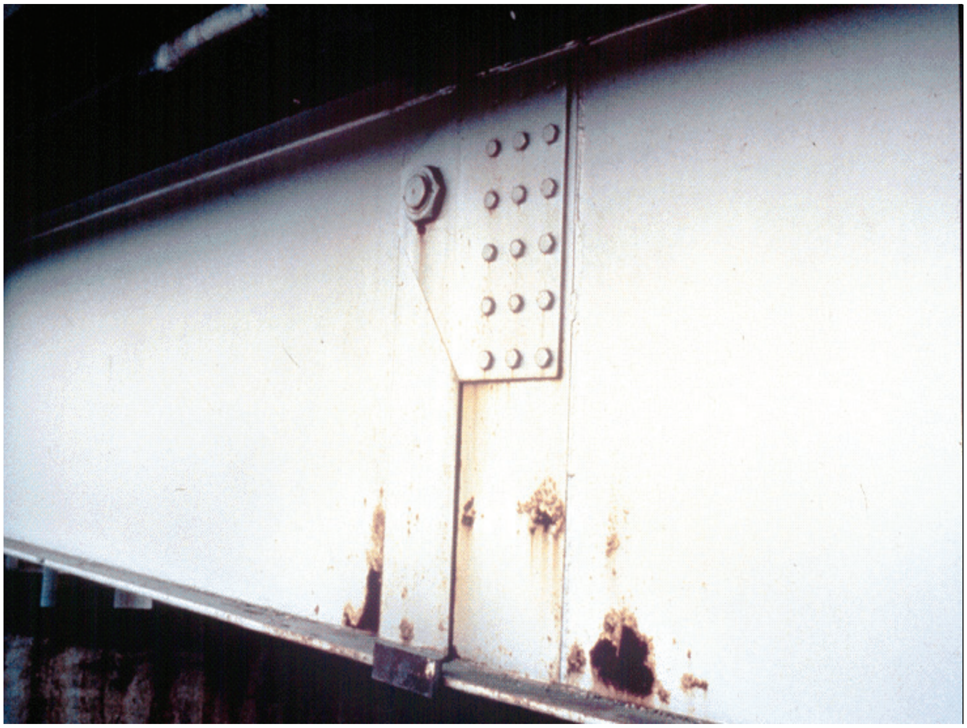

Figure 8.4.2 Single Pin with Riveted Pin Plate

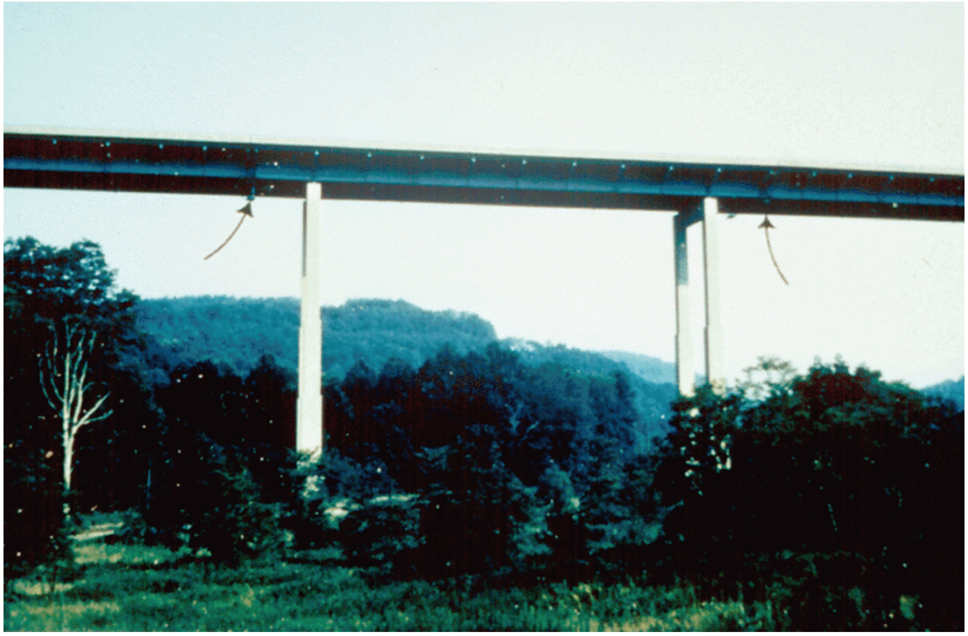

Figure 8.4.3 Pin and Hanger Assembly Locations Relative to Piers

8.4.2 Design Characteristics

Primary and Secondary Members

There are many different components to a pin and hanger assembly as Figure 8.4.4 demonstrates.

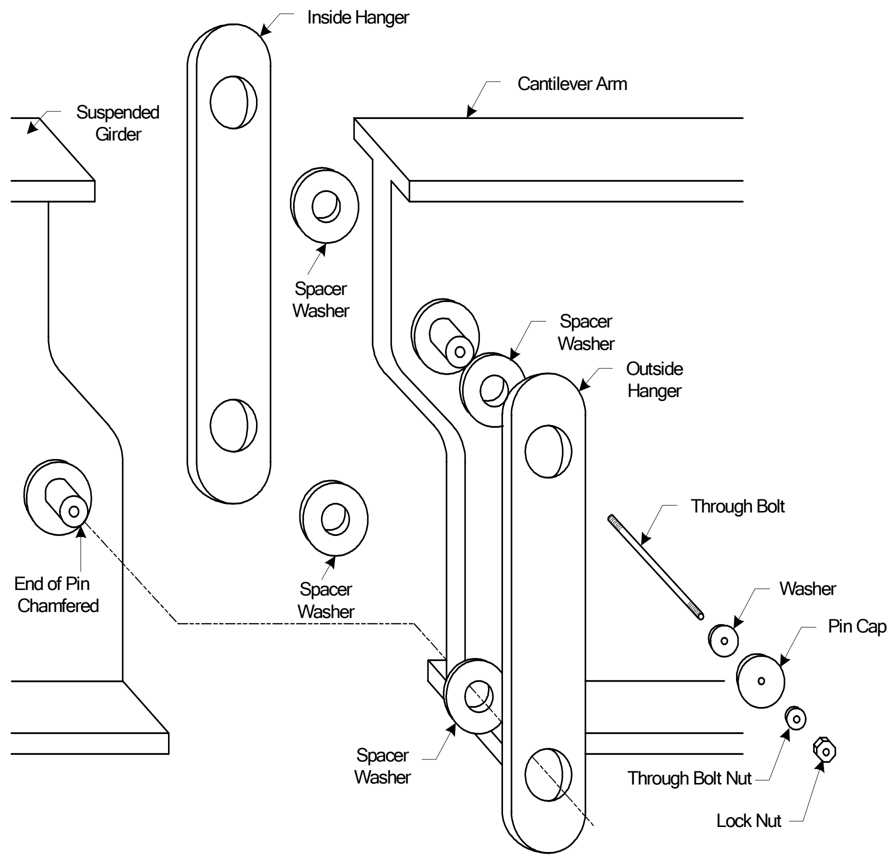

Figure 8.4.4 Pin and Hanger Assembly

The primary members of a pin and hanger assembly are the pin and the hanger link. The pin may be drilled to accept a through-bolt (see Figure 8.4.5) or threaded to accept a large nut (see Figure 8.4.6). Threaded pins are often stepped (or shouldered) to accept a small diameter nut. The hanger link may be a plain flat plate with two holes or an eyebar shaped plate (see Figure 8.4.7).

The secondary members of a pin and hanger assembly include through-bolts and the pin cap (see Figure 8.4.8), nuts (see Figure 8.4.9), cotter pins on small assemblies with pins less than 100 mm (4 inches) in diameter, spacer washers and doubler plates which reinforce the beam web around the pin hole (see Figure 8.4.10).

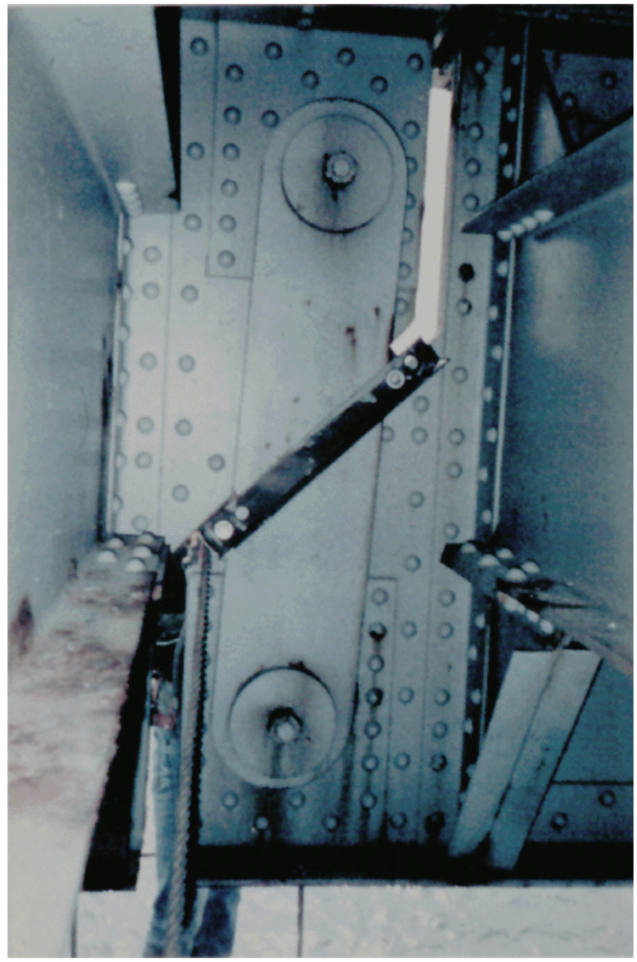

Figure 8.4.5 Pin Cap with Through Bolt

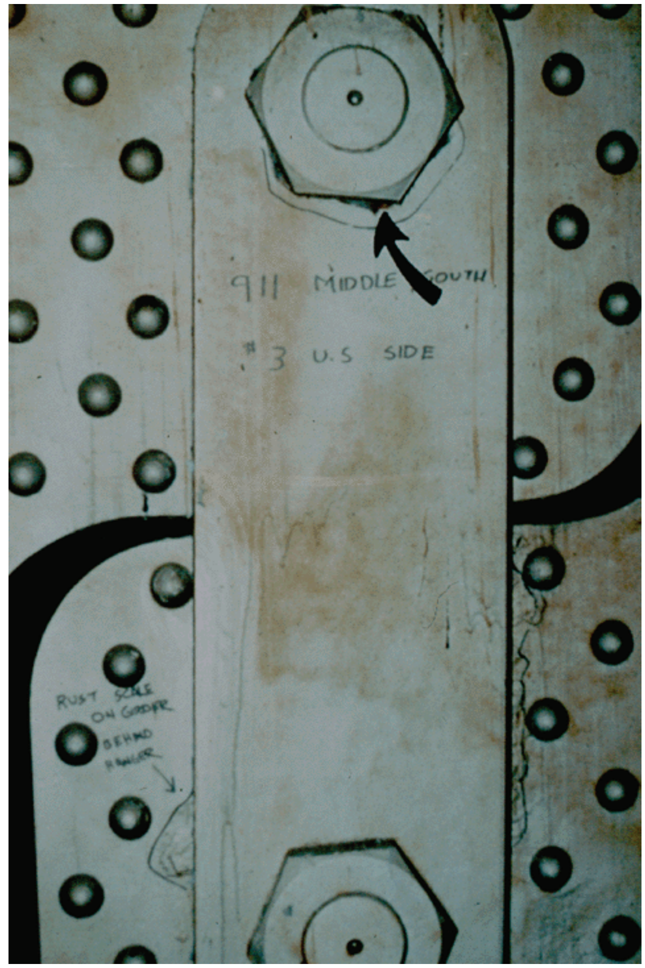

Figure 8.4.6 Threaded Pin with Retaining Nut

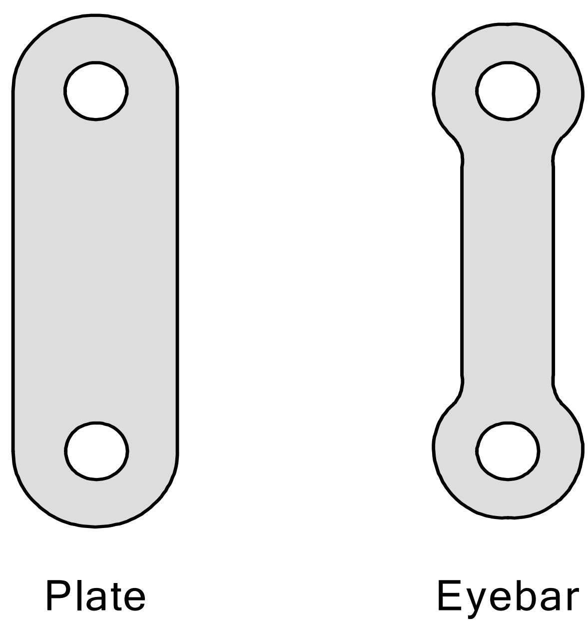

Figure 8.4.7 Plate Hanger and Eyebar Shape Hanger Link

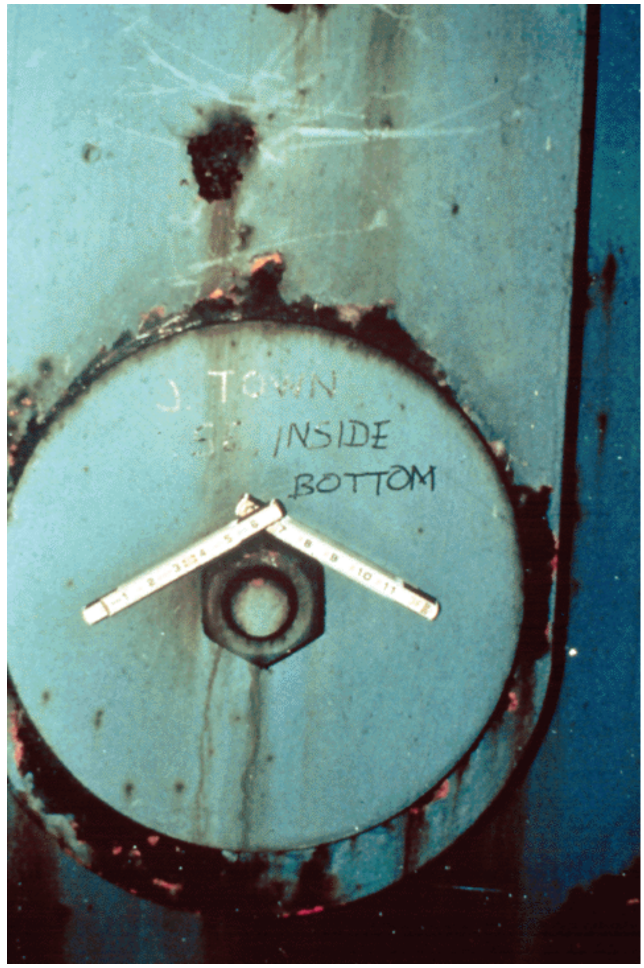

Figure 8.4.8 Pin Cap, Through Bolt and Nut

Figure 8.4.9 Retaining Nut

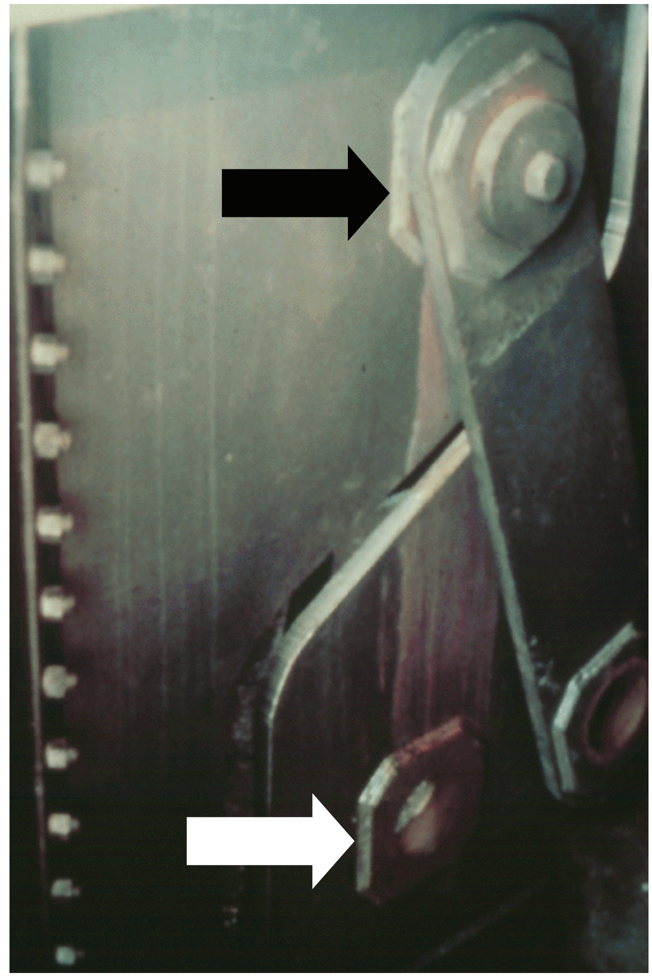

Figure 8.4.10 Web Doubler Plates

Forces in a Pin – Design vs. Actual

Some of the problems with the pin and hanger assembly can be attributed to deficiencies that cause forces that were not accounted for in the design. The hanger or links are designed for pure tension forces only (see Figure 8.4.11). However, in actuality, hangers see both pure tension and bending. In-plane bending results from binding on the pins due to corrosion between the pin and the hanger (see Figure 8.4.12). Out-of-plane bending (perpendicular to the wide face) results from misalignment, pack rust or skewed geometry.

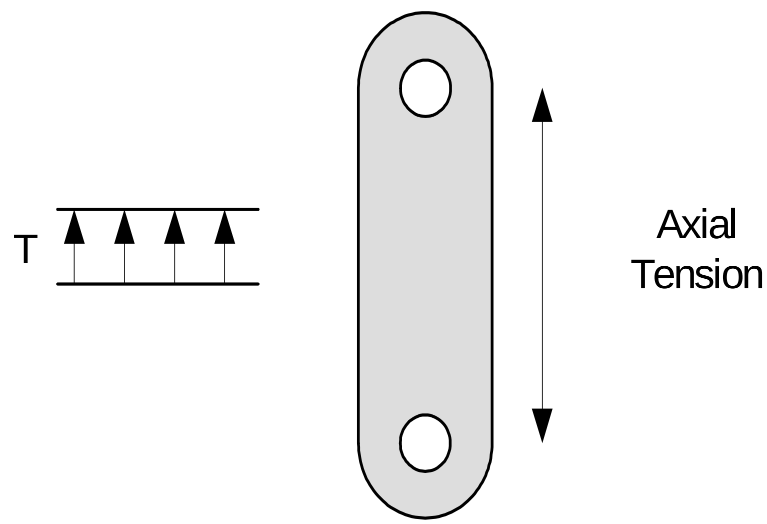

Figure 8.4.11 Design Stress in a Hanger Link(Tension Only)

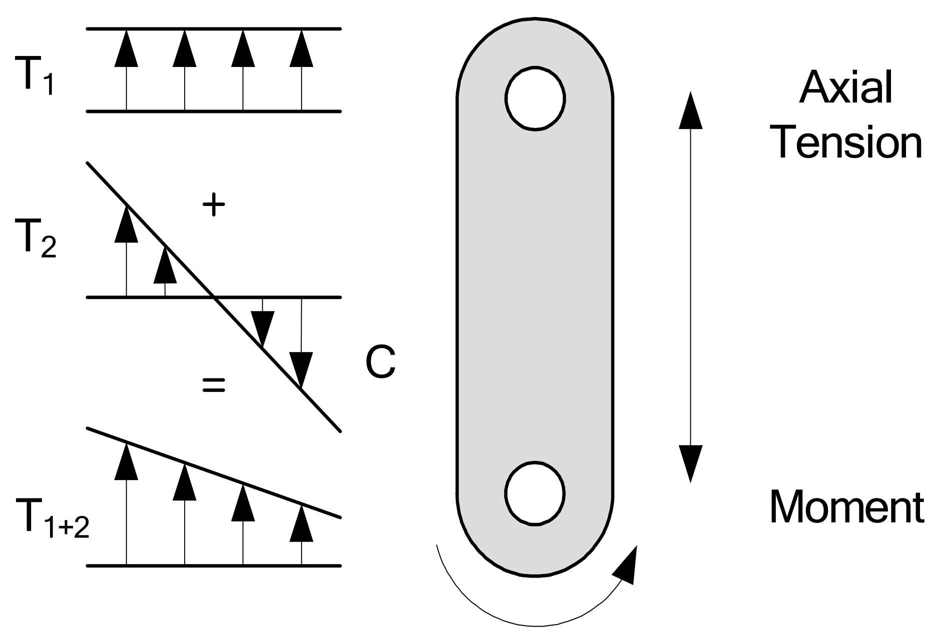

Figure 8.4.12 Actual Stress in a Hanger Link (Tension and Bending)

Pins are designed to resist shear and bearing on the full thickness of the hanger (see Figure 8.4.13). However, in addition to the designed forces, pins can see very high torsion (twisting) forces if they lose their ability to turn freely (see Figure 8.4.14). Corrosion and rust packing can inhibit or prevent the pins from turning properly. Pins can also be subjected to excessive bearing stress if the hanger shifts over the pin shoulder (see Figure 8.4.14).

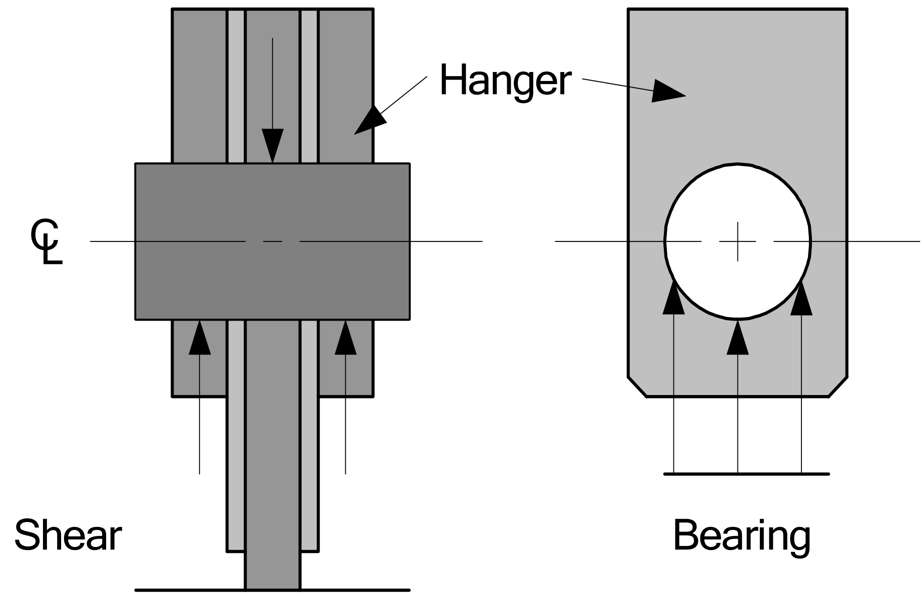

Figure 8.4.13 Design Stress in a Pin (Shear and Bearing)

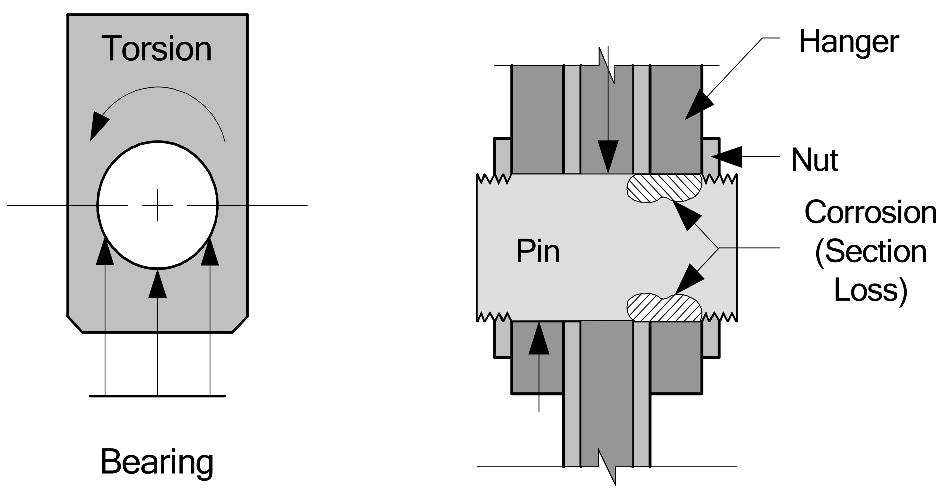

Figure 8.4.14 Actual Stress in a Pin (Shear, Bearing and Torsion)

Fracture Critical Pin and Hanger Assemblies

AASHTO "Manual for Condition Evaluation of Bridges", Section 3.12 calls for special attention during the inspection of pin and hanger connections on two or three girder systems. Failure of one pin or one hanger will cause collapse of the suspended span since there is no alternate load path. The collapse can be catastrophic as demonstrated by the Mianus River Bridge failure shown in Figure 8.4.15. The Mianus River Bridge failed due to the formation of rust between the hangers and the girder webs. As steel rusts, the rust can occupy up to 10 times the original steel volume causing unwanted expansion forces when in a confined space. When rust creates this type of expansion force, it is called "rust packing". In the case of the Mianus River Bridge, the rust packing pushed the hangers to the ends of the deteriorated pins and the pins eventually failed in bearing.

Figure 8.4.15 Mianus River Bridge Failure

Pin and hanger assemblies in multi-girder structures are not technically fracture critical, since multiple load paths are available. However, they do have the potential for progressive collapse. If all the pin and hanger assemblies at a joint location are frozen and consequently overstressed, the failure of one could cause an adjacent assembly to fail and so on (see Figure 8.4.16).

Figure 8.4.16 Multi-girder Bridge with Pin and Hanger Assemblies

8.4.3 Overview of Common Defects

Common defects that occur on steel pin and hanger bridge assemblies 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

8.4.4 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 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

Visual inspection of the pin may not be very effective. The majority of the pin is concealed inside the assembly and at best only the surface is available for inspection. Many internal flaws and defects can go undetected if an advanced inspection technique such as ultrasonic testing is not used.

Ultrasonic testing is currently the most common means available of checking pins in place (see Figure 8.4.17). For the results to be valid, careful planning and testing by trained individuals is required. For a more detailed look at ultrasonic testing refer to Topic 13.3.

Figure 8.4.17 Ultrasonic Testing of a Pin

Another method for inspecting the pin is to disassemble the pin and hanger unit. Disassembly of a pin and hanger joint should be undertaken only after proper engineering design is performed and auxiliary support supplied. It is not a routine bridge inspection procedure (see Figure 8.4.18).

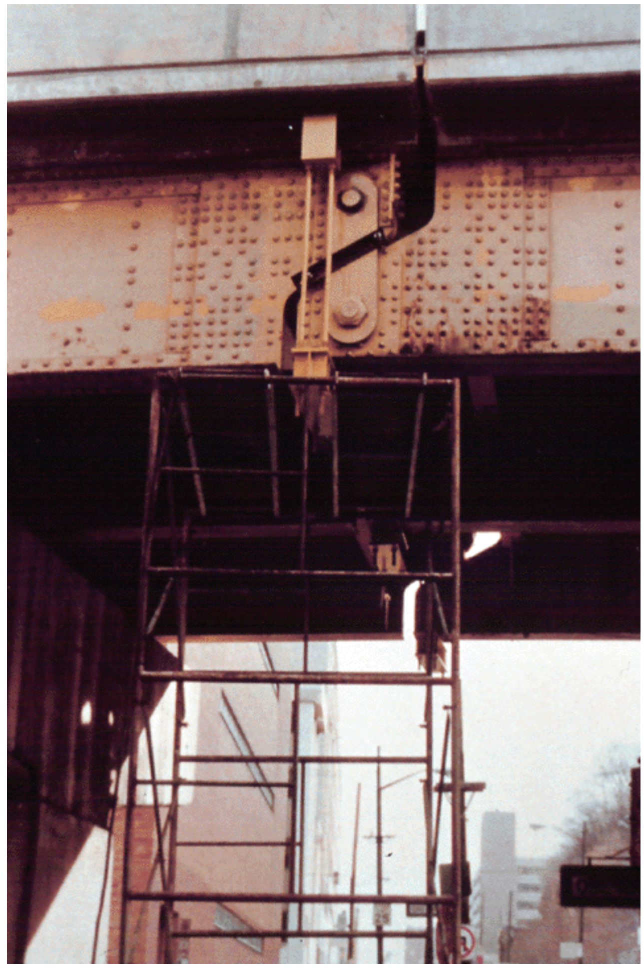

Figure 8.4.18 Alternate Hanger Link Retaining System

Hanger links and pins are often difficult to remove even after the retaining assemblies are taken off. This is not always true, however, and a pin on the verge of failure due to rust pack could fail suddenly when the nut is loosened.

Locations

General

Observe and record the general condition of the pin and hanger assembly. Check for alignment of the adjacent beam webs and flanges with a straight edge. If present, inspect the wind lock for signs of excessive transverse movement. A wind lock consists of steel or neoprene members attached to both the suspended and cantilever bottom flanges. Note if deck drainage is entering the assembly.

Measure the actual dimensions between the pins and also the distance from each pin to the end of the hanger assembly and compare these values to the as-built dimensions (see Figure 8.4.19).

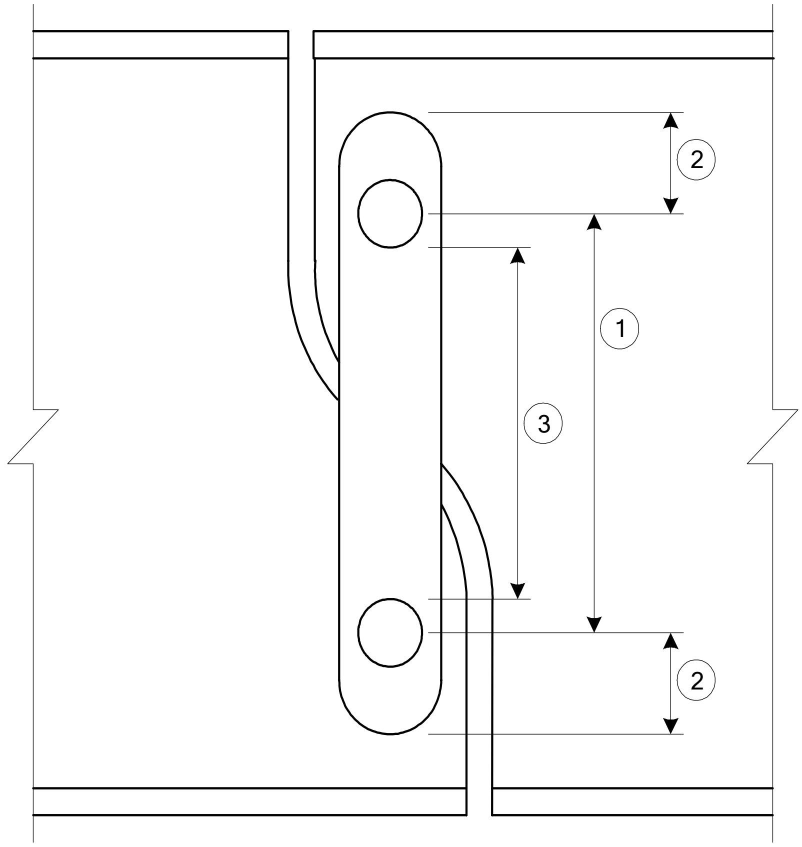

Figure 8.4.19 Pin Measurement Locations

Try to determine if movement is taking place. Corrosion can cause fixity at pin and hanger connections. This changes the structural behavior of the connection and is a source of cracking. Powdery red or black rust where surfaces rub indicates movement (see Figure 8.4.20). It may or may not indicate appreciable section loss. An unbroken paint film across a surface where relative movement should be taking place indicates the pin is frozen.

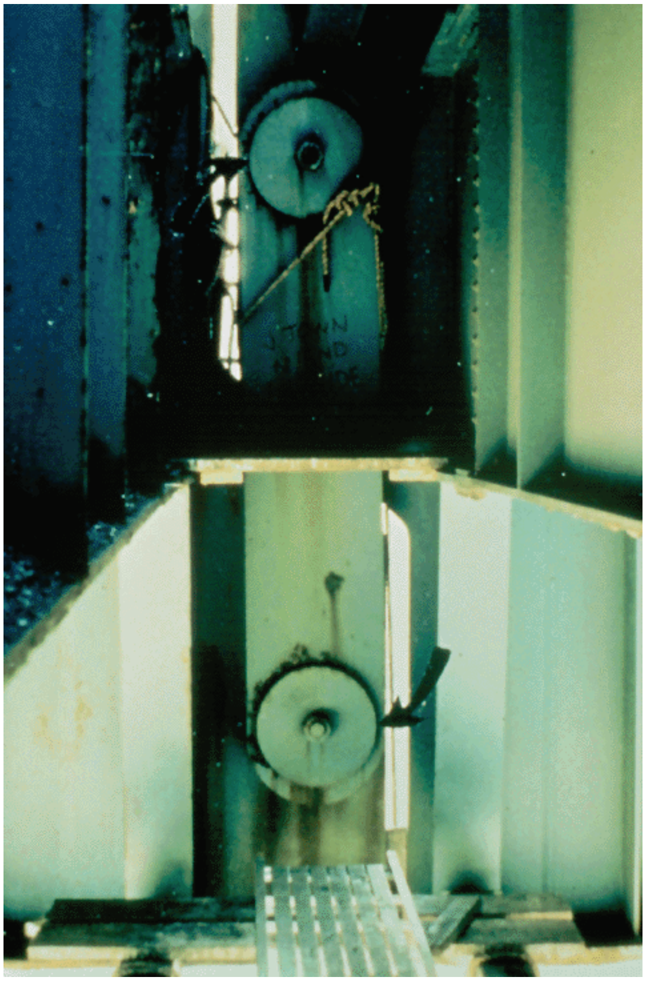

Figure 8.4.20 Rust Stains from Pin Corrosion

Some movement due to traffic vibration may be observable. If this movement is excessive, or if there is significant vertical movement with live load passage, the pins or pin holes may be excessively worn.

The expansion dam, beam ends, and any other structural components in the hinge area should be studied to see if any unusual displacements have taken place.

Hangers

Due to the rotation of the pins and hangers under live load and thermal expansion, they tend to incur wear over a period of time. Since portions of the assembly are inaccessible, they are not normally painted by maintenance crews and will, with time, begin corroding. This type of connection may be exposed to the elements and the spray of passing traffic. It may also be directly underneath an expansion dam where water and brine solutions may collect. This moist, corrosion-causing solution will slowly dry out, only to be reactivated during the next wet cycle.

Hangers are easier to inspect than pins since they are exposed and readily accessible. Try to determine whether the hanger-pin connection is frozen, as this can induce large moments in the hanger plates.

Examine accessible surface and edges closely for cracks (see Figure 8.4.21). The most critical areas are the ends beyond the pin centerlines and the juncture between the heads and shanks of eyebars. Note surface condition and section loss.

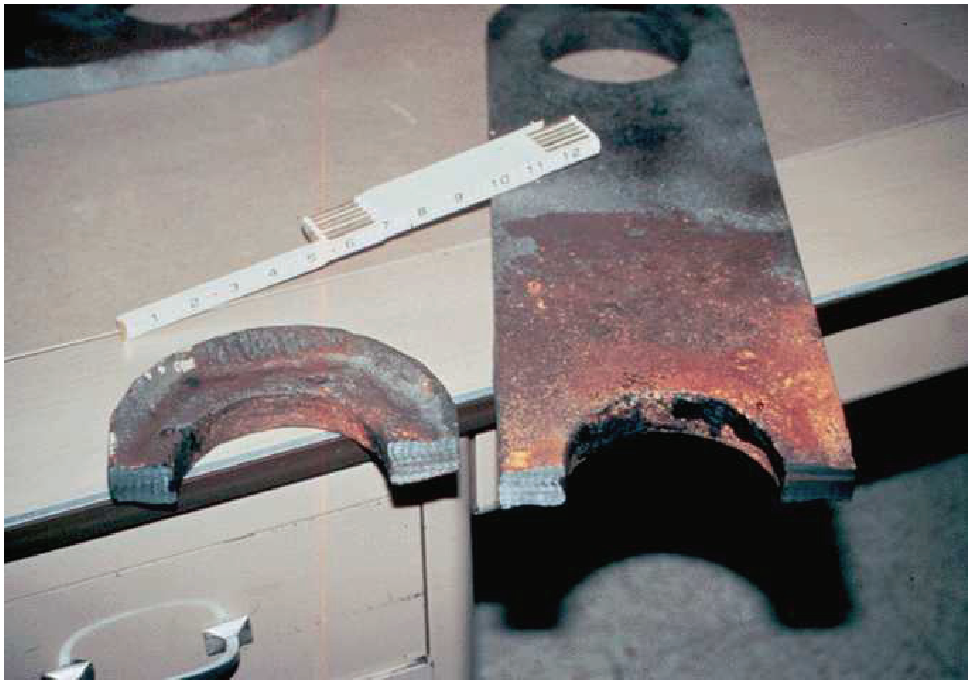

Figure 8.4.21 Corroded Hanger Plate

Assess the condition of the back side of the link by use of light and inspection mirror, if possible. Note the presence of corrosion. It may be helpful to probe with a wire or slender steel ruler.

Examine both sides of the plate for cracks due to bending of the plate from a frozen pin connection. Observe the amount of corrosion buildup between the webs of the girders and the back faces of the plates. Inspect the hanger plate for bowing or out-of-plane distortion from the webs of the girders (see Figure 8.4.22). Any welds should be investigated for cracks. If the plate is bowed, check carefully at the point of maximum bow for cracks that might be indicated by a broken paint film and corrosion.

Measure the distance between the back of the hanger and the face of the web at several locations. Compare these measurements from location to location and hanger to hanger. Variations greater than 3 mm (1/8 inch) could indicate twisting of the hanger bars or lateral movement due to rust packing. These measurements should be carefully described and recorded in permanent notes for comparison with as-built drawings and/or measurements taken at the next inspection.

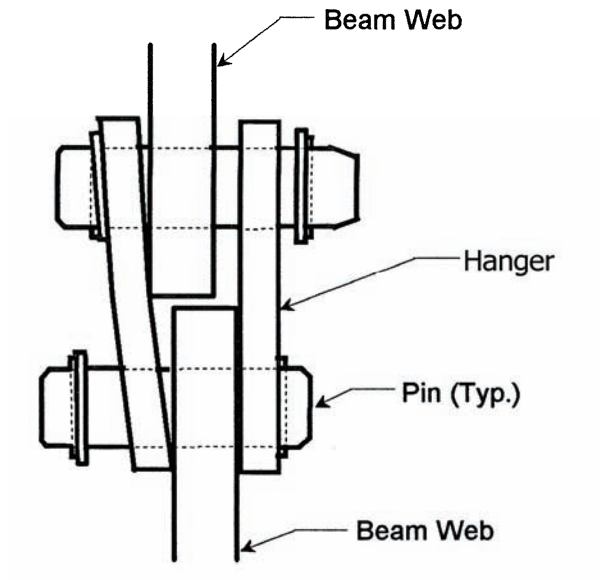

Figure 8.4.22 Bowing Due to Out of Plane Distortion of Hanger

Pins

Rarely is the pin directly exposed in a pin and hanger assembly. As a result, its inspection is difficult but not impossible. By carefully taking certain measurements, the apparent wear can be determined. If more than 3 mm (1/8 inch) net section loss of the diameter has occurred, it should be brought to the attention of the bridge engineer at once (see Figure 8.4.23). 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 at the bottom of the pin and the 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. When inspecting a pin and hanger assembly, locate the center of the pin, measure the distance between the center of the pin and the end of the hanger, and compare to the 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 mm (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.

In a fixed pin and girder, wear will generally be on the top surface of the pin due to rotation from live load deflection and attractive forces. Locate the center of the pin, and measure the distance between the center of the pin and some convenient fixed point, usually the bottom of the top flange. Compare this distance to the plan dimensions to determine the decrease in the pin diameter.

The pin cap, if part of the assembly, should be checked with a straight edge for flatness.

Figure 8.4.23 Corroded Pin and Hanger Assembly

Retrofits

Since there are many problems associated with pin and hanger assemblies, several retrofit schemes have been devised to repair and/or provide redundancy in pin and hanger assemblies:

- Rod and saddle
- Underslung catcher
- Seated beam connection
- Continuity (field splice)
- Stainless steel replacements
- Non-metallic inserts and washers

The first two (rod & saddle and underslung catcher), are added to the structure and only carry load if the pin or hanger in a joint fails (see Figure 8.4.24). The gap between the “catcher” and the girder must be kept as small as possible to limit impact loading. If it is too tight, however, joint movement may be restrained. A neoprene bearing may be included in the assembly to lessen impact. The inspector should find out what the relative positions of the components should be by design and measure the critical points in the field for comparison.

The seated beam connection completely replace the pin and hanger assemblies. Vacant pin holes may be left under some schemes. Inspection of these details should be the same as inspection at field splices and bearings.

Sometimes a pin and hanger assembly is retrofitted by using a bolted field splice. This is done only after a structural engineer analyzes the bridge to determine if the members can support continuous spans instead of cantilevered spans. The inspector must remember to inspect both the positive and negative moment regions of the superstructure. Additional deflections may be introduced into piers and more movements may take place at expansion bearings when continuity is introduced. The areas should therefore receive extra attention.

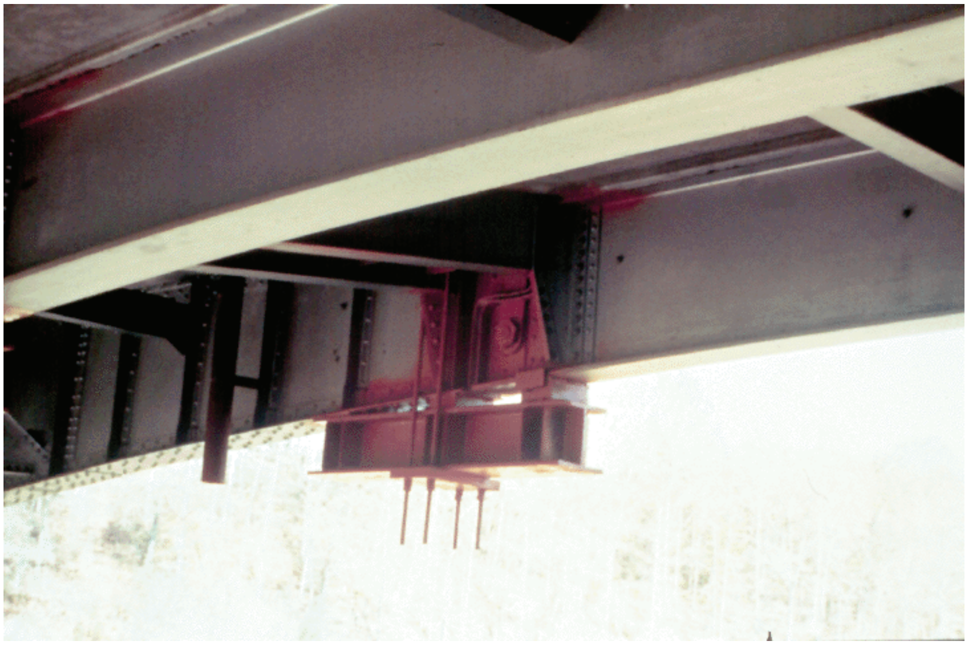

Figure 8.4.24 Underslung Catcher Retrofit

Replacing the pin and hanger assembly in kind with a structural grade of stainless steel eliminates potential failures due to corrosion related problems. Placing a non-metallic insert and washer prevents corrosion between the pin and hanger and allows for normal rotation.

Figure 8.4.25 Stainless Steel Pin and Hanger Assembly

8.4.5 Evaluation

State and federal rating guideline systems have been developed to aid in the inspection of pin and hanger assemblies. 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

Under the NBI rating guidelines, the pin and hanger assembly is considered part of the superstructure and does not have an individual rating. The rating for the superstructure should take into account the condition of the pin and hanger assembly and may be lowered due to a deficiency in the pin and hanger. The superstructure is still rated as a whole unit but the pin and hanger may be the determining factor in the given rating.

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 considered 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 girder bridge with a pin and hanger assembly, the AASHTO CoRe element is:

Element No.	Description
160	Unpainted Pin & Hanger Assembly
161	Painted Pin & Hanger Assembly

The unit quantity for the pin and hanger assembly is each, and must be placed in one of the four available condition states for unpainted and five available condition states for painted assemblies depending on the extent and severity of deterioration. 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 due to fatigue, the “Steel Fatigue” Smart Flag, Element No. 356, can be used and one of the three condition states assigned. For rusting between members, 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 pin and hanger assemblies with section loss due to corrosion, the “Section Loss” Smart Flag, Element No. 363, can be used and one of the four condition states assigned.