Guidelines for Inspecting Overhead Crane Structures

May 20, 2011

Prepared By:

Gary J. Davis, P.E.
Director of Consulting Services
Integrated Machinery Solutions (IMS)
Fort Worth, Texas

Texas Registered Engineering Firm #11499

www.team-ims.com • garydavis@team-ims.com • 817-659-2399

INTEGRATED
MACHINERY SOLUTIONS

Table of Contents

INTEGRATED
MACHINERY SOLUTIONS

1.0 Introduction

1.1 Purpose

This guide provides a comprehensive set of recommendations for structural inspection of overhead bridge cranes and trolley-hoists. Emphasis is placed on knowing *where* to look for structural damage. Basic concepts are introduced for identifying "hot spots" on the structure, and areas prone to fatigue. This guide is intended for plant maintenance personnel and crane service technicians who are responsible for periodic, visual structural inspections. This guide will also be useful for entry level engineers and experienced engineers who are new to field inspection.

Because structures *are* so reliable, it is easy to lose sight of their fundamental importance. ***"Failure to complete overhead crane and hoist inspections and proper equipment maintenance could lead to serious injury, death or destruction of property"*** [1]***.***

Implementation of a comprehensive and disciplined inspection plan has the following benefits:

- Reduced chance of fatality or injury to personnel.
- Reduced liability exposure.
- Improves equipment productivity.
- Prolongs equipment service life.
- Ensures compliance with laws, codes, and standards including: OSHA, ANSI, and ASME.

1.2 Scope

This guide is for overhead bridge crane structures including:

- Bridge girders.
- Bridge end trucks, end ties, equalizer saddles, sill beams.
- Platforms, ladders, stairs, cabs.
- Bolted and welded connections.
- Trolley frames, trolley end trucks.

1.3 Limitations of this Guide

- This information is not a substitute for prevailing inspection standards for cranes and structures, or recommended inspection procedures provided by original equipment manufacturers.

- This guide is intended to supplement the training and experience of personnel who are already qualified to perform structural inspections of overhead cranes.

[1] The Crane, Hoist and Monorail Alliance, an OSHA Cooperative Program, *Fact Sheet No. 1, Proper Inspection and Maintenance of Overhead Cranes,* http://www.mhia.org/industrygroups/osha

- Due to the wide variety of crane applications and equipment configurations, this guide can only provide generic guidance. Inspection provisions for special applications may not be addressed here. Special applications not addressed here include: under-running cranes, patented track systems, stacker cranes, jib cranes, portal cranes, gantry cranes, packaged trolley hoists, crane runways, and below-the-hook equipment.

2.0 Organization and Personnel

2.1 Implementation of a Disciplined Plan

The first step in designing a high quality inspection program is to create a controlled-document manual containing work instructions and procedures. The manual should be a "live" document that is continuously being improved. Manuals facilitate a systematic and repeatable approach, and set definite standards. Manuals also facilitate seamless transitions during changes in personnel. They help train new people, and identify existing plans to new management personnel. At a minimum, the manual should define the following:

- Personnel responsibilities and authorities.
- Minimum requirements for training and certification of inspectors.
- Provide inspection forms customized for various cranes in the plant.
- Standards for documentation and record keeping.
- When inspections shall be made.
- Minimum inspection intervals.
- Level of detail to be carried out for various inspection intervals.
- Criteria for reporting suspect and problem areas to the responsible engineer.

The entire program should be closely monitored and supervised by an engineer who is qualified to design and inspect structures. Each inspection should be reviewed and approved by the responsible engineer. To ensure that inspections are meeting minimum quality standards, the responsible engineer should perform inspections of recently inspected cranes (periodically at random intervals).

For long-interval inspections of major process cranes, hire a consulting engineer to do the inspection. It is important that the selected firm specializes in inspection and design of overhead material handling equipment. By periodically hiring an outside expert, it provides a good check on the quality of your in-house system.

2.2 Prerequisites for a Qualified Inspector

Only properly trained and qualified personnel should perform inspections. A formal training and certification program should be implemented to ensure that inspectors are qualified, and remain qualified. For additional guidance on minimum requirements for crane inspectors, refer to *CMAA Specification No. 78-2002, Standards and Guidelines for Professional Services Performed on Overhead and Traveling Cranes and Associated Hoisting Equipment.*

2.3 Recommended Inspection Team

The inspector should have an assistant present at all times. Assisting the inspector is ideal for training and qualifying new inspectors.

Primary duties for the assistant:

- Monitor the immediate area for hazards.
- Operate the aerial platform.
- Assist the inspector by taking notes and measurements as required.
- Handle tools, flashlight, camera, note pads, etc.
- Communicate with personnel on the floor and elsewhere via radio.
- In the event of an injury to either the assistant or the inspector, the other will provide assistance.

3.0 Inspection Safety

3.1 Pre-Inspection Safety Plan

Before starting the inspection, follow the safety procedures required by your company, OSHA, and state and local authorities. Generally recommended safety procedures include:

- Notify plant personnel (in advance) that an inspection will take place. Personnel who work near the area, or pass through the area should be notified.
- Locate the bridge away from crane activity in the same and adjacent crane aisles.
- If other cranes on the same runway must stay in service during the inspection, provide a means to prevent them from hitting the crane being inspected.
- If the mainline conductor system must remain energized during the inspection, all inspection personnel must remain aware of this hazard and stay clear of the conductors.
- If the inspection requires personnel maneuvering and potential exposure to cranes on an adjacent runway, install a guard or a barrier or provide other safe means to protect the inspector from contact with adjacent cranes.
- Remove all sources of stored mechanical energy including suspended load blocks.
- Disconnect, tag, and lock-out all electrical power to the crane.

3.2 Safely Maneuvering on the Structure

Safe, comfortable, and close access is required to all parts of the crane. If possible, the crane should be moved to an area that has good lighting, comfortable temperature, and is away from production processes, and adjacent crane activity.

Inspectors may be standing, sitting, kneeling, bending, squatting, climbing, or laying down to facilitate the inspection. The inspector must have physical agility to climb tall ladders, walk on parts of the runway, and climb over all parts of the bridge and trolley.

The inspector must be able to safely maneuver and position himself in areas that have limited footing and space. One commonly encountered example of limited footing is stepping onto runway beams where no platforms exist. Depending on the specific building design and crane location, access to the runway may be required to examine the condition of bridge end trucks, end ties, sill beams, equalizer saddles, squaring plates, girder connections, and bumper extensions.

3.3 Identifying Hazards

It is impossible to create a list of all possible hazards, but a few common sense guidelines for safe inspections are offered here:

- Never rush the task.
- Never move to a location where you cannot clearly see that you will have safe footing and if required, stable hand holds.
- Observe the condition of the walking surface and avoid walking on surfaces covered with lubricants or debris.
- Continuously monitor activities in all three dimensions of your surroundings.
- When climbing and maneuvering on the structure, both of your hands should be free for grasping hand holds. Take time to think about your movements in advance.
- Make sure that others know where you are. Don't assume that others are aware of your nearby presence. When passing behind someone, be sure to announce your presence.
- Even if power is disconnected and locked out from the crane, it's a good habit to remain aware of exposed conductor surfaces and not touch them.
- You should be accustomed to heights.
- Be familiar with the OSHA definition of a "confined space". Never enter a confined space without a permit.
- Identify potential pinch points and locations where you could be crushed.
- Watch for unguarded openings in floors and hand railings.

3.4 High Ambient Temperatures: Precautions and Planning

Special attention and planning are required for inspecting cranes in hot areas. Due to the adverse environment, these cranes may not receive the inspection time they deserve. The air temperature on melt shop cranes in a steel mill can exceed 140° Fahrenheit. The crane structure may be hot, and gloves are recommended for maneuvering on the structure during an inspection.

Consider inspecting high temperature cranes at night, early morning, or on cloudy days. When temperatures at the crane elevation are extremely hot, inspection time is considerably longer. When air temperatures are 120° to 140° F., inspection personnel should limit their exposure time. Productive inspection time may be limited to 15 or 20 minute increments before descending to the floor level, or entering an air conditioned cab or control room. For extremely hot environments, 60% cool-down time and 40% inspection time may be used as a rough guide for estimating inspection time.

3.5 Personal Safety Equipment

In addition to safety equipment mandated by OSHA, and if not already furnished by your company, the following articles should be considered:

- Two-way radio.
- Dust mask.
- Coveralls with zipper pockets.
- Gloves (light canvas type).

4.0 Preparation for Inspections

4.1 Cleaning the Structure

The surface of the crane should be clean before starting the inspection. For high production, process cranes, it is common for structural elements to be obscured by a thick coat of dust and lubricants. Areas covered by thick layers of undisturbed debris, may indicate long-term neglect of inspection.

Over time, accumulated debris may harden into a thick crust that requires vigorous mechanical cleaning. The nature and extent of the debris must be evaluated for planning the cleaning method, equipment, and manpower. Do not underestimate how tightly the debris may be bonded to the surfaces, crevices, and corners of the structure. Crevices and corners are important areas of interest and must be thoroughly cleaned for inspection. In extreme cases, pneumatic chiseling is required to remove debris.

When it is not feasible to clean the entire crane before an inspection, it becomes more important for the inspector to know *where* to look. The inspector must have a basic understanding of structures. Refer to section 10 for an overview of structure behavior.

4.2 Aerial Work Platforms

An aerial work platform (or man-lift) is required for hard to reach areas, including the underside of the trolley and bridge girders. When planning for the aerial lifting apparatus, consider the following:

- Identify areas of the crane that can be safely inspected without an aerial lift.
- Determine the highest elevation and farthest lateral reach required for the apparatus.

- Consider where the base of the apparatus must be maneuvered to reach the locations previously identified.
- Consider the travel path required to bring the apparatus through the plant, into the aisle, and under the crane.
- Use a trained equipment operator.
- The aerial lift should be operated b y someone other than the inspector.

4.3 Other Inspection Paraphernalia

The following items are recommended for local cleaning areas of interest, marking suspected areas, and documenting areas for reports:

- **Camera.** Use a compact, rugged, good quality camera. The camera must be suitable for sharp close-ups and should be weatherproof.
- **Mini audio recorder.** For dictating verbal descriptions that can be transcribed and edited for reports.
- **Mirror.** A small inspection mirror with an extension handle, or a 4” x 5” acrylic locker mirror.
- **Flexible borescope** with optical or video display. A borescope allows close-up inspection of inaccessible areas such as the interior of box girders, end trucks, and end ties.
- **Paint stick** (white or yellow) for identifying areas of interest.
- **Extra pens** and pencils.
- **Note pad** for sketches, measurements and notes.
- **Black marker** for identifying areas of interest.
- **Flashlight.** Use a good quality flashlight (Maglite® or equal quality).
- **Putty knife** for scraping debris to clean areas of interest.
- **Small wire brush** for cleaning areas of interest.
- **Tape measure.** A 16’ or 25’ is adequate. Use a wide blade tape measure for maximum reach to inaccessible locations.
- **Ball-peen hammer.** A small (2 oz. or 4 oz.) hammer can be used for tapping on the face of girder webs or other weldments to determine the locations of internal stiffeners. A hammer can also be used to tap on the heads of rivets and bolts to help determine if they are loose or broken.
- **Torpedo laser level** with magnetic base or a **small laser cross level.** A straight, level reference line is required to measure the elevation profiles of trolley rails. Use the brightest laser available (at least 100’ working range) so the beam will be visible for use with a tape measure.

5.0 General Inspection Guidelines

5.1 Getting Started

Start the inspection at the top and work your way down. This means starting at the top of the trolley. Then proceed to the top of the bridge. Inspect as much as possible without using the aerial lift. Note areas that are not accessible for later viewing from the aerial lift.

5.2 Where to Look

Overhead cranes have the same basic configurations, and a generic list of bridge and trolley inspection points is suggested in section 6 and 7. Since there are so many design variations for custom crane applications, it is not possible to identify *all* points of interest in this guide. A basic understanding of structure behavior can help to identify other inspection points. This guide includes a section on basic structure behavior to help technicians identify points of interest that may not be listed. A custom list of inspection points should be made to suit each crane in your plant.

5.3 Other Inspection Guidelines

- When a crack is discovered at one location, all other similar or typical locations must be carefully inspected. One example would be when a crack is discovered in the girder web adjacent to platform connections. There may be several other connection details identical to where the original crack was discovered. It is efficient to focus attention on typical locations that are discovered.

- A viewing distance of not more than two feet is recommended for visual inspections.

- Routinely inspect areas that have been repaired or modified.

- Previously repaired areas that use “patch plates” present a problem for inspection. The previously repaired area cannot be inspected because it is covered by the patch plate. Patch plated areas should be reported to the responsible engineer as damaged areas that require action. The patch plate should be removed and an engineered repair should be made. The engineered repair procedure should be completed by a qualified structural engineer.

- All areas of structural damage must be documented and reported to a qualified structural engineer for assessment before placing the crane back into service.

6.0 Trolley Structure Inspections

Table 6.1: Trolley Structure Inspection Points		
Item	**Description**	**Points of Interest for Inspection**
1	Main and auxiliary hoist load girts: bottom flange.	Where stiffeners are welded to girts or where other members are welded on or near the lower flange of girt. Check welds and adjacent base metal.
2	Main and auxiliary hoist load girts: bottom edges of members.	Edges of members adjacent to running wire ropes. Look for scuffing, erosion, and "sawing" action from wire rope contact with structure.
3	Main and auxiliary hoist load girts: end connections.	Welds and adjacent base metal where girts are welded to end trucks. When the depth of the girt member is less than the end truck, check for flexing of the wall of the end truck at the bottom edge of the girt.
4	Sheave boxes	Welds and base metal.
5	Other load girts.	Similar to items 1 and 2. Look for other load-carrying girts, including supports for hoist drums, drum pinion supports, and equalizer sheaves.
6	Trolley end trucks: frame connections	Where load girts are welded to the end truck, especially on or near the lower flange. Check welds and adjacent base metal.
7	Trolley end trucks: wheel assembly mounting.	For 90° and 45° MCB type wheel assemblies, check for cracking at stiffeners and corners.
8	Trolley end trucks: bumper attachments, bumper chocks.	Welds and base metal. Check bolted connections per section 8.0.
9	Trolley end trucks: bolted splice for trolley frame.	Check bolted connections per section 8.0. Check welds and base metal for connection plates.
10	Trolley end trucks: jacking pads or jacking brackets.	Damage from jacking on edges of end truck flanges or directly on the bottom flange plate of the end truck. Check welds and base metal around jacking locations.
11	Trolley drive mounting brackets.	Look for cracks at corners or notches. Check welds and base metal where brackets are welded to the trolley frame.
12	Hoist reducer support bracket.	Look for cracks at corners or notches. Check welds and base metal where brackets are welded to the trolley frame.
13	Torque arm brackets for hollow-shaft trolley reducers.	Inspect bracket arm and weld to end truck.
14	Bearing supports for drum, bearing support for external drum pinion.	Check welds and base metal at connection to trolley frame.

15	Hand rails, guard rails, ladders, platforms, stairs, cantilevered platform supports.	Check welds and base metal. Check tightness of all fasteners. Look for loose, broken, or missing bolts. Check for proper fastener hardware. Check for missing or damaged gates or chains. Check for sharp edges or corners near personnel passage ways.
16	Cab attachments, cantilevered cab support structures.	Check bolted cab connections per section 8.0. Welds and base metal for connection plates. For cabs suspended outside the bridge girder, inspect the cantilevered support structure.
17	Tow arm for conductors.	Check tow arm and the bolted or welded connection to the trolley frame.

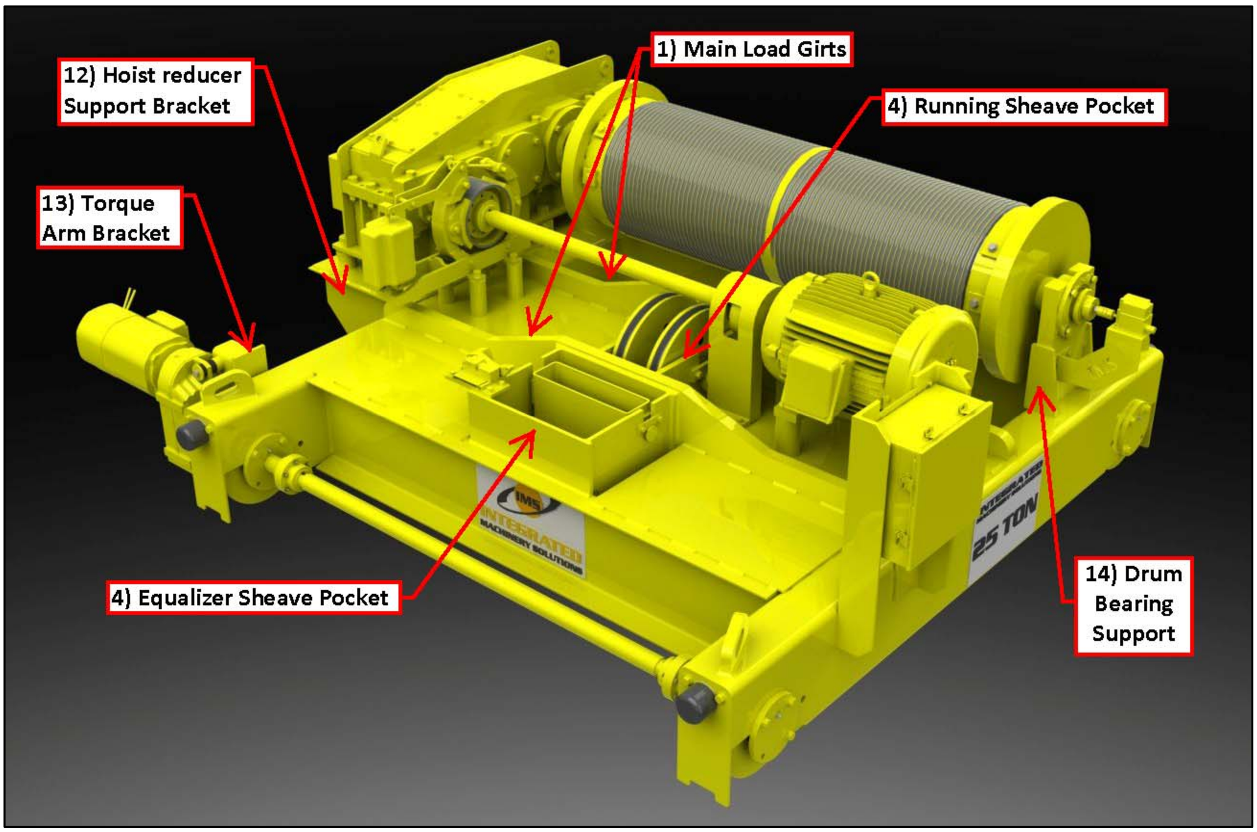

Figure 6-1

See section 6.1 for trolley inspection points.

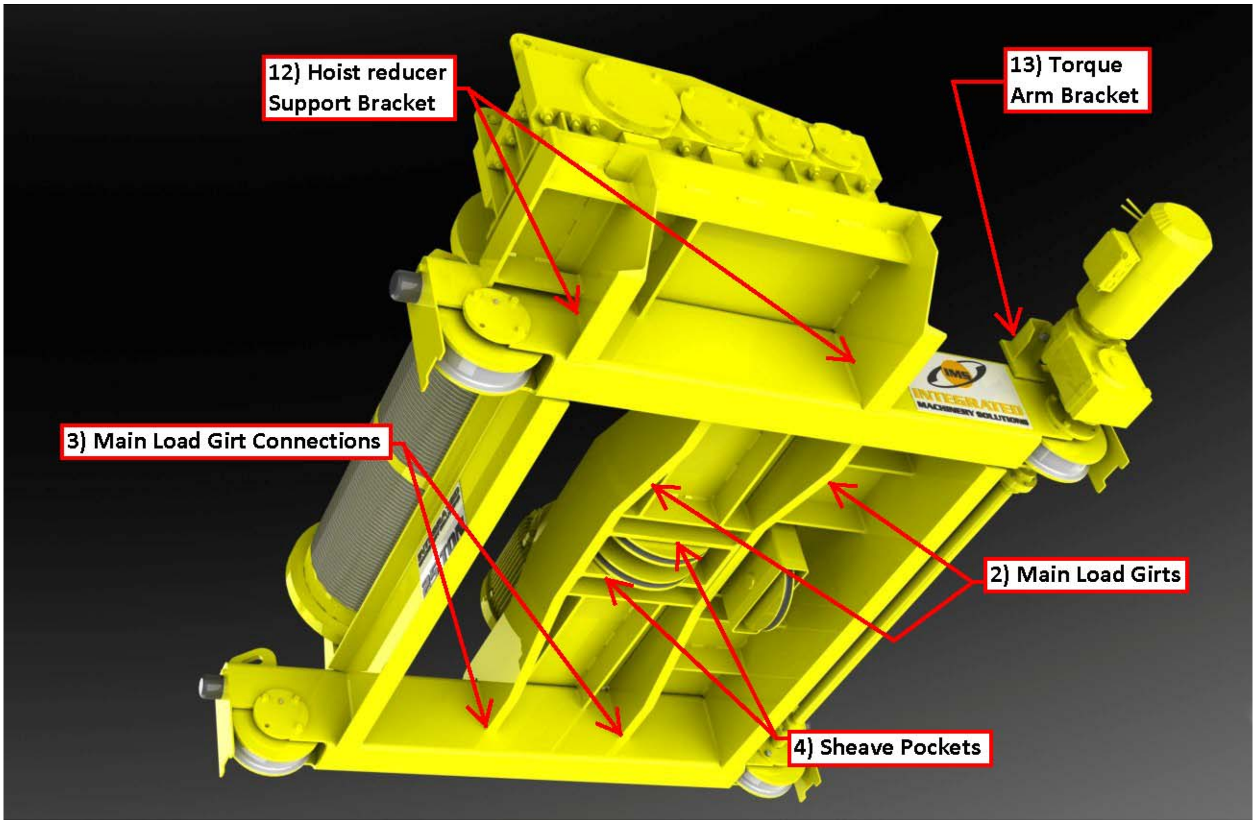

Figure 6-2
View underneath trolley, showing typical structure inspection points.

7.0 Bridge Structure Inspections

Table 7.1: Bridge Girder Inspection Points		
Item	**Description**	**Points of Interest for Inspection**
1	Trolley rail bolted splices.	Loose and missing splice bolts, check for improper hardware. Joint bar bolts have straight shanks to the head and are made per ASTM A449. Nuts are per A563 grade B. A325 bolts and nuts may also be used. Check/tighten splice bolts every 3 months. Fasteners should include a helical spring lock washer per AREA specification.
2	Trolley rail clamps or clips.	Check for fractured clamps, cracked welds, loose and broken bolts. See note 2.
3	Trolley rail: erosion under rail base.	Under the base of the rail, check for erosion of the girder flange or the wear plate (if present). See note 3.
4	Trolley rail support.	Check for top flange cracking at the edge of the rail base. Check for tack welds at the edge of the rail base. See note 4.

5	Trolley rail elevations.	From one end of the trolley rail, sight down the rail head. Sight over the entire length of the rail for dips in elevation. Check for local deformation of the girder flange that supports the rail. "Dishing" or dips in the girder flange may indicate broken intermediate diaphragms or broken welds. Check this condition at both trolley rails. See Figure 7-1.
6	Girder camber.	Position the trolley at the extreme end of the bridge. From the end of the bridge opposite the trolley, position your line of sight to be in-line with one of the trolley rails, and nearly at the same elevation as the rail head. The elevation of the rail near the middle of the bridge span should be visibly higher than near the ends (positive camber). If conditions do not permit this observation, or if positive camber is not observed, detailed measurements are required. Repeat the procedure for the other trolley rail. See note 6.
7	Torsion-box rail support.	For box girders that support the trolley rail directly over the inside web plate, check for cracking of the girder flange-to-web weld.
8	Trolley end stops.	Welds, base metal, and attachment to girder. Confirm that trolley bumpers make simultaneous contact with the end stops at both ends of trolley travel.
9	Bridge drive mounting bases.	Check the condition of girder web where bridge machinery is attached. Look for out of plane deformation of the girder web or cracking of the material adjacent to where bars are welded. See Figure 7-2.
10	Line shaft bearing supports.	Check the condition of girder web where bearing supports are attached. Look for out of plane deformation of the girder web or cracking of the material adjacent to where bars are welded. See Figure 7-2.
11	Platform connections to girder.	Check the condition of girder web where platform support gusset plates are attached. Look for out of plane deformation of the girder web or cracking of the material adjacent to gusset attachments. See Note 11. See Figure 7-3, 7-4, 7-5.
12	Festoon/span conductor supports.	Check the condition of girder web where conductor supports are attached. Look for out of plane deformation of the girder web or cracking of the material adjacent to where gussets or bars are welded.
13	Pendant festoon supports.	Check support members, welded and bolted connections.
14	Riveted girders.	Inspect riveted construction per section 8.
15	Girder welds.	Longitudinal flange-to-web welds. Inspect the location of shop splices for web and flange plates. See note 15.

16	Girder lower flange and web.	Inside edges of the bottom flanges, including the adjacent web area for damage due to wire rope abrasion, impact from load blocks, or lifting beams. For cranes with lifting beams, also check the condition of the bottom surface of the bottom flange for impact from two-blocking accidents. If rope guards are present, inspect the rope guard attachments to the girder.
17	Walk-in girders.	Welds and base metal for intermediate and full depth diaphragms, girder webs, girder flanges. See note 17.
18	Bolted girder splices.	Check bolts in top and bottom flange splices and web splices per section 8.
19	Girder connection notch.	See Figure 7.6. Check welds and base metal at corners and where welds meet at corners. Check welds where girder webs are welded to horizontal shelf plate.
20	Equalizer saddles.	See Figure 7-7. Check welds and base metal where the vertical saddle plates are welded to the horizontal saddle plate. Also check welded connections to girder.
21	Platform truss.	Welds and base metal for all truss members and gusset plates. See Figure 7-4.

7.1 Bridge Girder Inspection Notes

The following item numbers correspond to the items in Table 7.1.

2. Rail clips resist a small uplift force from the trolley rail. See Figure 7-1. The rail deflects downward directly under the trolley wheel. On either side of the trolley wheel, the rail reacts by deflecting upward. The upward force is resisted by the rail clips. The clips or welds may break due to fatigue.

3. Erosion of girder flange material under the rail base is more likely in wet, corrosive, or abrasive environments. The erosion is caused by the sliding and creeping action of the rail relative to the girder. This action is normal and cannot be prevented unless a rail pad is used. Erosion under the rails is a very slow process. It may take several years before material loss can be observed.

4. Due to high carbon content, ASCE crane rails are not readily weldable. Tack welding (or any other welding) on crane rails must be removed by grinding. NDT the girder flange base metal for cracking after rail welds are removed.

6. When camber cannot be visually observed, elevation measurements are required. The preferred method is to set a self-leveling laser level near the center of the span on one of the girders. At 5 foot increments along the span, measure and record the vertical distance from the laser line to the top of the rail head. Measurements for both girders should be taken from one instrument set-up. Alternately, a small “torpedo” laser level

can be used to obtain the rail camber elevations on each individual girder. With this method however, the elevation difference of the girders cannot be measured.

11. For cranes that use a truss to support the outside edge of the platform, the platform connections to the girder are prone to fatigue damage. See Figure 7-3. The bridge girder deflects due to the trolley load, but the outrigger truss does not. The platform connection that frames into the girder web is forced to translate vertically relative to the truss end. The forced vertical translation causes a large bending action at the platform connection to the girder. Figures 7-4 and 7-5 show typical girder web cracks near the girder tension flange caused by out-of-plane flexing of the girder web.

15. Shop splices are sometimes difficult to locate. The external appearance of shop-spliced material may vary by OEM. Shop splices may be found by noting subtle changes in the profile of edges and surface texture. This is difficult to detect under a thick coat of paint. Bottom flange (tension flange) splices should have been ground flush with the base material by the OEM.

17. Before entering a walk-in girder, review and follow applicable safety requirements for entering and working in confined spaces.

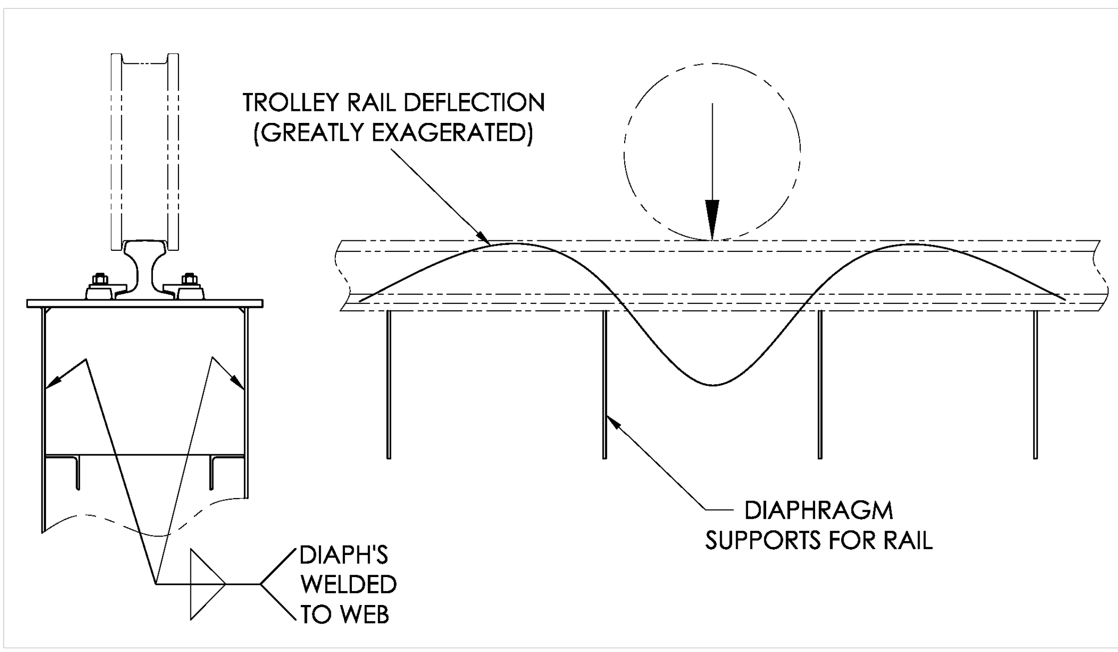

Figure 7-1

Schematic illustration of how the trolley rail deflects. The upward force produced by leverage from the trolley wheel is resisted by the rail clips or clamps.

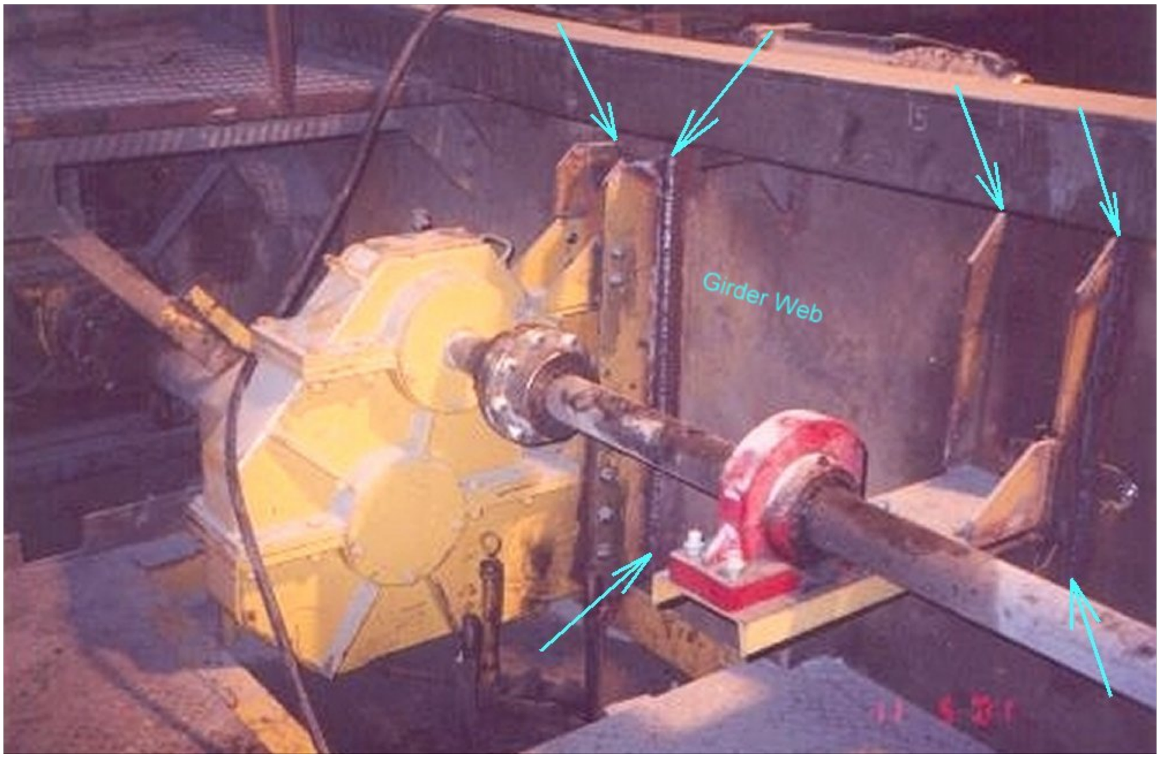

Figure 7-2
Bridge machinery supports.
Check girder web and welds for vertical bars to web.

Figure 7-3
Crane with an outrigger truss. The diagonal members are part of the truss that supports the platform, bridge machinery, and festoon track.

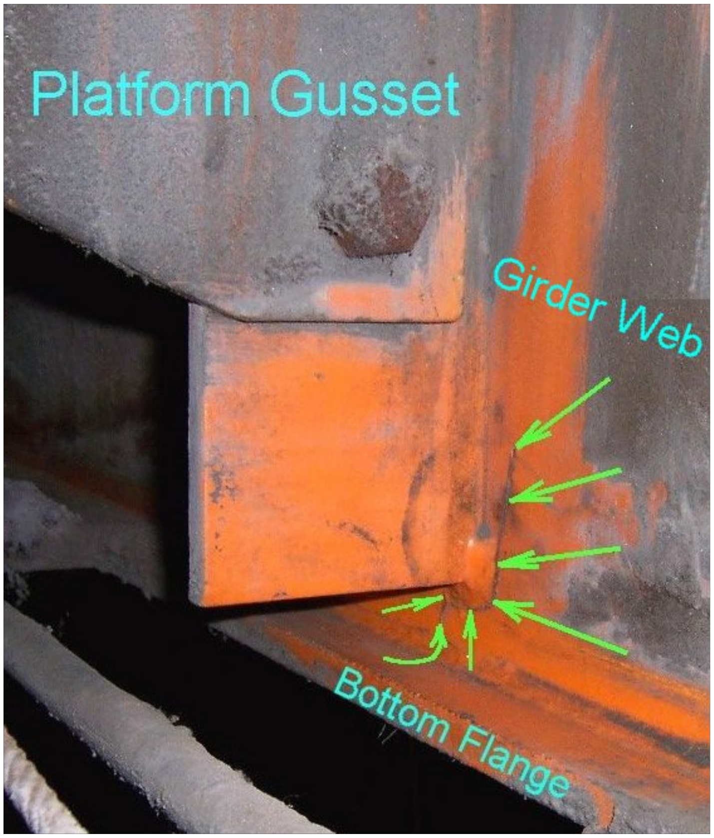

Figure 7-4
The girder web is cracked at the toe of the fillet weld for platform connection bar.

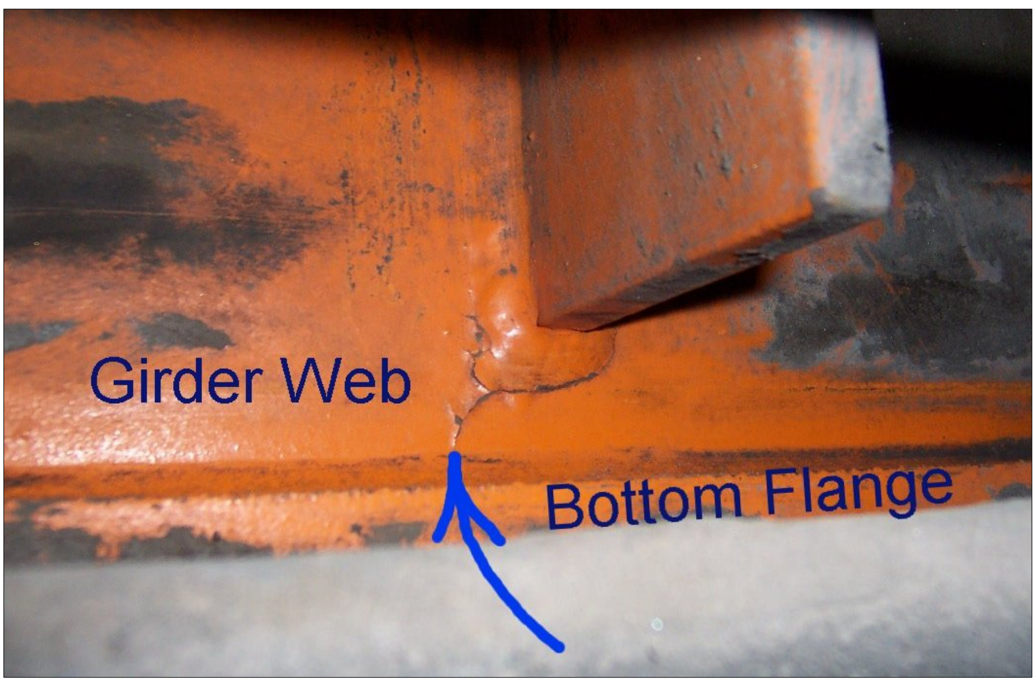

Figure 7-5
This is a close-up view of Figure 7-4. The arrow points to the end of the crack. The crack is propagating toward the bottom flange of the girder. Cracks in the bottom flange of a girder can cause a catastrophic girder failure.

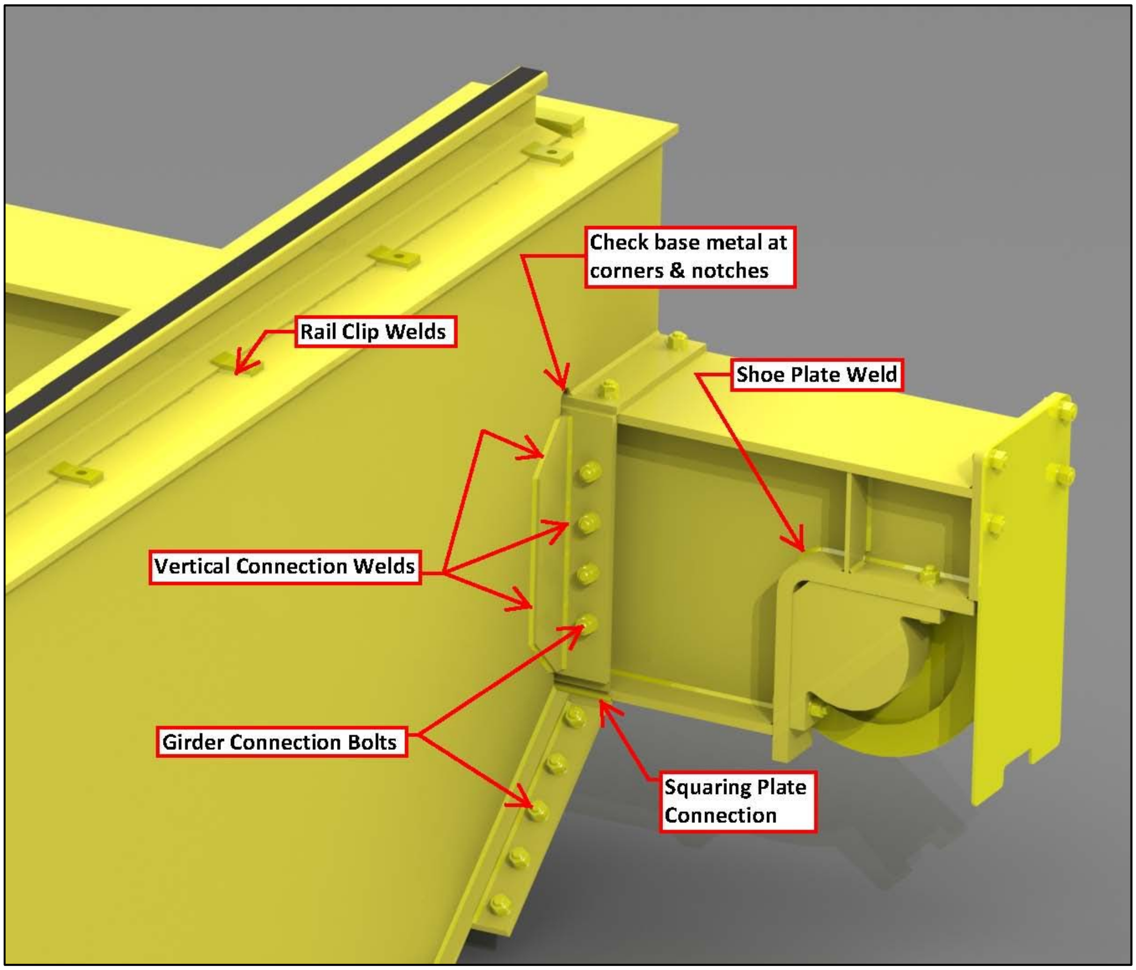

Figure 7-6
Girder End Connection

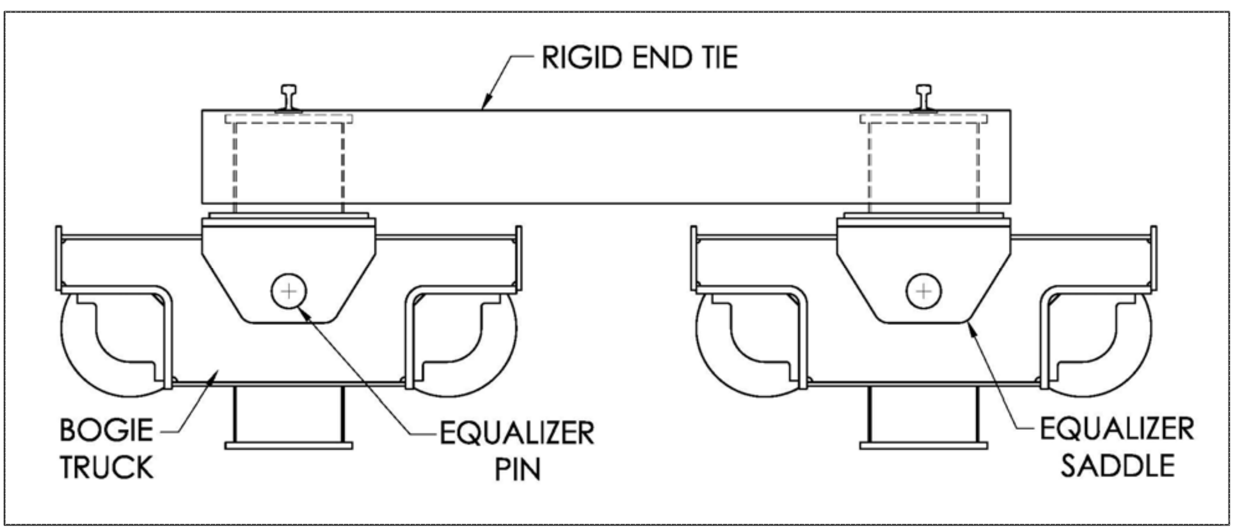

Figure 7-7
Equalized bogie trucks with rigid end tie

Table 7.2: Bridge End Truck and End Tie Inspection Points		
Item	**Description**	**Points of Interest for Inspection**
1	Squaring plate connection.	See Figure 7.6. Check bolted connections for loose, broken, or missing bolts. Loose bolts should be removed and replaced with new bolts of the same grade, size, and length. See section 8 for bolted connections.
2	Rigid end tie connections.	See Figure 7-7. The ends of the rigid end tie are bolted to the girders in one horizontal plane and two vertical planes. See section 8 for bolted connections.
3	Compensating end tie connections.	See Figure 7-8 for compensating end tie connection. Check bolts per section 8.
4	Sill beams.	Check flange-to-web welds, check welds and base metal at corners, abrupt changes in geometry, and where welds meet at corners.
5	End trucks: wheel assembly mounting.	For 90° and 45° MCB type wheel assemblies, check for cracking at stiffeners and corners. See Figure 7.6. Check weld for shoe plate to end truck web.
6	End trucks: equalizer pin supports.	Check welds and base metal around the doubler plate supporting the equalizer pin.
7	Torque arm brackets for hollow-shaft trolley reducers.	Inspect bracket arm and weld to end truck.

7.2 Bridge End Truck and End Tie Inspection Notes

The following item numbers correspond to Table 7.2.

3. Compensating end ties should be flexible for bending in the vertical plane, and rigid for bending in the horizontal plane. Improper design, crane service misapplication, and runway misalignment can make compensating end ties prone to cracking, especially at their vertical end connections. The fatigue cracks are caused by complete reversal of the bending stress.

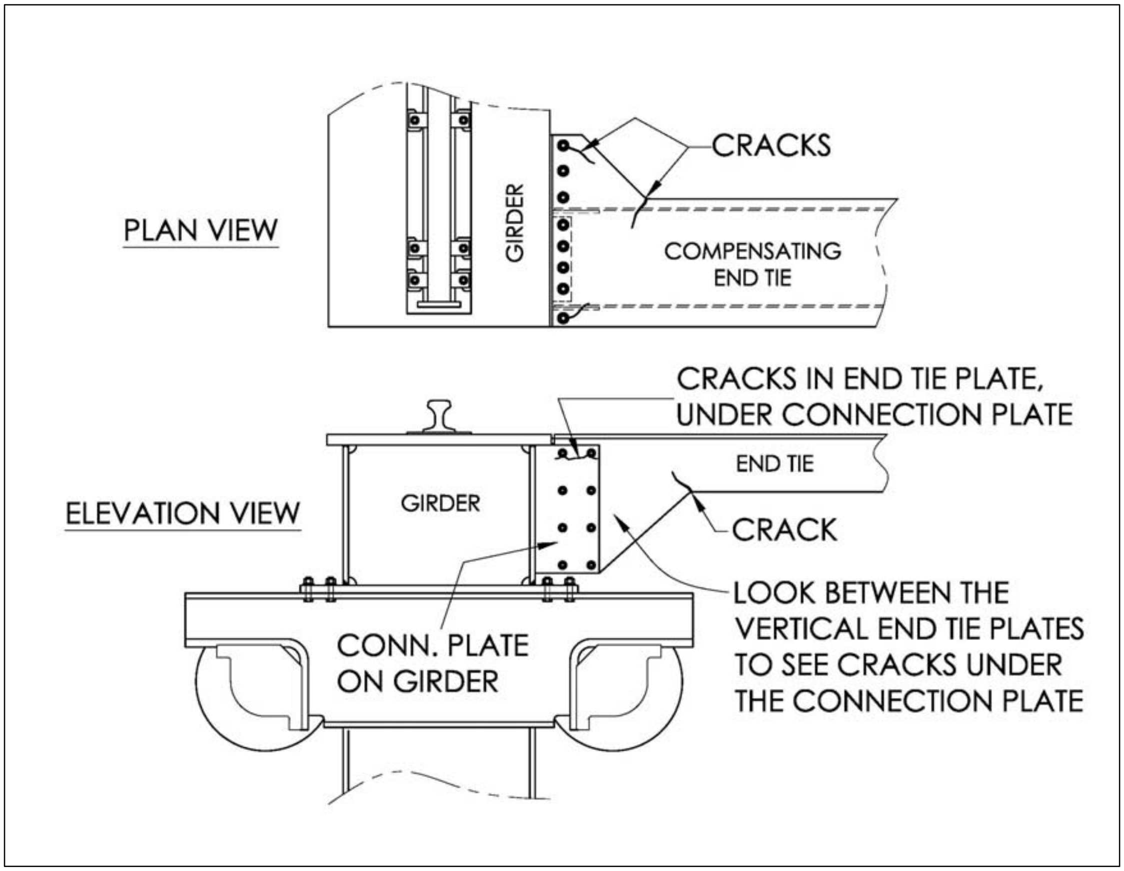

Figure 7-8
Bolted connections for compensating end ties

Table 7.3: Bridge Miscellaneous Inspection Points		
Item	**Description**	**Points of Interest for Inspection**
1	Handrails, ladders, stairs, gates.	Welds and base metal. Check bolted connections per section 8. Look for loose, broken, or missing bolts. Check for proper fastener hardware. Check for missing or damaged gates or chains. Check for sharp edges or corners.
2	Platforms.	Check condition of platform deck, deck support members, and welded connections. Check bolted connections per section 8.
3	Mainline guard.	Check for broken members and broken welds. Check bolted connections per section 8. Bent members are acceptable if at least 3" clearance remains between the guard and nearest obstruction. Check condition of safety tie-off cables. If cables are not present, they should be installed.
4	Mainline collector support.	Check for broken members and broken welds. Check bolted connections per section 8. Check condition of safety tie-off cables. If cables are not present, they should be installed.
5	Mainline repair cage.	Hanger connections and cage frame. Check ladder per item 1. Check for broken members and broken welds. Check bolted connections per section 8. Check condition of safety tie-off cables. If cables are not present, they should be installed.
6	Safety cables.	Check condition of safety tie-off cables. Items that could fall to the floor should have safety cables installed. These items include: mainline guards, mainline collector supports, bumpers.
7	Operator cab structure and supports.	Hanger connections and cab frame. Check for broken members and broken welds. Check bolted connections per section 8. Check ladders, stairs and handrails per item 1.

8.1 Bolted Connections; Description and Function

High strength bolted connections are used for primary load path members including girders, end ties, and bolted field splices. They may also be used for cab and platform connections. High strength bolts are tightened to develop a high tensile stress in them which results in a predictable clamping force on the joint. The actual transfer of loads through the joint is due to the friction force developed in the pieces to be joined.

8.2 How to Check for Broken, Damaged, and Loose Bolts

Apply penetrating oil to the fasteners to be inspected. Using a hand wrench with at least a 16" handle, apply full effort to tighten the element. The element to be turned (either the nut or the bolt head) should be the same element that was tightened during the original installation. The turned element should have a hardened flat washer under it. If the element turns, the bolt is considered to be loose.

When a loose bolt is found, it must be replaced with a new bolt or removed and inspected. For inspection, thoroughly clean the bolt and check for damage including deformation, elongation, wear, cracks, or stripped threads. Elongation can be detected by using your fingers to install an unused nut on the bolt threads. If the nut stops turning after a certain point, the bolt has elongated and should be discarded.

Primary connections are designed to resist the crane rated capacity (the live load) plus the weight of the bridge and trolley structure (the dead load). Since the live load is usually several times greater than the dead load, it is usually safe to remove one or two fasteners from a connection containing several bolts under dean load only. Consult with a qualified person before removing any fasteners. Do not release the crane for service until the replaced or inspected bolts have been properly installed.

Broken, damaged, and very loose bolts may be found using the "hand wrench" procedure suggested here. The formal procedure for inspection of high strength bolted connections is given in *RCSC Specification for Structural Joints using ASTM A325 or A490 Bolts, (*see reference 6). The above method is presented as an alternative for situations where the formal method cannot be used due to limited space or other practical considerations. Consult with a qualified structural engineer to determine if the formal method of checking bolt tightness is warranted for your inspection plan.

8.3 Riveted Crane Construction

Many riveted cranes are still in service. Before electric arc welding, bridge girders, end ties, and end trucks used built-up riveted construction, and some trolley frames consisted of large castings. When properly installed, rivets are very effective connectors for crane components. During installation, a rivet is squeezed from each end causing the body of the rivet to expand

and completely (or nearly) fill its hole. Rivets are installed after heating to a light cherry-red. When the rivet cools, it shrinks and provides a clamping force. Even if the clamping force was not great enough to carry the load, the “body bound” rivet still maintains joint alignment.

8.4 Rivet Inspection

Examine the condition of the rivet heads. The full circumference of the rivet head should be in firm contact with the material. Using a small ball-peen hammer, tap the rivet head at about 45° to the rivet axis. If the hammer impact sounds like a dull “thud” or if any movement is observed, the rivet is loose. Tight rivets will have a solid “ring” when hit by a hammer. Mark the loose rivets with a paint stick and document their location.

8.5 Cautions for Reuse of Bolts

It may be tempting for maintenance and inspection personnel to simply retighten loose fasteners on the spot, but A325 bolts can only be retightened once or twice. If you don’t know how many times the bolt has been retightened after the original installation, it should be replaced. Retightening high strength bolts causes them to lose the ability to stay tight. A490 bolts shall not be retightened. In general, touching up or retightening previously tightened bolts which may have been loosened by the tightening of adjacent bolts is not considered to be reuse. High strength bolts shall be tightened per *RCSC Specification for Structural Joints Using ASTM A325 or A490 Bolts*, (see reference 6).

There should be no excessive elongation of the bolt in the threaded area which would be present if the bolt had been over tightened. The bolt can be reused if the nut can be installed by hand for the full thread length, and the bolt is not otherwise damaged. When in doubt, replace the bolt with the same grade, size, and length as the original.

8.6 Checking for Proper Fastener Hardware

Figure 8-1 shows typical hardware used for high strength bolted connections. When inspecting primary bolted connections, note the following:

- Confirm that high strength bolts are installed in connections for primary members, including girders, end ties, and trolley splices. See Figure 8-2 for standard head identification marks for high strength bolts.

- Hardened flat washers shall be installed under the turned element.

- Lock washers shall not be used in high strength bolted connections.

- When bolting to sloped surfaces such as S-beam flanges and channel flanges, beveled washers must be used. Figure 8-3 illustrates a typical installation for beveled washers.

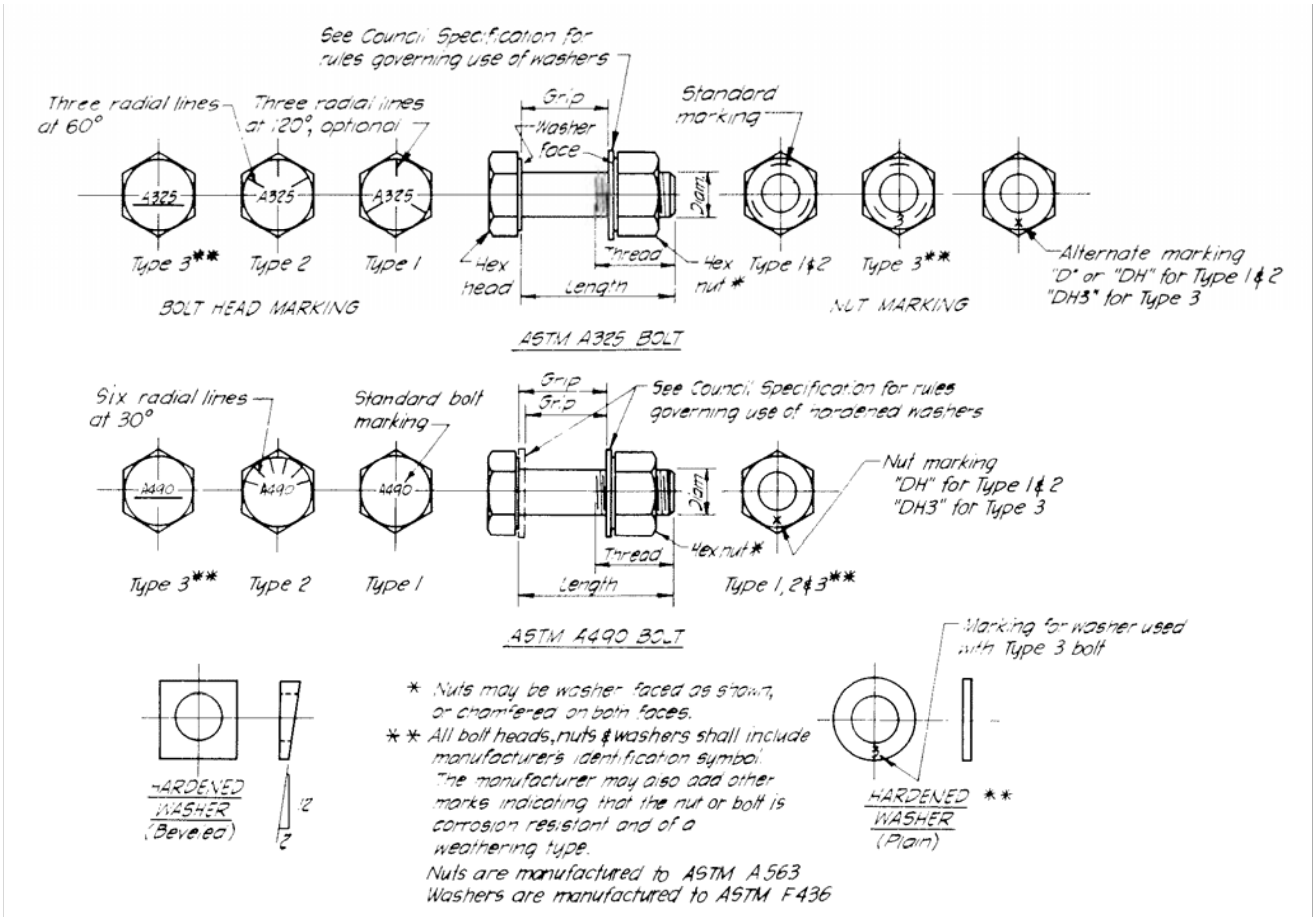

Figure 8-1

Typical hardware for high strength bolted connections.
(From Reference 11.)

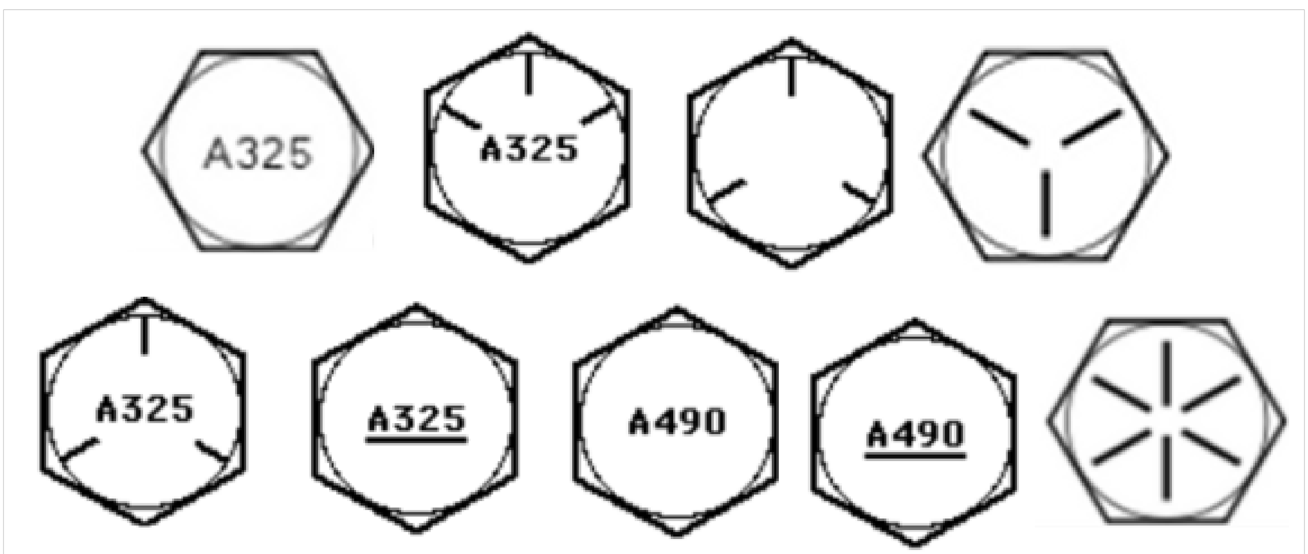

Figure 8-2

Standard head identification marks for high strength bolts

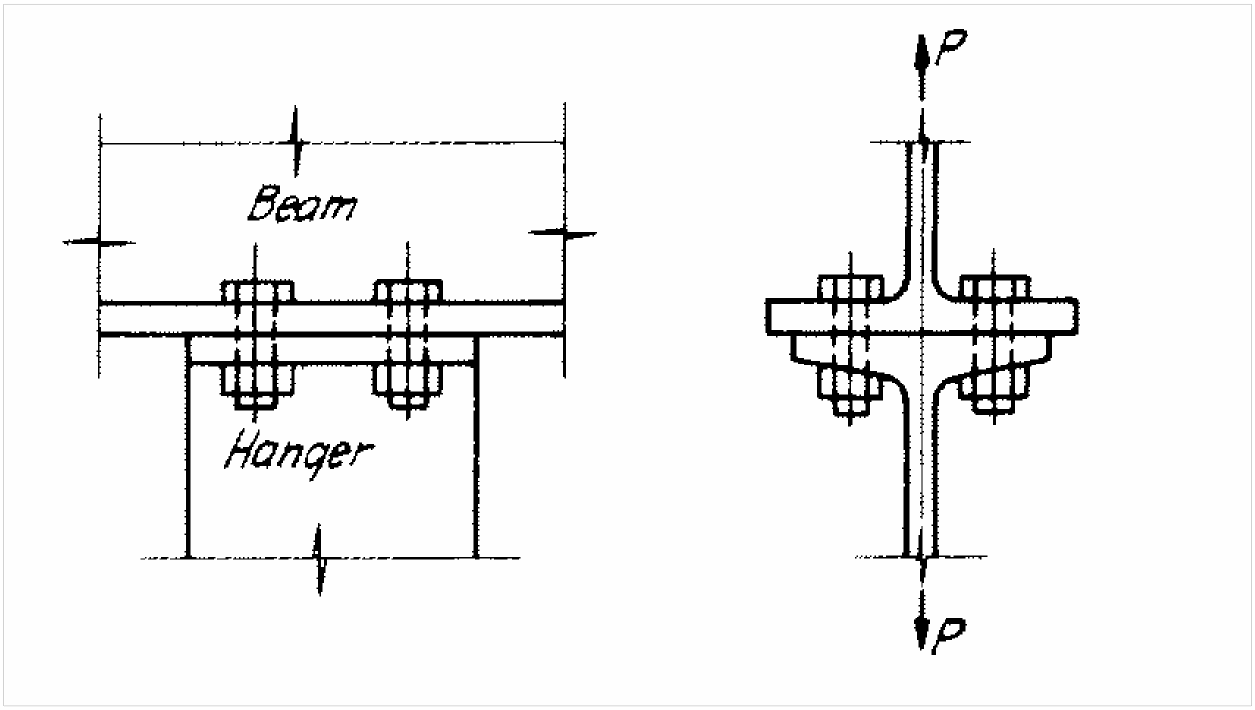

Figure 8-3
Example of beveled washer installation
(From Reference 11)

9.0 Inspection Intervals

9.1 When to Inspect

Check the original manufacturer's manual for recommendations about inspections. If a copy of the manual is no longer available, refer to the following reference documents:

- *ASME B30.2-2005, Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)*
- *OSHA 29 CFR 1910.179(j) for Overhead and Gantry Cranes*
- *CMAA Specification No. 78-2002, Standards and Guidelines for Professional Services Performed on Overhead and Traveling Cranes and Associated Hoisting Equipment*

10.0 Basic Structure Behavior

10.1 Where to Look

Knowledge of *where* to look for structural damage is very important for the inspector. When inspection time is limited, and the structure is covered by debris, knowledge about *where* to look becomes very valuable. Since structures respond to loads in predictible ways, some of the most likely places to inspect can be identified.

A basic understanding of crane structure behavior gives focus to the inspection. This section provides basic concepts and guidelines to help determine the locations most likely to have damage.

10.2 Tension, Compression, and Bending

For beam members, look for cracks in the tension zone and at the end connections. See Figure 10-1. For simple beams, the bottom surface is in tension. The middle 2/3 of the length of the tension zone should be checked first. Material near the top surface of the beam is compressed, and the bottom is pulled into tension. If there are cracks in the compression zone, they will not grow. Cracks in the tension zone will grow, but the speed of growth depends on the magnitude of the loading, and the number of loading cycles.

10.3 Shear

In Figure 10-1, the high shear zones are near the beam ends. Failures in the high shear zones are more likely to be sudden and catastrophic. Shear failures can occur in bolted connections and welds. The connected base material can also fail by shear but usually the shear is combined with tension and compression. Shear can be visualized as the tendency of the material to slide on itself. Figure 10-2 illustrates the difference between shear and tension. A scissors cuts paper by applying a shear force. Horizontal shear in a beam can be illustrated by a stack of boards spanning between two supports. When you push down on the middle, the stack deflects and the surface of each board slides relative to the other. The tendency for the boards to slide is caused by shear.

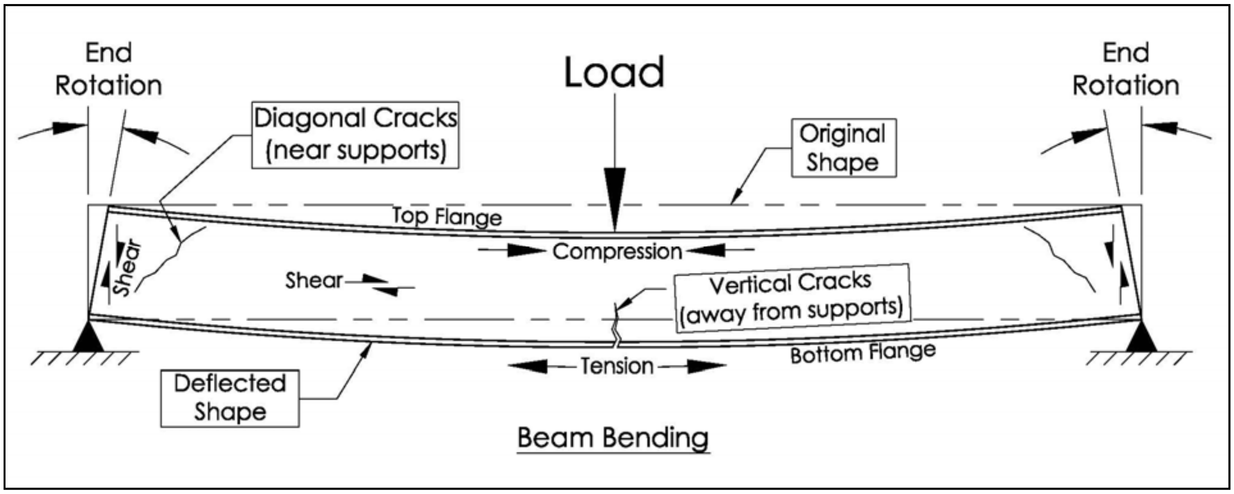

Figure 10-1
Internal forces and deformation of a simple beam

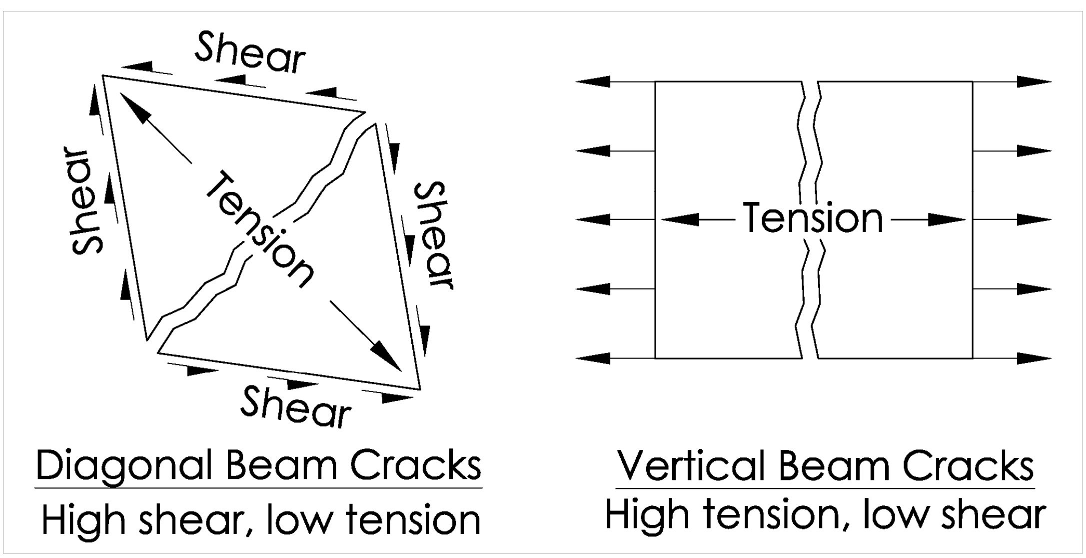

Figure 10-2

10.4 Deflection and Camber

There is a common misconception that deflection indicates weakness of a structure. A structure can have low strength and little deflection, or high strength and large deflection. Deflection is caused by stretching and/or compressing the material. The actual deformation that causes visible deflection is too small to be seen with the unaided eye because it is distributed over the length of the member. Local elongation or compression of the material may only be a few thousandths of an inch long, but the cumulative effect is visible as deflection. The beam assumes a bowed shape because the length of the top material gets shorter and the bottom becomes longer.

Sometimes paint will crack from these small deformations. Areas of cracked paint can indicate high stress, and deserve a close look during an inspection.

10.5 Buckling

Some visible deformations/deflections are caused by buckling. Buckling is caused by excessive compression. In plate material, buckling can also occur from excessive shear. The surface of a buckled plate will appear wavy or rippled. Free edges of plates and bars are subject to buckling. When viewed along the edge, the buckled plate appears wavy. For straight (non-plate) members such as building columns or legs of a gantry crane, buckling appears as a bowing of the normally straight member.

10.6 Effect of Welding

In general, welding creates an internal, local restraint that creates biaxial and triaxial stress and strain conditions. Triaxial stress can be visualized as a solid cube with a perpendicular load applied to each face. Structural steel is very ductile, i.e., it will undergo a very large deformation before failing. But when steel is loaded triaxially (or biaxially), it behaves like a brittle material. When welds cool, they shrink in all directions. Internal reaction forces are created when welds shrink. This is because the base metal outside of the heat affected zone resists the weld shrinkage force. One example for this is when three welds meet at a common corner as shown in Figure 10-8. Each line of weld shrinks in its long direction. The point at the corner is subjected to tension forces in three perpendicular directions. Since this corner would be the most likely spot for a crack to form, it should be a priority for inspection. Refer to Figures 10-3 and 10-4 for common examples of welded connections that are prone to fatigue cracking. These illustrations also show the expected crack pattern. This information can help the inspector identify locations that are most likely to crack.

10.7 Stress Concentration and Fatigue

Cracking will eventually occur in hard-worked cranes with poor engineering details and/or poor weld quality. In order of importance, keep an eye on the following conditions:

1) Previously repaired areas.
2) Girder and end tie connections.
3) Locations where cyclic flexing of thin-walled elements may occur.
4) Sharp corners.
5) Welded attachments to the tension flange.
6) Jagged or flame cut edges not ground smooth.
7) Welds that meet in corners. See Figure 10-8.
8) Arc strikes & tack welds.
9) Abrupt changes in structure geometry (stress concentrations).
10) Locations where the state of stress regularly fluctuates between tension and compression (stress reversals).

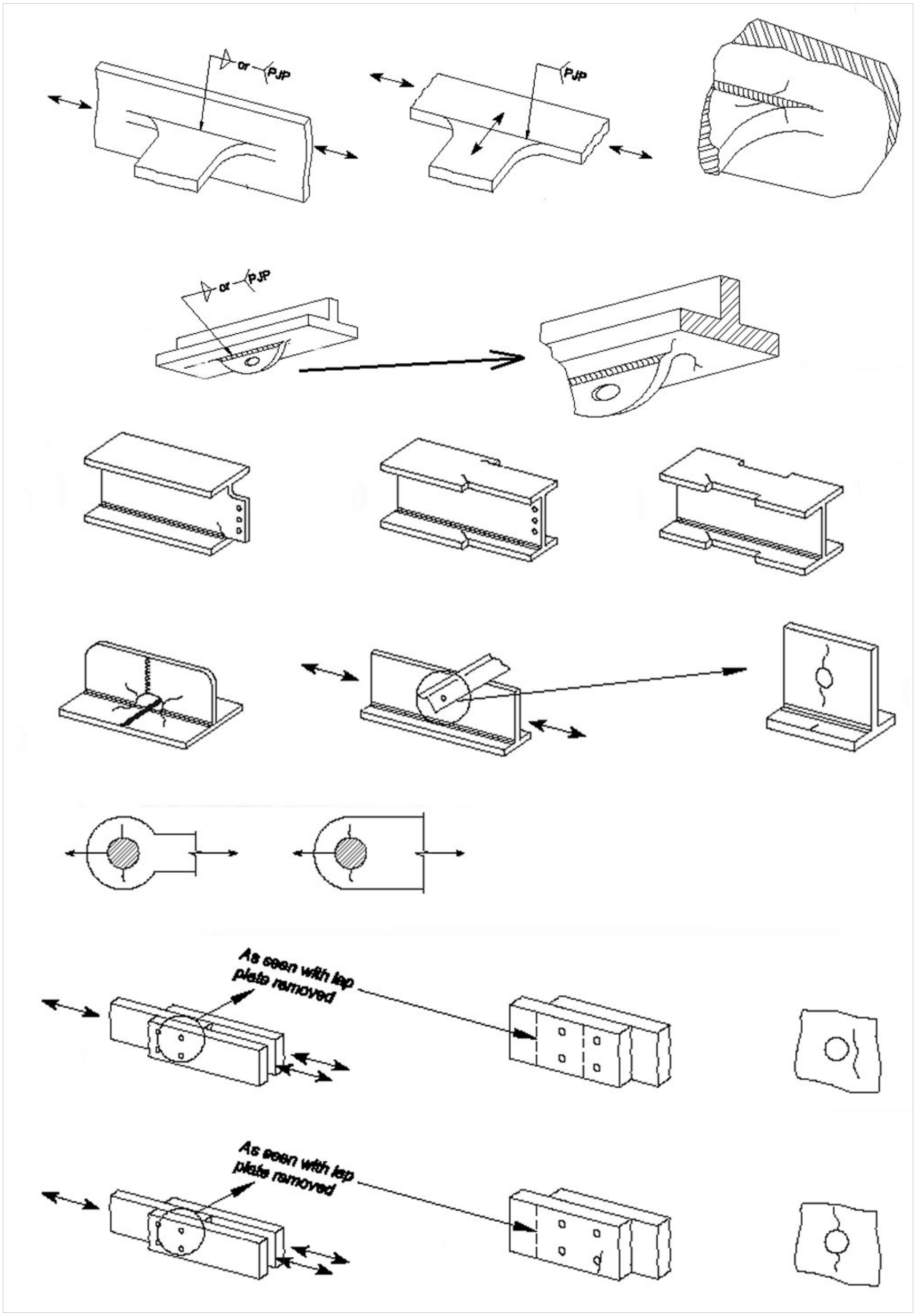

Figure 10-3
Examples of conditions that may result in fatigue cracking
(From Reference 13)

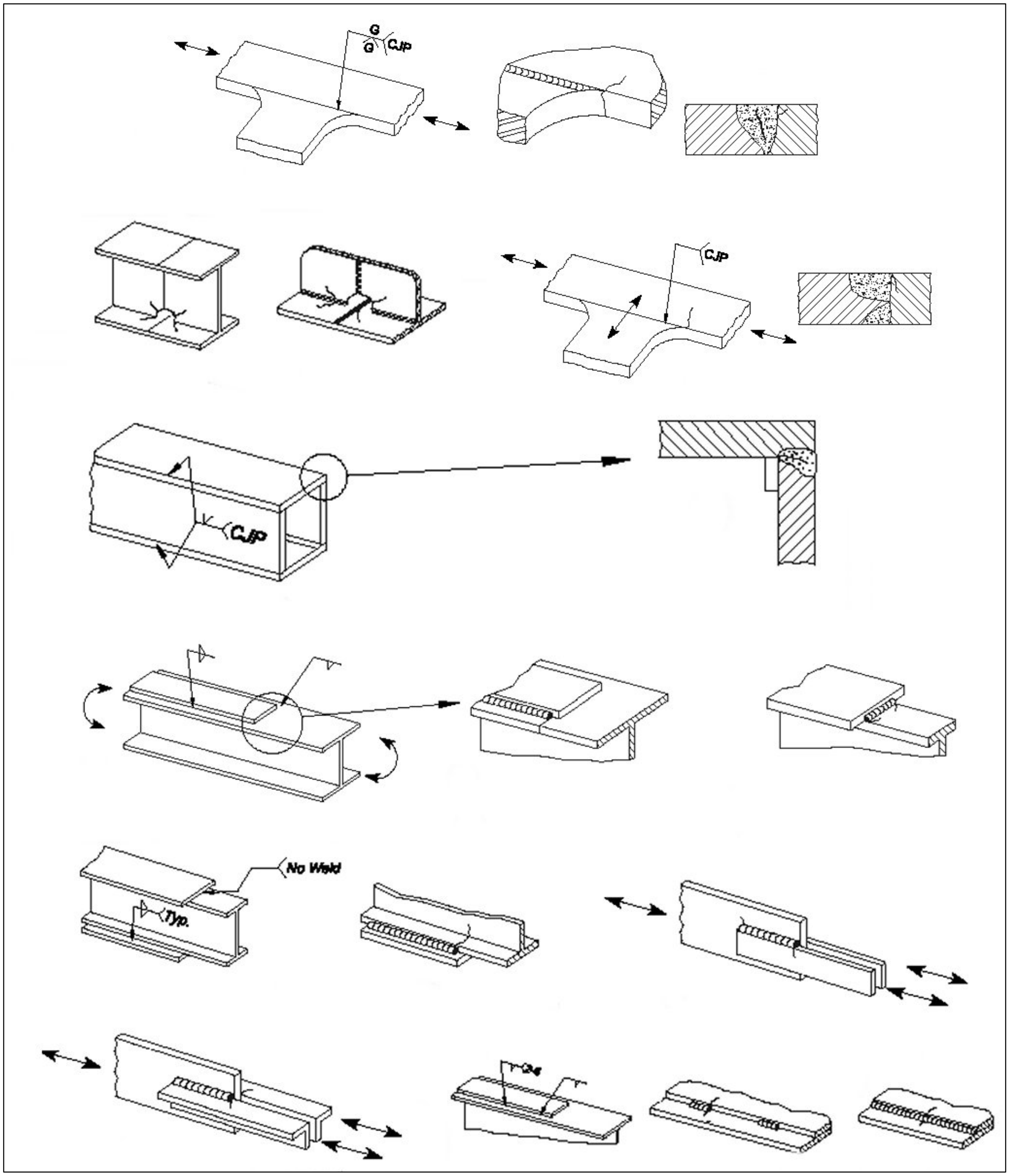

Figure 10-4
Examples of conditions that may result in fatigue cracking
(From Reference 13)

10.8 Attachments Create Discontinuities

In Figure 10-5, there is a tack weld at the bottom of the vertical connection plate. This is the most likely place where the crack started. Tack welds cool rapidly, making the adjacent base metal hard, brittle, and prone to crack.

In Figure 10-5, stress is concentrated at the corners formed by the squaring plate welded to the bottom flange of the end truck. The stress field may be visualized as a set of stream lines analogous to fluid flowing through a duct. Figure 10-6 illustrates the analogy for stress and fluid flow. Abrupt geometry changes, inclusions, gouges, or notches create stress concentrations that are prone to fatigue cracking. Figure 10-7 shows how the stress intensity varies in the flange. Red represents the highest level of stress.

Figure 10-5

The blue arrows point to a crack through the bottom flange of a bridge end truck. This crack may have been caused by the effect of the tack weld (pink arrow) combined with the stress concentration shown in Figure 10-6. See Figure 7-6 for a view of the complete connection.

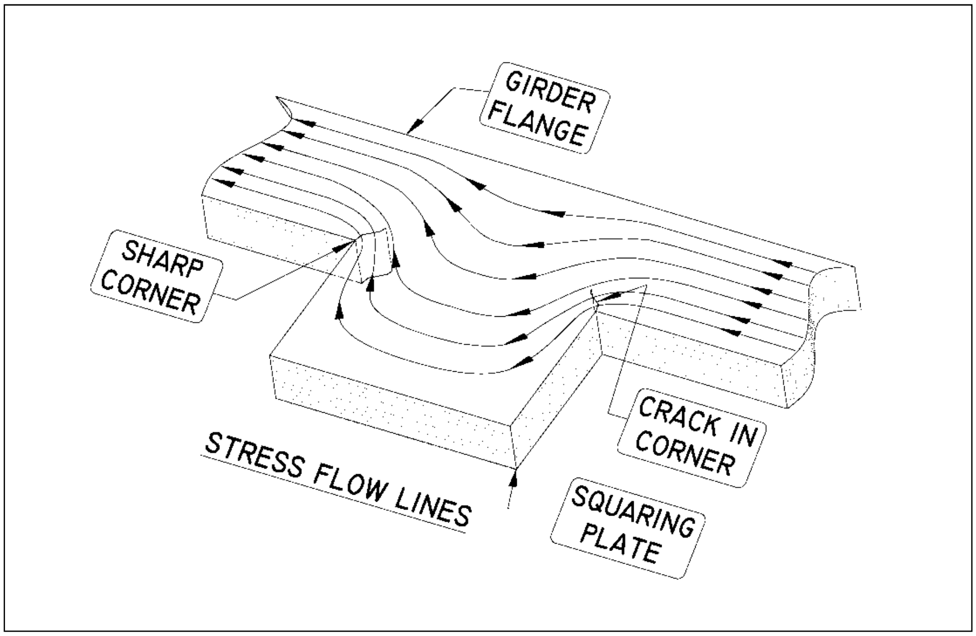

Figure 10-6

Look for sharp corners, notches, and abrupt changes in geometry

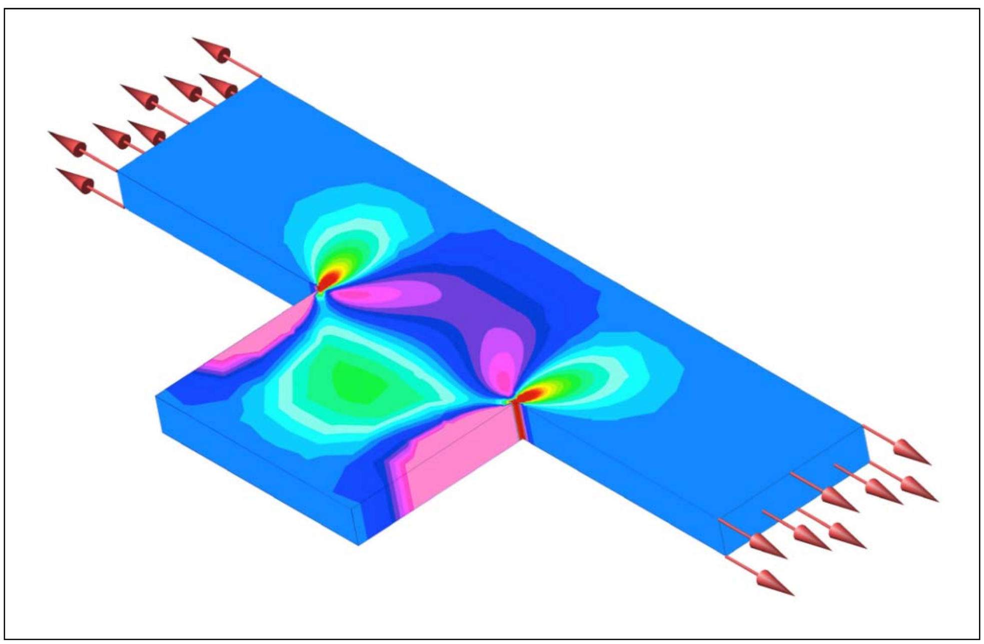

Figure 10-7

This is a qualitative illustration of increased stress caused by a sudden change in the geometry of the load path. The red areas indicate the highest stress.

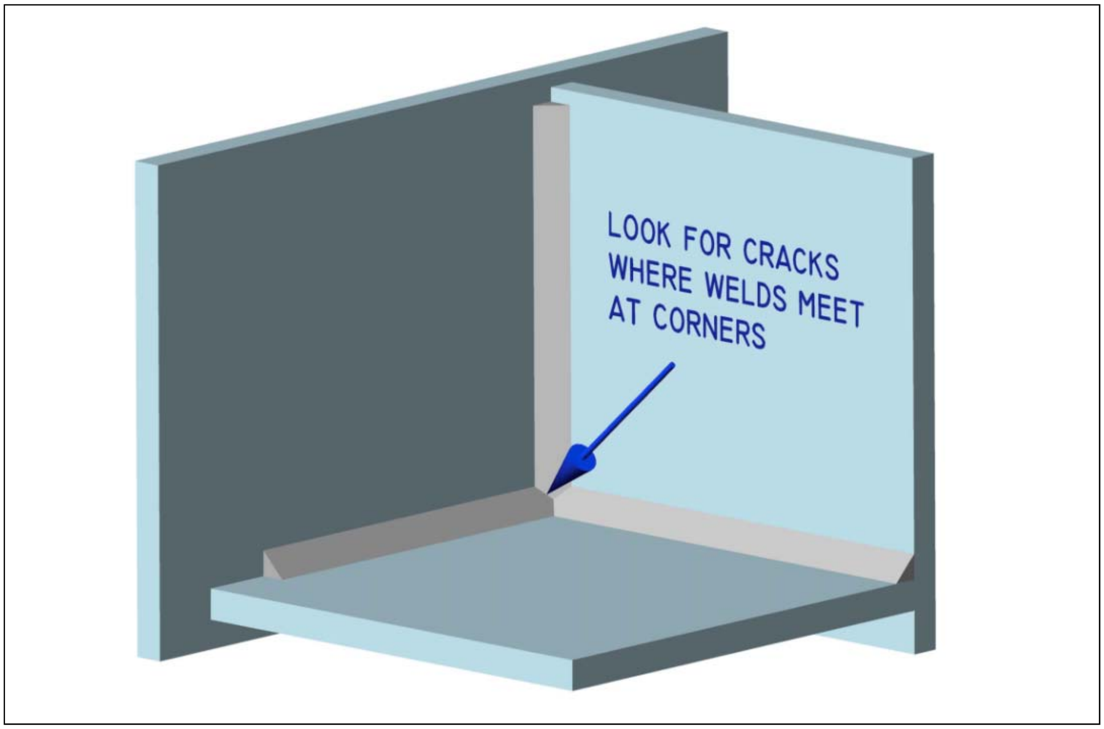

Figure 10-8
A triaxial stress condition is created from longitudinal shrinkage of three welds that meet at a corner.

10.9 Single Failure Points

Be able to recognize single failure points. Look for areas in the main load path where no redundancy exists. The load path is redundant if the failure of one element does not cause complete failure. Redundant load paths have a "backup" structure that can support the load. A chain is an example of a non-redundant structure. If one link in the chain fails, the entire chain has failed. A redundant structure is like a parallel circuit, a non-redundant structure is like a series circuit. Inspection priorities should be for elements of the main load path that are single failure points.

10.10 Manufacturing Quality and Fatigue-Resistant Design Details

Preference should be given to crane builders that have a proven track record for design and manufacture of hard-worked cranes. The crane vendor must have knowledge of the application, and experience with fatigue-resistant design.

High quality welding is important for dynamically loaded crane structures. Geometric imperfections such as undercut, porosity, slag inclusions, incomplete fusion, craters, melted corners, and hydrogen entrapment create stress concentrations. These flaws may cause the adjacent material to yield and crack.

11.0 Trolley Structure Behavior

11.1 Trolley Structure Design

The trolley structure is a framework of beams. Figure 11-1 shows the construction of a simple trolley frame. Each beam member in the frame behaves as shown is Figure 10-1. Locations with the highest tension and shear stress should be inspected. The highest tension stress is located on the bottom surface of each member, at the midpoint of its length. The highest shear stress is at the end of each member. The maximum shear stress in the girt is at the welded connection to the end truck.

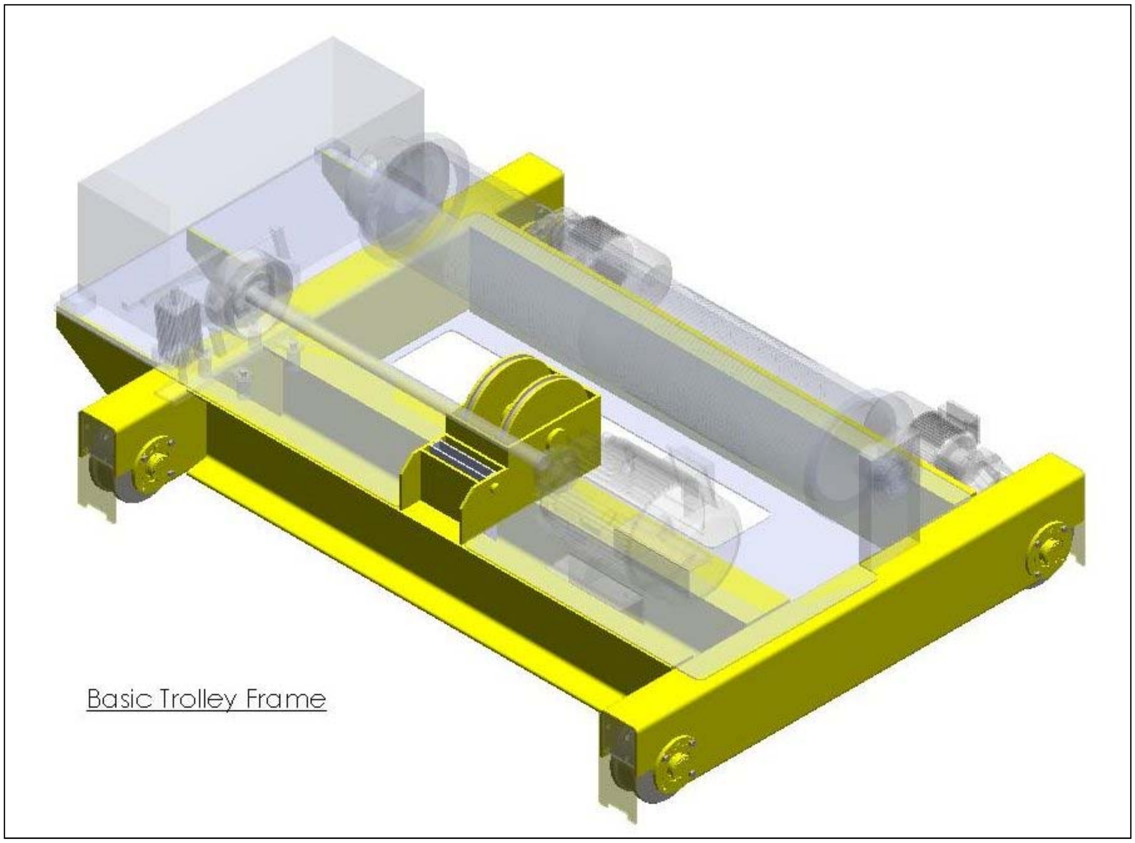

Figure 11-1
Illustration of a simple trolley frame

11.2 Trolley Deflection

When loaded, the trolley frame will deflect as shown in Figure 11-2. Each girt that spans between the end trucks will deflect as shown in Figure 11-2. When girts deflect, their ends rotate and this causes the trolley end trucks to tilt toward each other. The alignment of hoist machinery may be adversely affected if the trolley frame is too flexible. This is especially true for trolley frames with a relatively large span between the trolley rails.

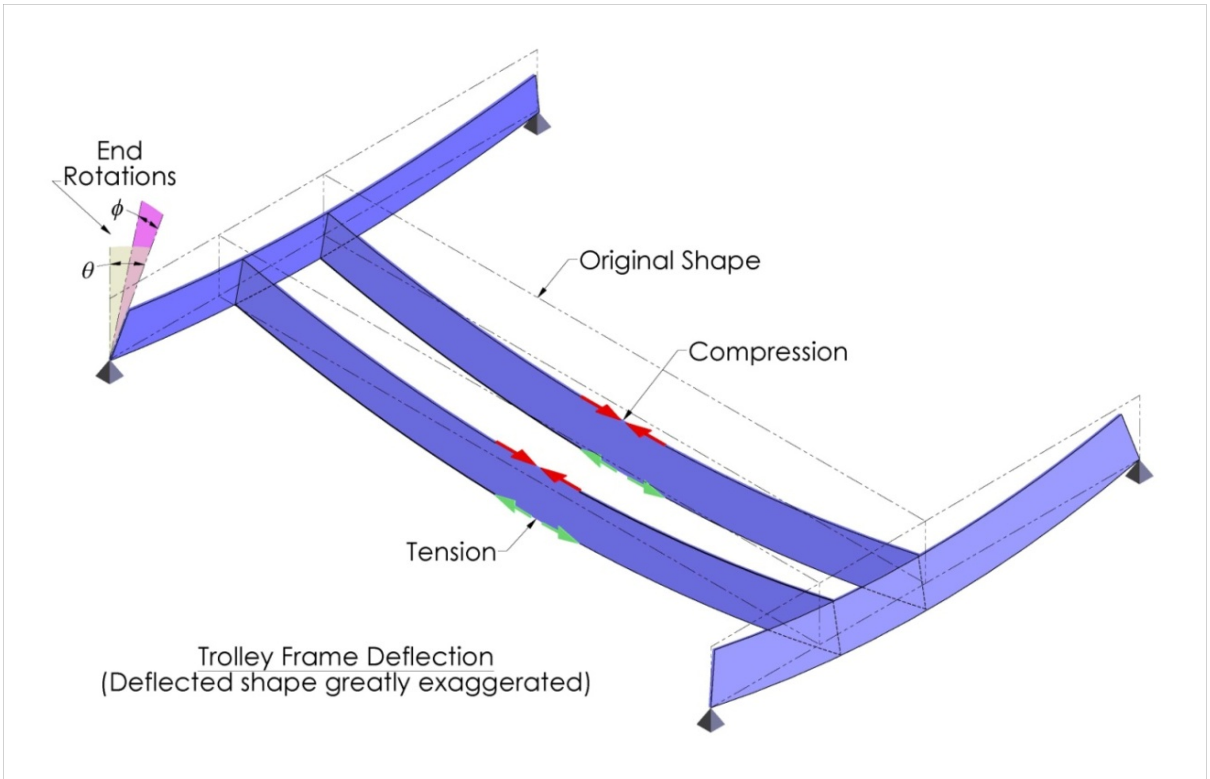

Figure 11-2

12.0 Bridge Structure Behavior

12.1 Bridge Structure Design

Viewed from the top, the bridge structure is a rectangular frame with rigid corners. The bridge girders support the trolley load by bending in a vertical plane between the runway rails. The end trucks or end ties also bend in a vertical plane. For vertical loading, the bridge structure behaves similar to the trolley frame shown in figure 11-2. The bridge end trucks tilt toward each other when the girders bend.

12.2 Bridge Structure Response to Lateral loads and Skewing

The purpose of the bridge frame is to keep the end trucks parallel. See Figure 12-1. Unbalanced accelerations from the bridge drives and lateral bridge wheel forces from tracking cause the frame to skew. Lateral girder bending from trolley inertia (and wind loads) along with skewing, cause the corners of the frame to rotate. The corner rotation steers the wheels into the side of the rail and tracking performance is affected. The bridge girders and end ties (or end trucks) must have enough stiffness to prevent excessive corner rotation of the frame.

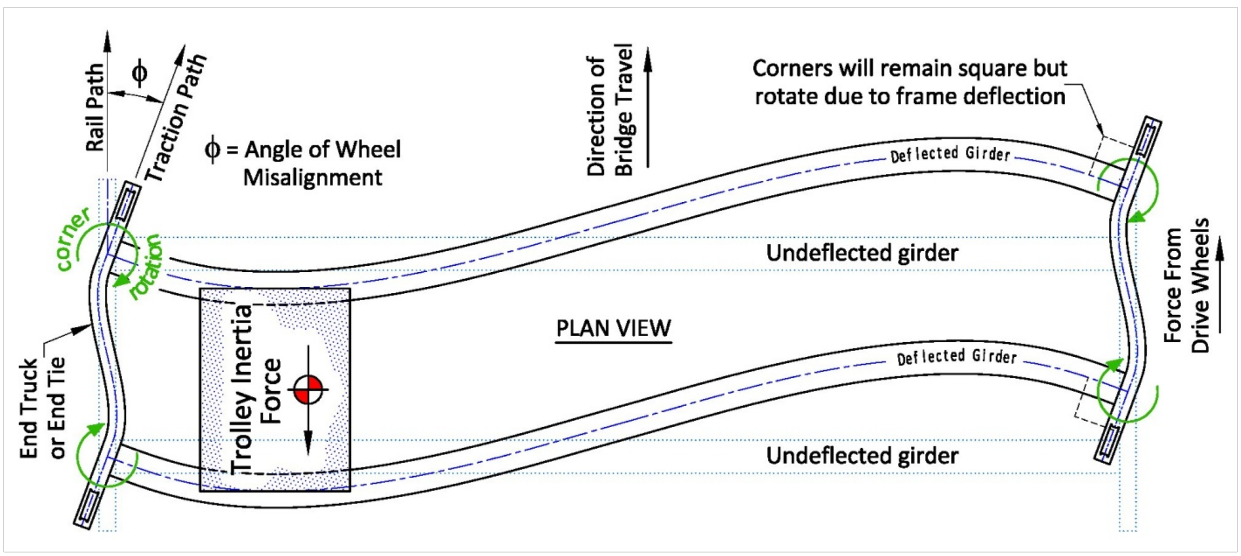

Figure 12-1

13.0 Examples of Crane Structure Damage

Figure 13-1

The span for this bridge was increased by inserting a deeper section at the center of the new span. The dashed lines show the original girder. The horizontal dashed lines show where the original girder flange overlaps the web of the new section. The splice at the other end of the added section did not have a flange overlap, and this is where the failure occurred. The flange overlap creates a transition for the sudden change in girder depth. Without the flange overlap, the reaction force in the bottom flange of the original girder does not have enough of an “anchor”. In this case, the lower flange force was distributed into the diagonal flange plate and the web of the added section. The welded joint in the overlap between the flange of the original section and the web of the new section must be long enough to carry 100% of the force in the bottom flange of the original section.

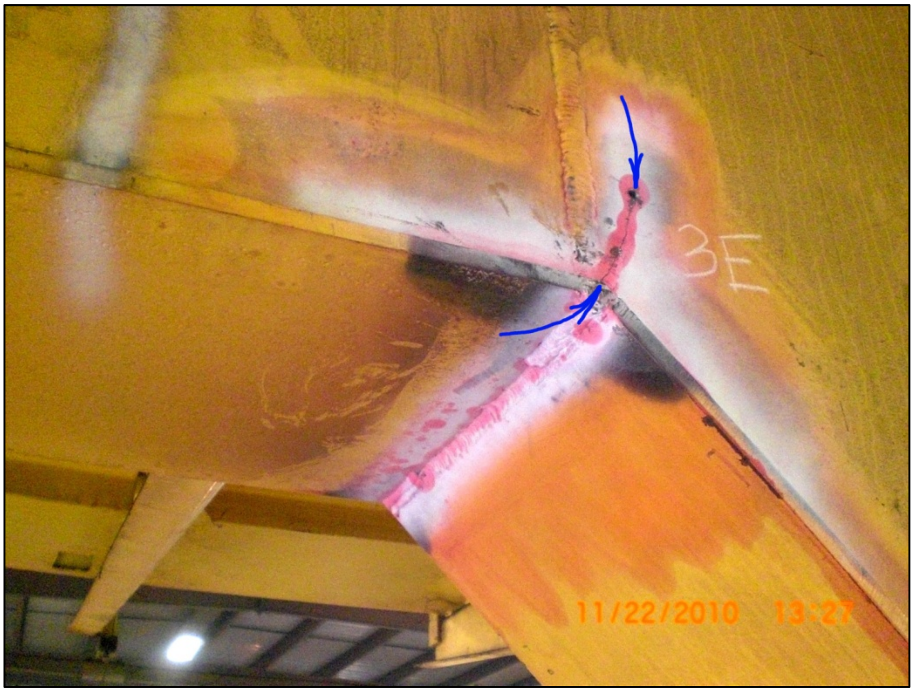

Figure 13-2

This is a close-up of Figure 14-1 showing typical cracking at the splice between the original and added section. The original girder flange was terminated abruptly and welded to the diagonal flange of the inserted section.

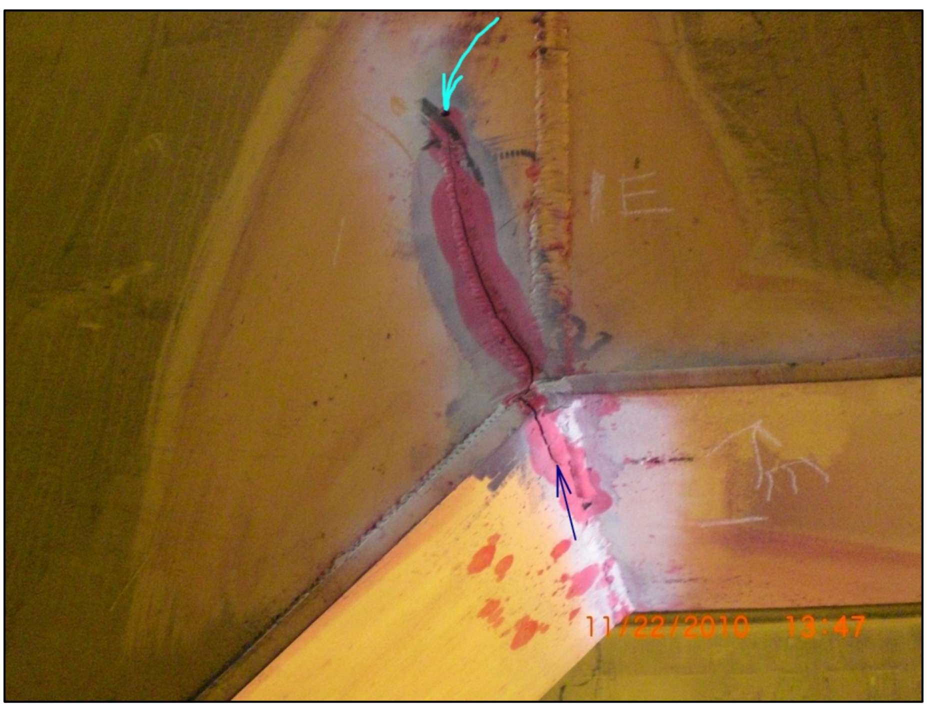

Figure 13-2

It is likely that the crack started at the flange splice, and then propagated into the web of the inserted section. (From Figure 14-1)

Figure 13-3

This is a close-up from Figure 14-1 showing the crack propagating into the web plate of the inserted section. A hole was drilled at the end of the crack to stop propagation. The re-spanned crane had been in service for about 5 years.

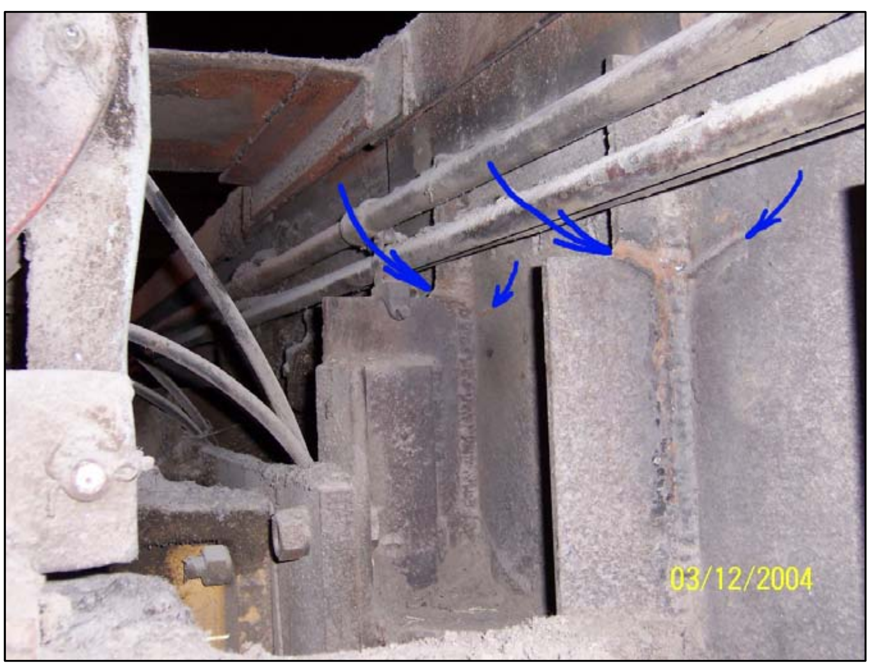

Figure 13-4

These vertical bars support the bridge drive for a high production crane. A similar configuration is shown in Figure 7-2. The bars were trimmed to install the grease lines. The cutting created a notch at the corner which initiated a crack that propagated into the girder web. Due to multiple repairs that could no longer support the load, large sections of the girder web were replaced and the drive mounting was re-designed.

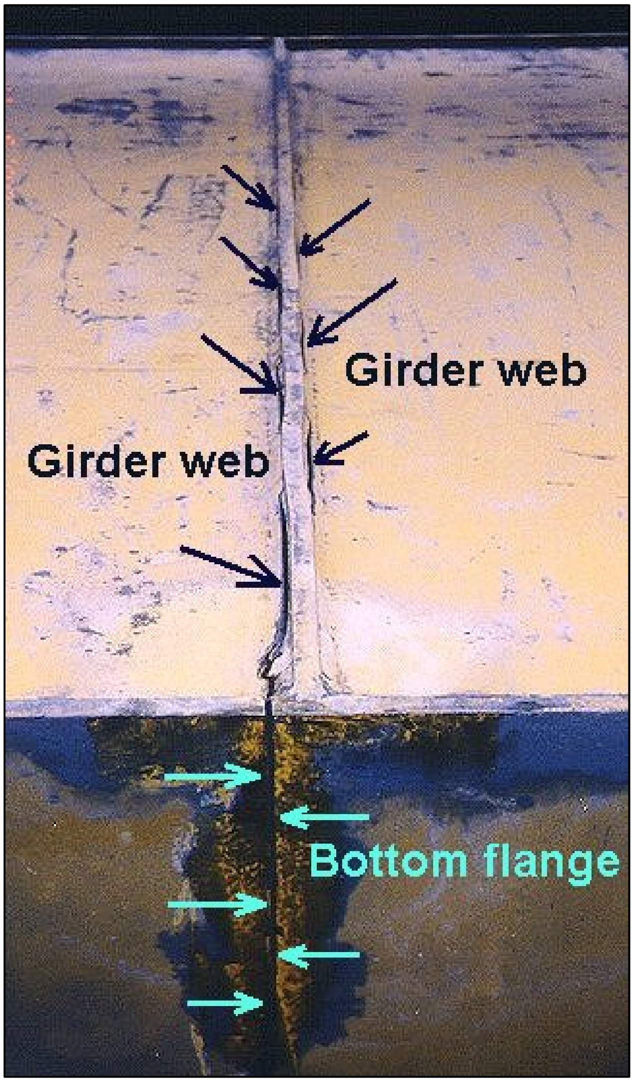

Figure 13-5

This is a bridge girder looking up from below. The vertical edge of a full depth diaphragm is shown. This girder was being used for a class “F” bucket handling crane. The girders were in service only one year before they failed. This failure was due to improper welding and detailing. The girder web consisted of individual plates welded between full depth diaphragms. The vertical edges of the web segments were connected to the full depth diaphragms by intermittent fillet welds. For box girders, most of the bending is carried by the flanges, but web material near the flanges is subjected to nearly the same strain. In this case the strain was tensile near the bottom flange. The tensile force in the web was carried by a single-sided fillet weld to the diaphragm. This caused a cyclic and eccentric loading about the throat of the weld that resulted in rapid failure of the weld. The cracked web welds propagated into the lower flange which caused a complete failure of the girder.

14.0 References

1. Omer W. Blodgett, *Design of Welded Structures,* James F. Lincoln Arc Welding Foundation, Cleveland, Ohio, 1976.

2. Kulak, Fisher, Struik, *Guide to Design Criteria for Bolted and Riveted Joints,* American Institute of Steel Construction, Chicago, Illinois, 2001.

3. American Institute of Steel Construction, *Steel Construction Manual, 9th ed.,*Chicago, 1989.

4. American Welding Society, *Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment, ANSI/AWS D14.1:2005,* Miami, Florida, 2005.

5. American Welding Society, *Structural Welding Code-Steel, ANSI/AWS D1.1:2010,* Miami, Florida, 2010.

6. Research Council on Structural Connections, *Specification for Structural Joints Using ASTM A325 or A490 Bolts,* American Institute of Steel Construction, Chicago, 2004.

7. Charles G. Salmon, John E. Johnson, *Steel Structures, Design and Behavior,* Intext Educational Publishers, New York, NY, 1971.

8. U.S. Department of Transportation, *High Strength Bolts for Bridges, report No. FHWA-SA-91-031,* May, 1991.

9. American Society of Mechanical Engineers, *Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist), ASME B30.2-2005,* New York, NY, 2005.

10. Occupational Safety & Health Administration, *29 CFR Part 1910.179 Overhead and Gantry Cranes.*

11. American Institute of Steel Construction, *Detailing for Steel Construction,* Chicago, 1983.

12. Crane Manufacturers Association of America, Inc., *CMAA Specification No. 78-2002, Standards and Guidelines for Professional Services Performed on Overhead and Traveling Cranes and Associated Hoisting Equipment,* Charlotte, NC, 2002.

13. American Institute of Steel Construction, *ANSI/AISC 360-05, Specification for Structural Steel Buildings,* Chicago, 2005.

14. S. Timoshenko, *Strength of Materials, Part II,* 2nd edition, D. Van Nostrand Co., Inc., New York, 1941.