

# INDOT BRIDGE INSPECTION MANUAL

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## PART 5

### FATIGUE & FRACTURE CRITICAL INSPECTIONS

# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

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### Table of Contents

<b>LIST OF FIGURES...</b>	<b>3</b>
<b>5-5.0 FATIGUE AND FRACTURE CRITICAL INSPECTIONS</b>	<b>4</b>
5-5.01 THE FRACTURE CRITICAL INSPECTION	4
5-5.01(01) <i>Classification of Fracture Critical Members</i>	4
5-5.01(02) <i>Inspector Qualification</i>	5
5-5.01(03) <i>Inspection Interval</i>	6
5-5.01(04) <i>Inspection Preparation</i>	6
5-5.01(05) <i>Field Inspection</i>	6
5-5.01(06) <i>Field Inspection Reporting</i>	9
<b>FIGURES</b>	<b>10</b>

# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

---

### LIST OF FIGURES

<u>FIGURE</u>	<u>TITLE</u>
Figure 5:5-1:	Fracture Critical Truss Connection
Figure 5:5-2:	Fracture Critical Floor Beam Connection
Figure 5:5-3:	Fracture Critical Connection at Through Girder
Figure 5:5-4:	Example Inspection Plan Sketch (Truss)
Figure 5:5-5:	Example Inspection Plan Sketches (Through Girder)
Figure 5:5-6:	Typical Pin and Eyebar Details
Figure 5:5-7:	Forged Eyebar with Extensive Section Loss

# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

---

### 5-5.0 FATIGUE AND FRACTURE CRITICAL INSPECTIONS

#### **5-5.01 The Fracture Critical Inspection**

Proper identification, classification, inspection, and reporting of all fracture critical bridges and the required close-up, arms-reach inspection of the fracture critical members, components, and connections are crucial to the longevity of Indiana's bridges and the safety of the public. Uniformity in reporting will allow the inspectors to monitor any problems accurately and closely throughout the life of the structure. Detailed and accurate reporting also allows the bridge owner to maintain a comprehensive history of the service life of each bridge containing fracture critical members, components, and connections, and all corrective actions done for the bridge before major problems evolve.

#### **5-5.01(01) Classification of Fracture Critical Members**

The FHWA defines a fracture critical member as a steel member either fully in tension or with a tension element, whose failure would probably cause either a portion of, or the entire, bridge to collapse. A fracture critical bridge is one that contains one or more non-load path redundant steel tension member, component, or connection. The FHWA presents two criteria for identifying a fracture critical bridge:

1. The bridge must have one or more steel members, components, or connections in tension. These loading conditions may include tensile forces and flexure. Load analysis may indicate that some members experience a stress reversal (varies from tension to compression) under various loads. Such members shall be included under these criteria.
2. There must be no load path redundancy of the bridge, in which no other structural elements can carry the load if a main load-carrying member fails. For a bridge to be defined as non-load path redundant, it must have two or less load paths.

Some bridge types that may be considered fracture critical include, but are not limited to, the following types:

1. Truss bridges (such as deck, through, and pony trusses) containing two main load-carrying members
2. Through girder bridges
3. Two-girder bridges
4. Tied arch bridges
5. Box girders
6. Cable-stayed bridges
7. Suspension bridges

# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

---

8. Steel rigid frame bridges
9. Bridges containing steel cross-girders or steel pier caps

See Appendix 5A for examples of fracture critical bridges, components, bending diagrams, typical crack locations, and typical pin-and-hanger parts.

Timber covered bridges (trusses) with steel vertical tension hangers shall have Critical Feature Inspection Item 92A coded “N” unless a structural analysis determines these hangers as primary fracture critical members. Otherwise, they are a non-fracture-critical secondary member.

Once a bridge is designated as fracture critical, each individual member and connection determined by structural analysis as a fracture critical member, component, or connection must be identified for the inspection. Any attachment connected to the tension area of a fracture critical member and having a length in the direction of the tension stress greater than four inches shall be considered part of the tension component and, therefore, shall be considered fracture critical. For definition purposes and uniformity in reporting, the portions of the fracture critical member within a minimum of 12 inches of the entire connection (gusset plates, connection plates, etc.) shall be considered a fracture critical **connection**, whereas the portion of the tension member beyond the 12-inch window shall be considered a fracture critical **member**. See Figures [5:5-1](#), [5:5-2](#) and [5:5-3](#) for examples of this definition. The Inspection Team Leader shall use sound judgment to expand the minimum 12-inch criteria to include additional fatigue details and consider the scale of the bridge and associated members. Floor beam connections, lateral bracing connections, bearings, gusset plates, connection angles, pins, hangers, etc. are all typically considered a part of the fracture critical connection.

In the event the original design plans of a fracture critical bridge clearly indicate that a tension member is not fracture critical due to internal redundancies within the bridge, these members will still require a detailed inspection as part of the overall Fracture Critical Inspection. These tension members may only be omitted from the Fracture Critical Inspection if permission is given by both the owner and the State Program Manager.

### 5-5.01(02) Inspector Qualification

All Inspection Team Leaders for fracture critical bridges must:

1. Meet requirements in Part 1, Chapter 2
2. Possess adequate knowledge and understanding of how a fracture critical bridge functions, and where possible defects may occur
3. Possess suitable knowledge of the function of the specific bridge undergoing the inspection and, subsequently, the more complex bridges will warrant more knowledgeable,

# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

---

experienced inspectors; knowledge includes the understanding and ability to perform testing or recommend advanced testing procedures at problem areas; must be current on issues with the type of bridges being inspected

4. Physical ability to provide a hands-on inspection of all fracture critical members and their appurtenant connections in the individual bridge

### 5-5.01(03) Inspection Interval

Fracture Critical Inspections shall be performed at a regular interval not to exceed 24 months. If necessary, the inspection interval may be reduced.

### 5-5.01(04) Inspection Preparation

The fracture critical Work Plan and Hazard Analysis must be developed and/or reviewed and updated prior to performing a Fracture Critical Inspection. This inspection work plan plays a crucial role in assisting all current and future inspectors at the bridge, and serves as an important first step in performing a thorough and complete investigation of all fracture critical members, while identifying necessary means, methods, and equipment required to perform this inspection. This inspection work plan is a required element for every fracture critical inspection report. These minimum requirements must be met for acceptance of the report by the Indiana Department of Transportation (INDOT). A Fracture Critical Inspection Notes and Report template is included in Appendix 5B of this manual. A Fracture Critical Work Plan and Hazard Analysis template is included in Appendix 5C.

Other items that should be reviewed and made available to the inspector, if available, prior to the inspection include the following:

1. Existing bridge plans and any repair/rehabilitation plans
2. Historical data and maintenance history of the bridge
3. Prior load ratings or a preliminary load rating (invaluable in determining fracture critical members)
4. Prior inspection reports

Note: Panel points are typically labeled beginning from South to North or from West to East in [Figure 5:5-4](#).

### 5-5.01(05) Field Inspection

The National Bridge Inspection Standard requires a hands-on inspection of all fracture critical

# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

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members, components, and connections. Hands-on is defined as being within arm's reach (i.e. two feet) of these components. The hands-on inspection requirement warrants the utilization of ladders, man lifts, climbing, and under-bridge vehicles to inspect all fracture critical members, components, and connections. Cracks and other deficiencies cannot be adequately located and inspected with the utilization of binoculars or outside of the inspector's reach from the member.

Primary compression members, floor beams, and secondary members such as lateral bracing, portal bracing, etc. are not considered fracture critical. These items require inspection and reporting during the Routine Inspection cycle. However, special consideration should be given to ensure that all primary and secondary members are inspected during the Routine or Fracture Critical Inspection so that no members are missed during the entire inspection cycle. At a minimum, the Inspection Team Leader should perform a brief walkthrough of all secondary and non-fracture critical primary members during the Fracture Critical Inspection as a simple means to ensure all members have been inspected. When expensive equipment such as an under-bridge vehicle or man lift is utilized during the Fracture Critical Inspection, the Inspection Team Leader should strongly consider and plan to utilize this equipment for the inspection of any difficult-to-inspect, non-fracture critical members or problem areas on the bridge.

It is imperative that the inspector adequately identify and inspect each fracture critical member and fatigue detail. Inspection for fatigue cracks in welded bridges should be performed at, but not limited to, the following locations:

For out-of-plane distortion in welded bridges, inspect the following locations if present:

1. Girder webs at floor beam and diaphragm connections
2. Ends of diaphragm connection plates in girder bridges
3. Box girder webs at diaphragms
4. Lateral bracing gusset plates on girder webs at floor beam connections
5. Floor beam and cantilever bracket connections to girders
6. Pin-connected hanger plates and fixed-pin plates

For main members in welded bridges, inspect the following locations, if present:

1. Ends of welded cover plates
2. Groove welds in flange plates
3. Butt welds in longitudinal stiffeners
4. Web plates with cut-outs and filler welds
5. Intersecting groove welds
6. Welded repairs and reinforcement

# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

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7. Back-up bar splices
8. Other stress risers

For connections and attachments in welded bridges, inspect the following locations, if present:

1. Cut short flanges
2. Coped beam ends
3. Blocked flange plates
4. Welded rigid connections of cross-girders at bents
5. Welded flange attachments
6. Intersecting welds at gusset plates and diaphragms

In general, the locations where fatigue cracks develop in riveted and bolted bridges are like those in welded bridges. Inspection for fatigue cracks in riveted or bolted bridges should be performed at, but not limited to, the following locations:

1. Rivets/bolts at end connections (check for cracking and prying)
2. End connection angle
3. Girder webs at floor beam connections
4. Floor beam connections to girders
5. Diaphragm connections to girders
6. Cantilever bracket connections to girders
7. Truss hangers
8. Eyebars (see [Figures 5:4-6](#) and [Figures 5:4-7](#))
9. Tack welds
10. Rivet heads and bolts made of certain types and ages of steel on older bridges may have fatigue issues, especially if pack rust has developed between connection members; additional stress may be placed on the nut or rivet head at these locations

The thickness of primary truss gusset plates shall be measured as a part of a Fracture Critical Inspection. If the section cannot be adequately measured with traditional measurement devices, inspectors should use an appropriate NDT technology to assess the gusset plate condition and quantify the plate thickness.



# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

---

### 5-5.01(06) Field Inspection Reporting

Each bridge owner has unique requirements and preferences for bridge reporting. The guidelines listed in this section are the minimum reporting requirements for acceptance of a fracture critical inspection report. Although these minimum requirements must be met for acceptance of the report by INDOT, the inspecting agency may provide alternate report formats meeting internal guidelines, if the criteria set forth in this chapter are met. A template Fracture Critical Bridge Inspection report has been provided in Appendix 5B, and a template Fracture Critical Work Plan and Hazard Analysis has been provided in Appendix 5C. The following are minimum requirements for a Fracture Critical Inspection report:

1. Fracture Critical Framing Plan/Diagram identifying all fracture critical members, components, and connections
2. Fracture Critical Inspection Notes and Report (Appendix 5B for template)
3. Fracture Critical Work Plan and Hazard Analysis (Appendix 5C for template)
4. Location Map (BIAS)
5. National Bridge Inspection Data and Item Codes (BIAS)
6. Element Quantities and Condition State Quantities, if applicable (BIAS)
7. Overall condition photographs
8. Photographs of every fracture critical member, connection, or component assigned a condition rating of 4 or less
9. Photographs of each fracture critical member at a frequency of not greater than 10 years (to be included in the bridge file)
10. Photographs of any cracks inspected
11. Documentation of inspection results within the Fracture Critical Inspection Notes and Report; specifically, within the “Table of Fracture Critical Elements Inspection Findings” summary table for each individual fracture critical member, component, and connection, to include the following:
  - a) Individual member rating
  - b) Noted areas of section loss; report section remaining
  - c) AASHTO fatigue category
  - d) Brief condition statement, including the presence of any cracks
  - e) Documentation of fatigue damage

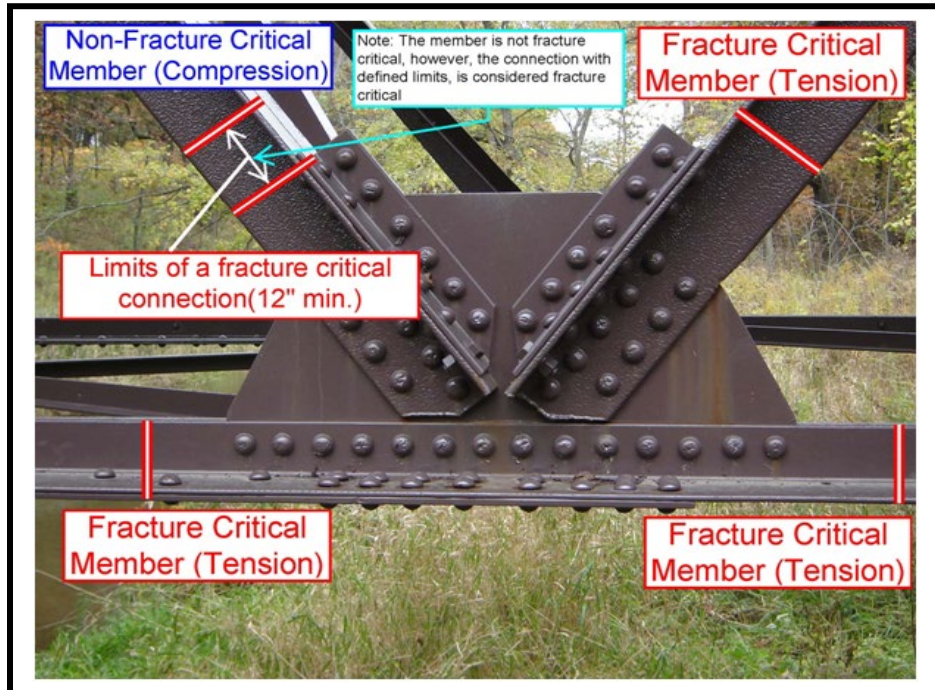
# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

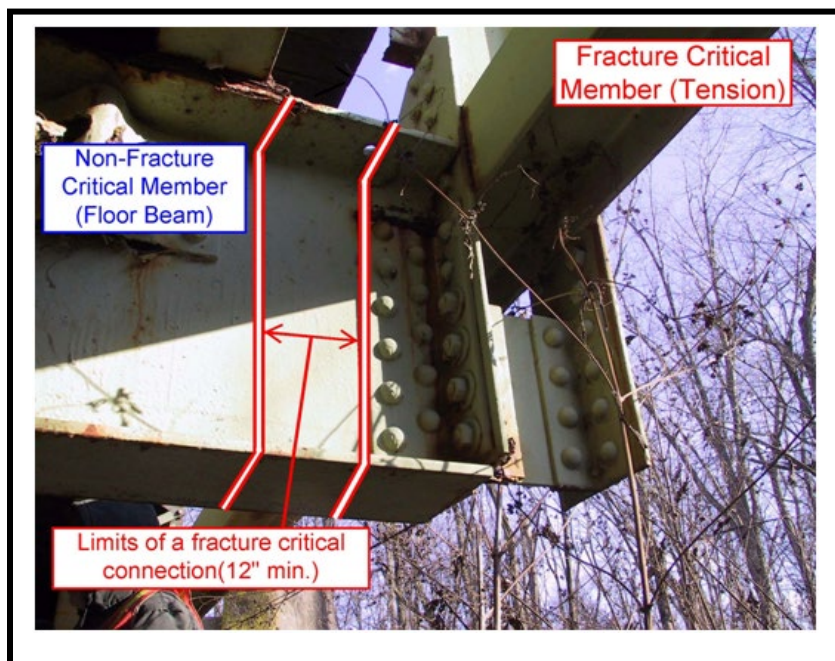
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### FIGURES

**Figure 5:5-1: Fracture Critical Truss Connection**



**Figure 5:5-2: Fracture Critical Floor Beam Connection**



# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

Figure 5-5-3: Fracture Critical Connection at Through Girder

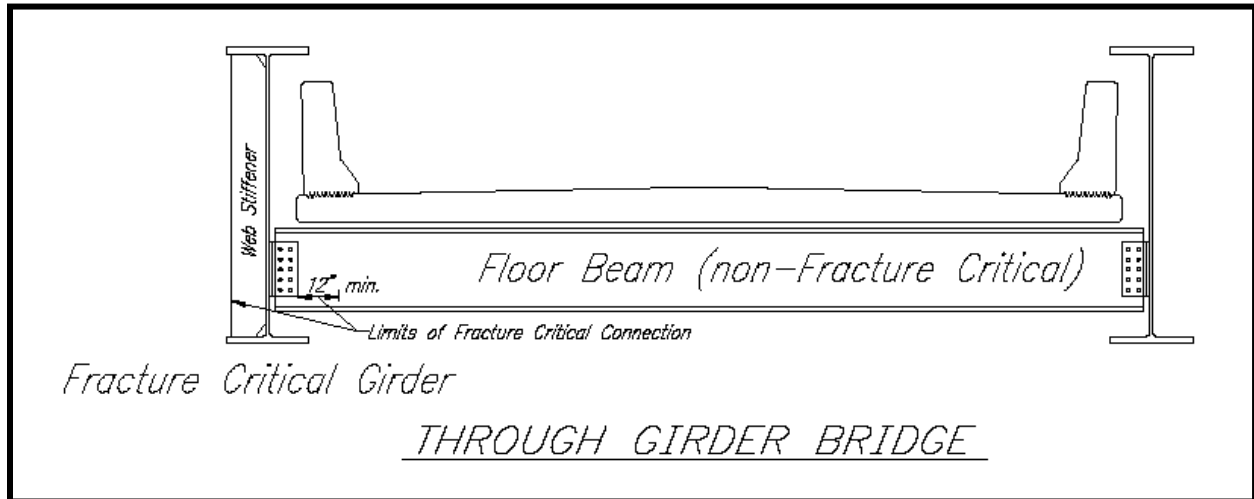
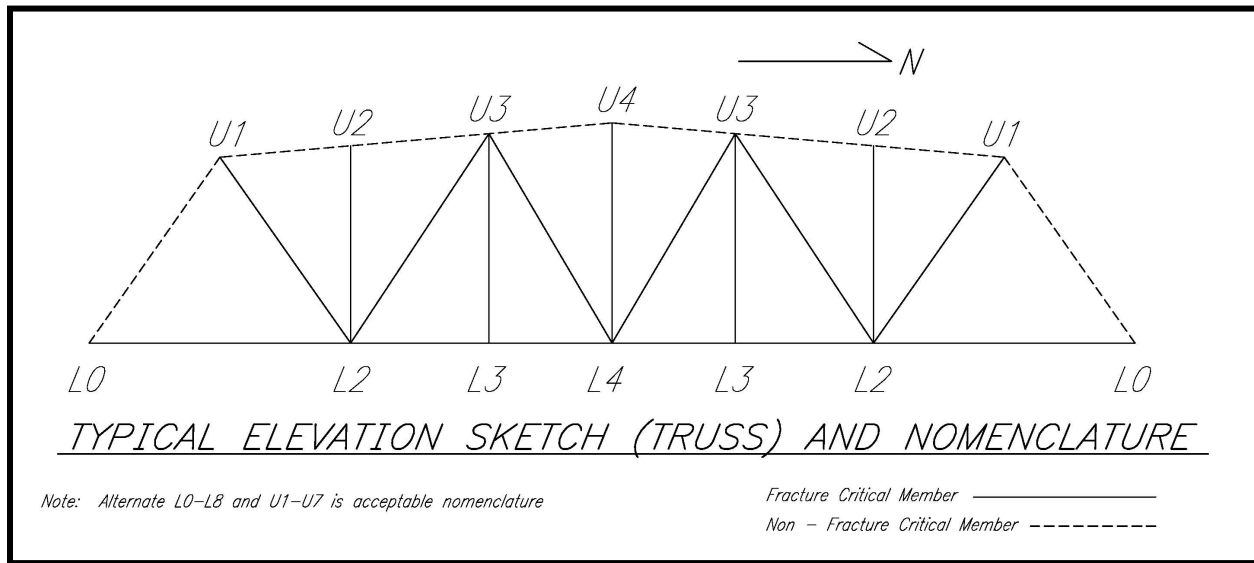


Figure 5-5-4: Example Inspection Plan Sketch (Truss)



# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

Figure 5-5-5: Example Inspection Plan Sketches (Through Girder)

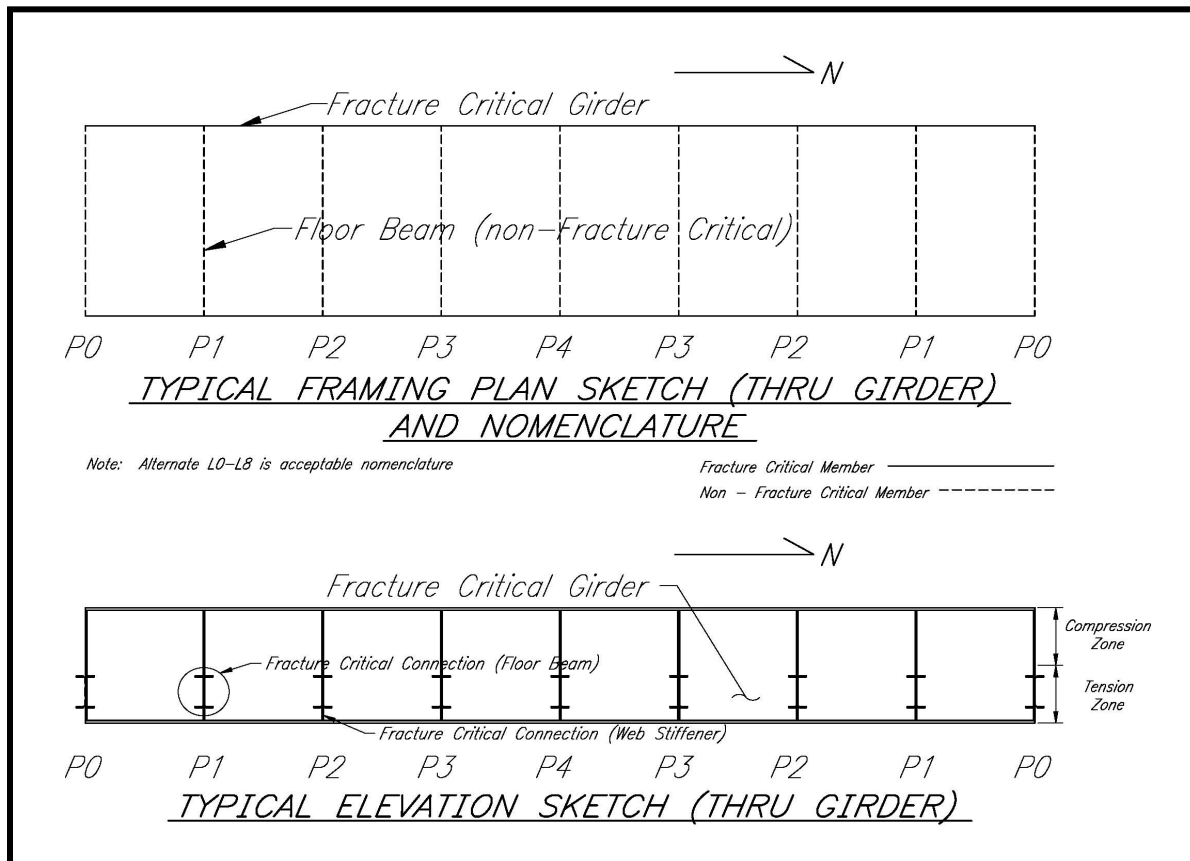
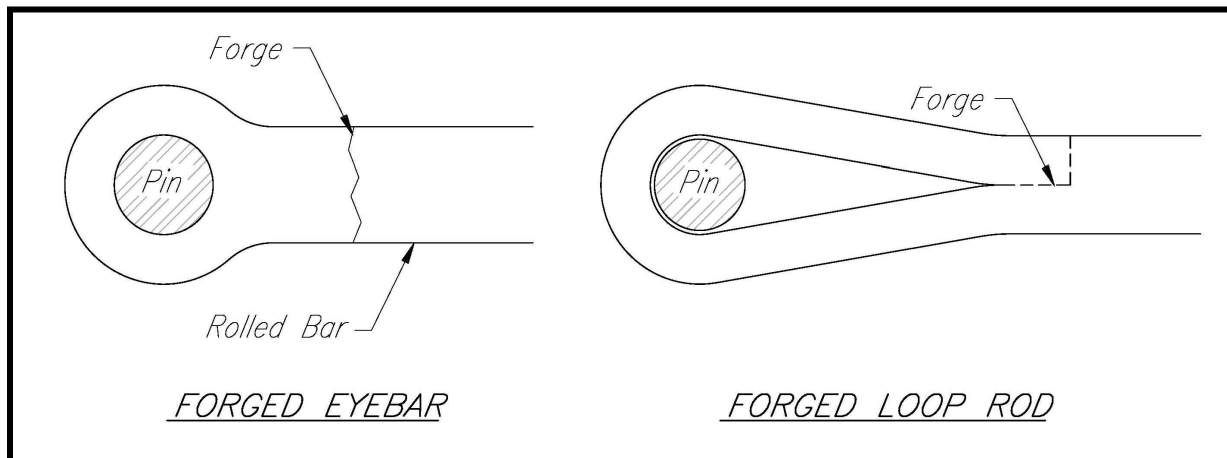


Figure 5-5-6: Typical Pin and Eyebars Details



# BRIDGE INSPECTION MANUAL

## PART 5: BRIDGE INSPECTION

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**Figure 5-5-7: Forged Eyebar with Extensive Section Loss**

