Participant Workbook

Section 8

Inspection and Evaluation of Steel Superstructures

Topic 8.6A

Inspection & Evaluation of Truss Gusset Plates

Course No. 130055

Safety Inspection of In-Service Bridges

Lesson Duration	85 Minutes (Includes 35 minute class exercise)
Participant Materials	Participant Workbook Pencil

Participant Notes:

Background Information

NTSB Safety Recommendation, HAR-08-03, November 14, 2008, http://www.ntsb.gov/publictn/2008/HAR0803.pdf

Technical Advisory "Load-carrying Capacity of Gusset Plates in Non-load Path Redundant Steel Truss Bridges" http://www.fhwa.dot.gov/legsregs/directives/techadvs/t514029.htm

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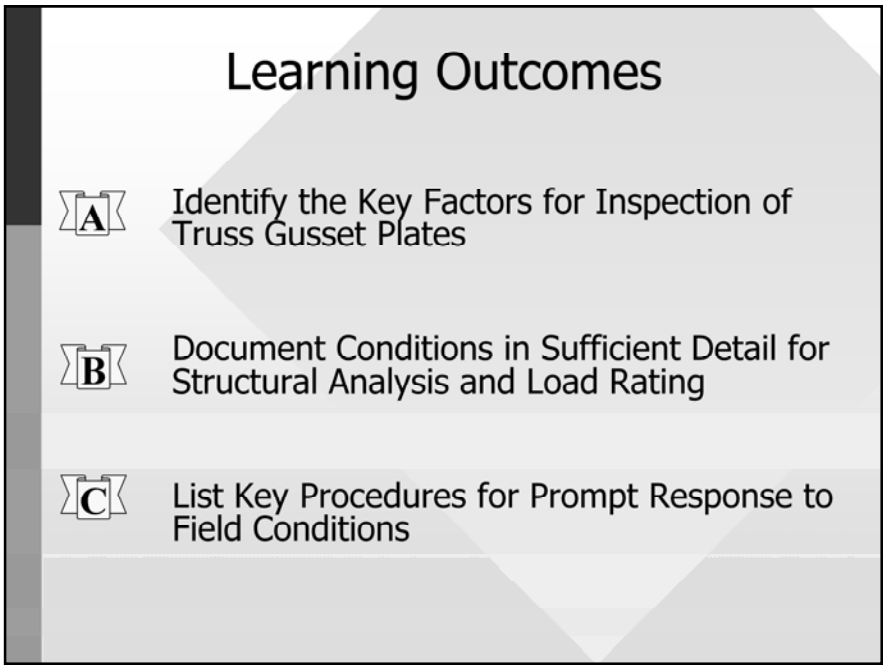
On Wednesday, August 1, 2007, the Interstate 35W (I-35W) highway bridge over the Mississippi River in Minneapolis, MN collapsed after experiencing a superstructure failure in the 1,000 foot long deck truss portion of the structure.

The ensuing NTSB investigation discovered the original design process led to a serious error in sizing of some of the gusset plates in the main trusses. These gusset plates were roughly half the thickness required.

This design error was not detected during the internal review process conducted by the design firm responsible for the original design in the early 1960's.

The NTSB concluded that the bridge was designed with undersized gusset plates, and the design firm did not detect the error when the plans were created. Because of this error, the riveted gusset plates became the weakest link in the structural system.

Although inspections conducted in accordance with the NBIS are not designed or expected to uncover such design related problems, this bridge catastrophe has raised much awareness in the safety inspection of truss gusset plates.



Participant Notes:

Background Information

NA

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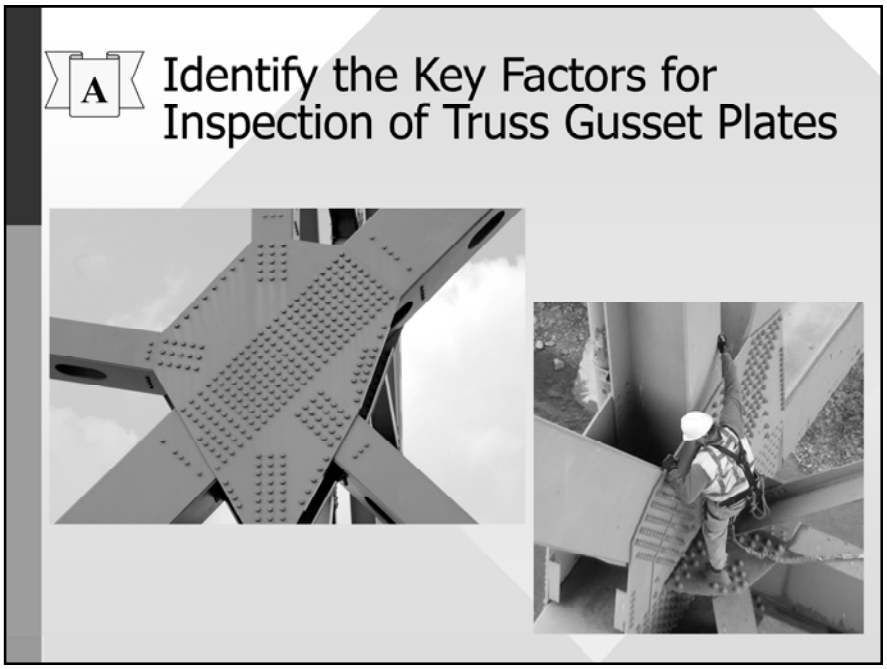
Learning Outcomes

A. Identify the Key Factors for Inspection of Truss Gusset Plates
   - "What to look for"
   - "How to look" – tools and techniques
   - How to document findings – sketches and notes

B. Document Conditions in Sufficient Detail for Structural Analysis and Load Rating
   - Compare to original drawings and account for defects found during inspection

C. List Key Procedures for Prompt Response to Field Conditions
   - Analysis
   - Posting/closing
   - Revised inspection schedule



Participant Notes:

Background Information

NA

Participant Workbook

A panel point is the location where the truss members are connected together. The connections are typically made using gusset plates and are accomplished by riveting, bolting, welding or a combination of these methods.

There are usually two types of gusset plates. The first type connects truss members (chords, diagonals, verticals) and the second type connects bracing members to the truss.

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What to Look For

- Compare actual gusset plate findings to original drawings
- Out-of-plane distortion of gusset plates
- Coating system failures
- Gusset plate corrosion and section loss
- Cracked gusset plates and tack welds
- Loose, missing, or deteriorated fasteners
- Repairs and/or retrofits

Participant Notes:

Background Information

NA

Actual versus Planned

- Measure Gusset Plates / Fasteners and compare dimensions to planned design or As-built drawings
- Record Defects

Participant Notes:

Background Information

NA

Participant Workbook

The inspector will be responsible for practicing good and thorough documentation.

Measure the gusset plates and fastener dimensions and compare to the planned design. The accuracy of measurements should be within a tolerance 1/16".

Record defects such as :

- Out-of-plane distortion
- Coating system failure
- Section loss
- Cracks
- Fastener condition
- Presence of repairs or retrofits

Note: The required measurements above are normally required to be taken only once if a rating is to be performed. The measurements should be included in the permanent Bridge File records.

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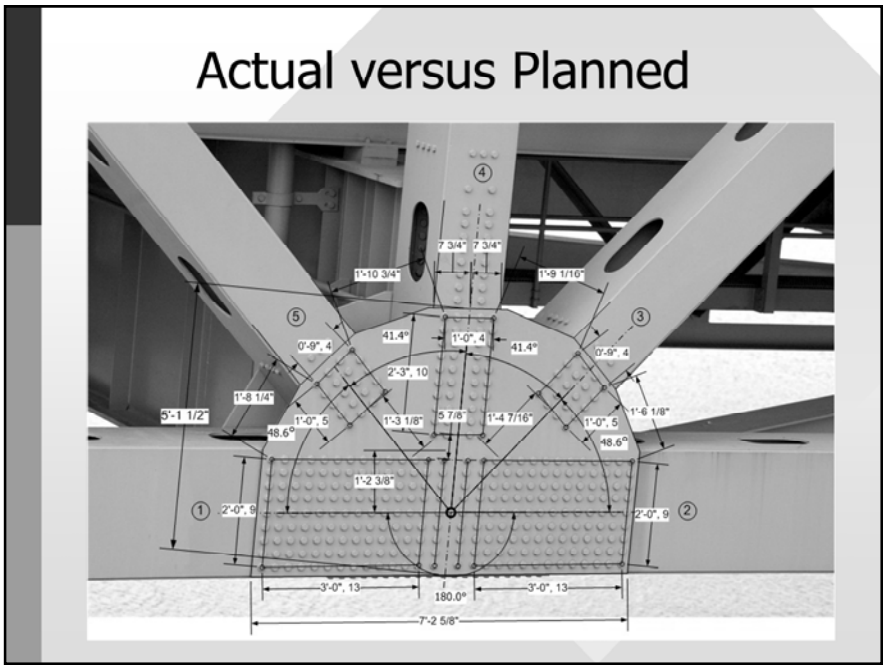
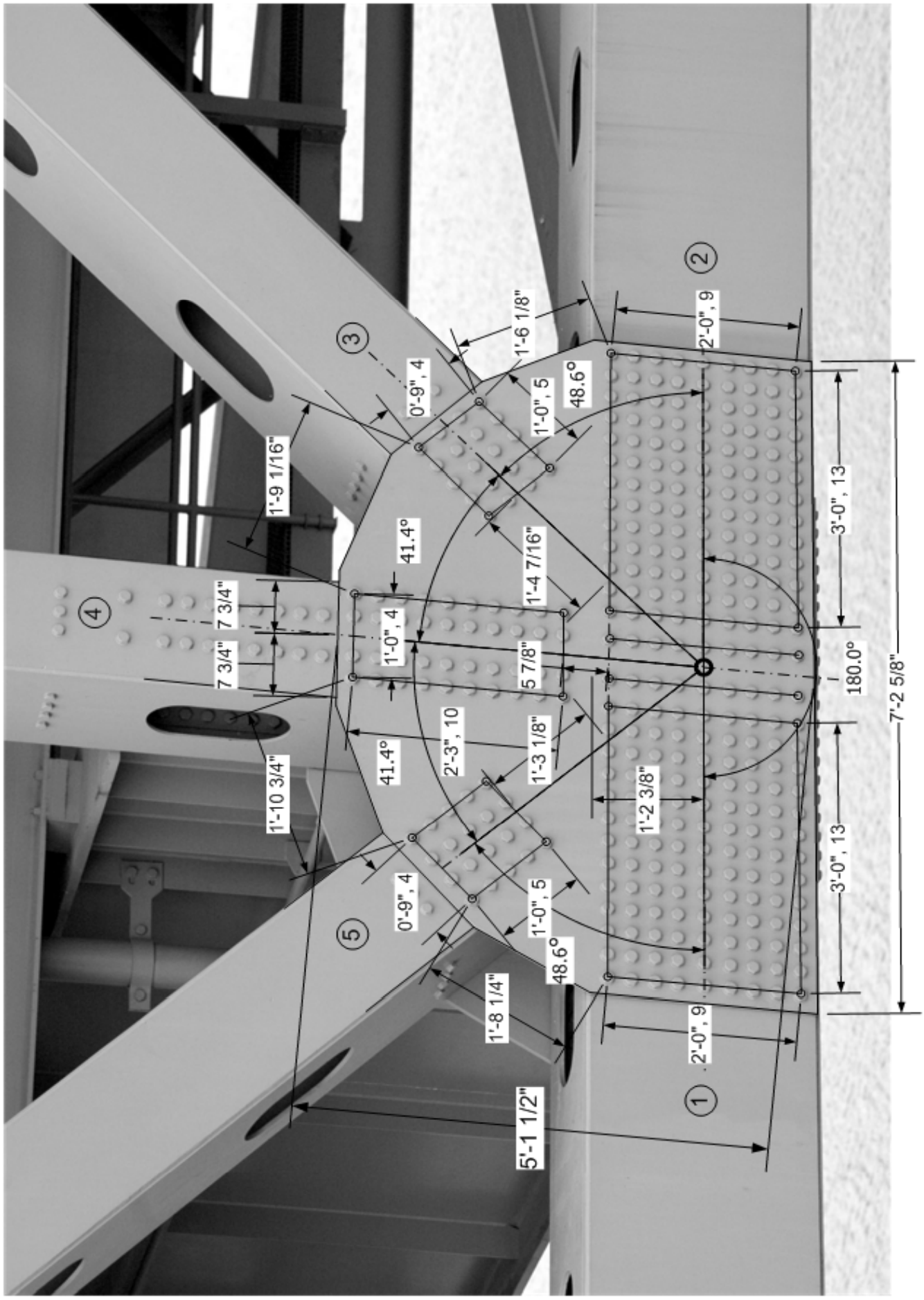


Compare the dimensions that were taken in the field to the dimensions on the planned design or As-built drawings of the gusset plate.

Participant Notes:

Background Information

NA


1
2
3
4
5
2'-0", 9
2'-0", 9
3'-0", 13
3'-0", 13
7'-2 5/8"
180.0°
1'-2 3/8"
1'-6 1/8"
1'-0", 5
48.6°
1'-0", 5
48.6°
0'-9", 4
0'-9", 4
1'-4 7/16"
1'-3 1/8"
5 7/8"
1'-0", 4
41.4°
41.4°
2'-3", 10
1'-9 1/16"
1'-10 3/4"
1'-8 1/4"
5'-1 1/2"
7 3/4"
7 3/4"

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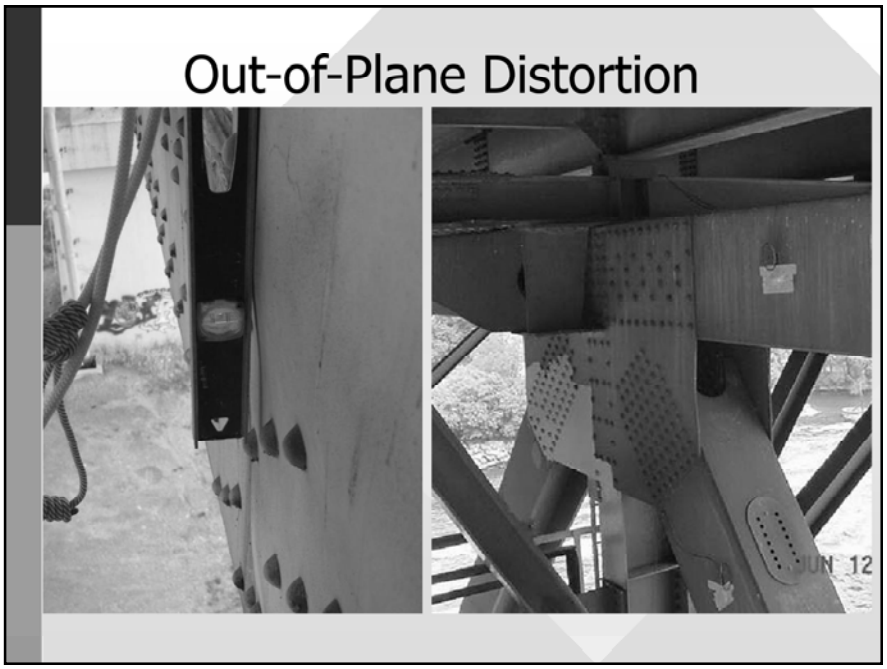


Participant Notes:

Gusset plate distortion can be caused by overstressing of the plate due to overloaded vehicles or inadequate bracing during the initial erection. Other causes include fit of the connected members, section loss due to corrosion, design error, increased dead load, etc. These can be broken down into two categories…geometry driven and load driven.

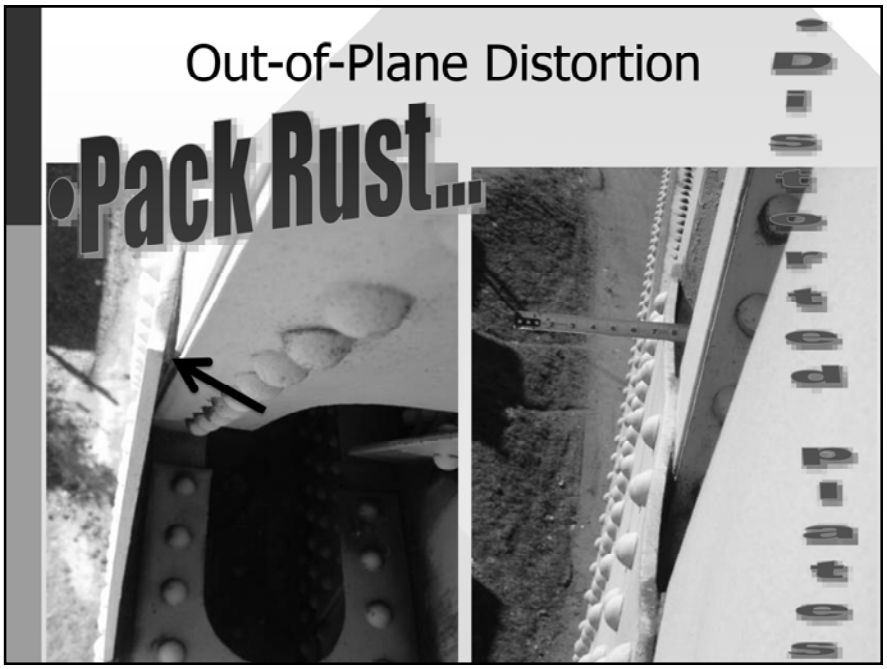
A straight edge should be used to evaluate and quantify any distortion of the un-braced gusset plate edges between members. Gusset plates on both sides of a given truss member should be checked for out-of-plane distortion. Any distortion found needs to be documented with respect to a common reference.

Measure and indicate the amount of plate distortion by measuring from the straight edge to the plate. Set up a reproducible reference system to record measurements against. Measurements of the distorted gusset plates are to be measured from a reference point on the plate. This reference point should be used in subsequent inspections to provide findings based on a consistent point.

Background Information

NA

Participant Workbook



Pack rust (corrosion) is formed between two mating steel surfaces when there are the correct combinations of moisture, oxygen and failure of the protective coating.

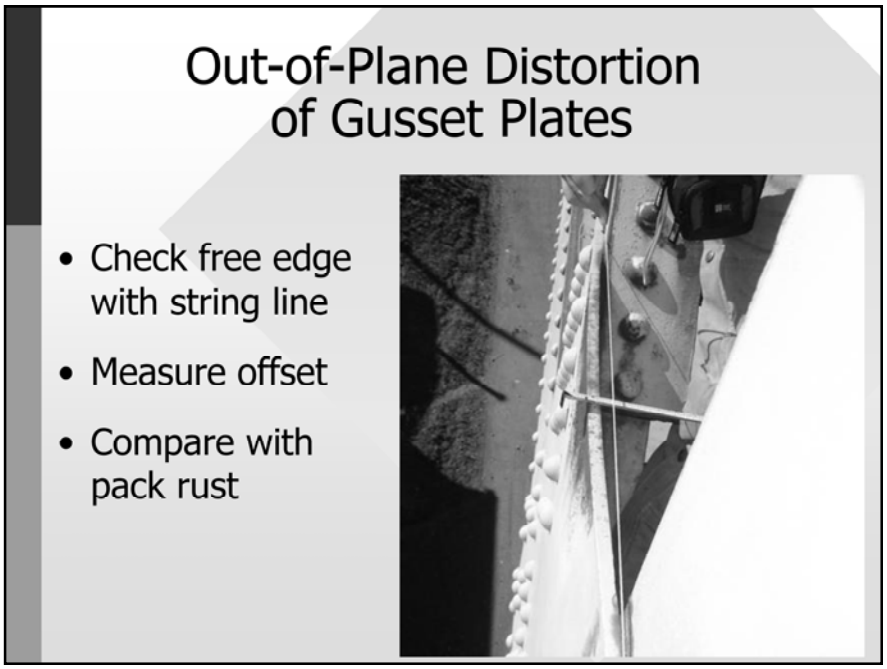
As steel corrodes, it expands and generates pressure between the steel surfaces and forces them to separate.

Depending on the detail, this separation can sometimes cause plate distortion and lead to overstressed mechanical fasteners.

Participant Notes:

Background Information

NA



Participant Notes:

Background Information

NA

Participant Workbook

Gusset plate distortion caused by pack rust is generally observed to be directly proportional to the amount of pack rust observed between the plate and member.

The amount of distortion can be easily obtained by using a taut string line along the free edges of the plate and measuring the distance between the line and the inside edge of the plate.

Gusset plate distortion should be thoroughly documented using notes, sketches and photographs.

Distorted gusset plates connecting compression members are more critical than gusset plates connecting tension members.

Any distortion can be considered critical and the inspector should recommend analysis.

The documentation should include, at a minimum, the amount of gusset plate distortion (along all relevant free edges) and the amount of pack rust present at each end of the gusset.

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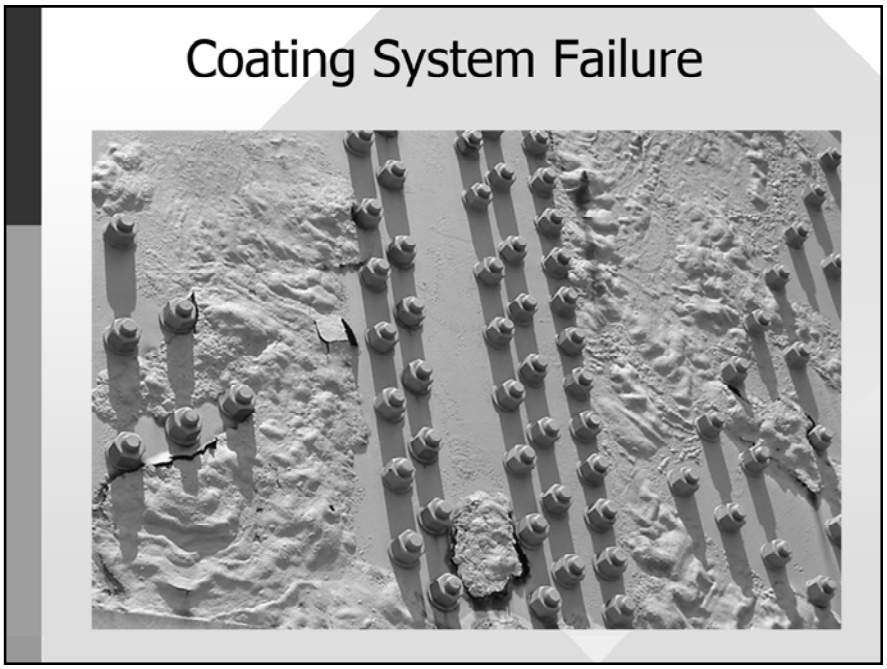


Steel gusset plates are normally protected from corrosion by painting or using weathering steel.

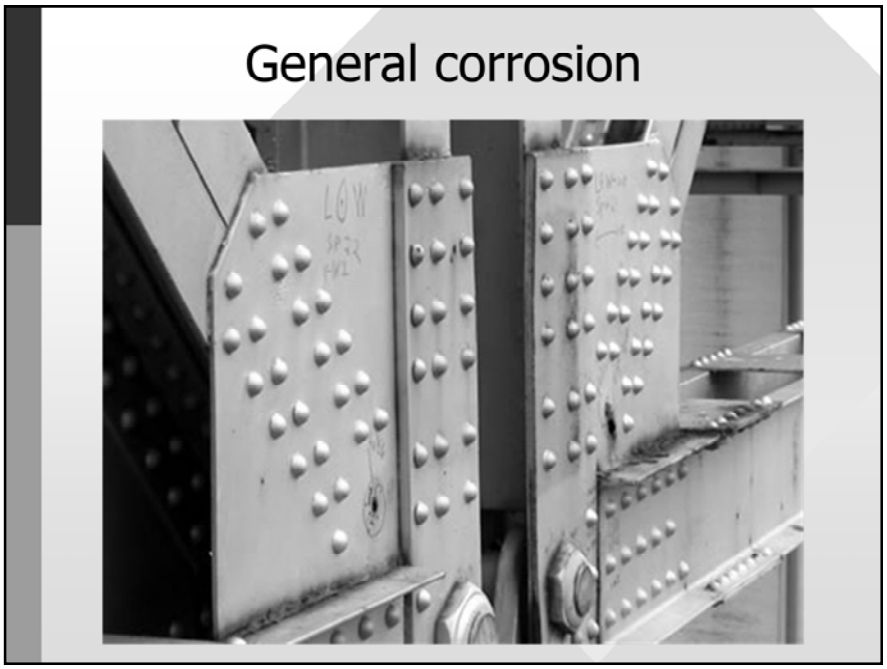
The failure of a coating system can eventually lead to corrosion and section loss on the gusset plates.

Participant Notes:

Background Information

NA

Participant Workbook



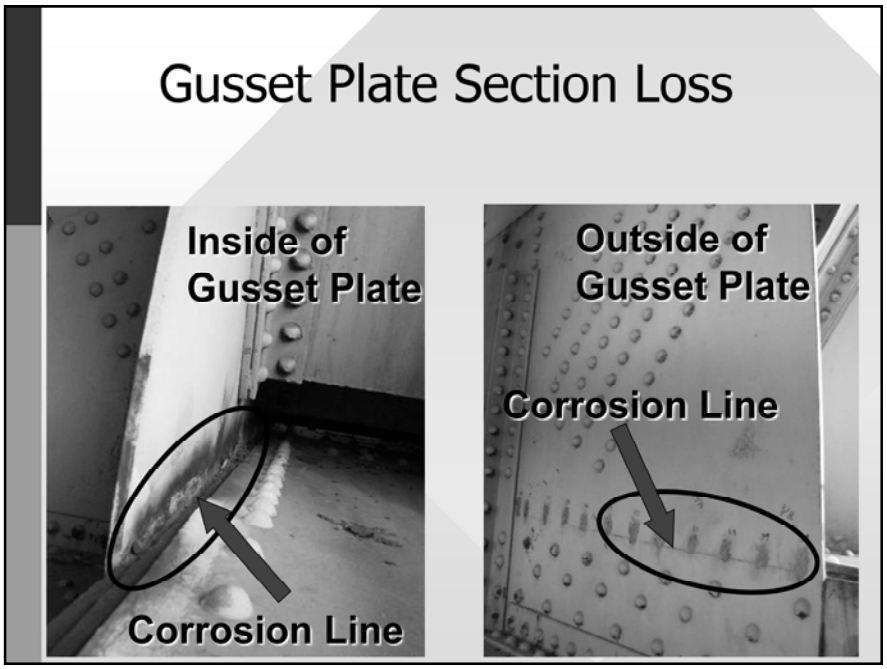
Surface corrosion occurs first and that can lead to section loss.

Corrosion can also occur on the surfaces between the gusset plate and the connecting truss member. This type of corrosion, often referred to as "scaling corrosion," can lead to section loss on the interior surface of the gusset plate and/or the connecting truss member.

Participant Notes:

Background Information

NA



Participant Notes:

Background Information

NA

Participant Workbook

Significant section loss can occur due to corrosion where horizontal members frame into the gusset plates.

Proper visual inspection can be impeded due to debris built-up on the member or from heavy rust or corrosion.

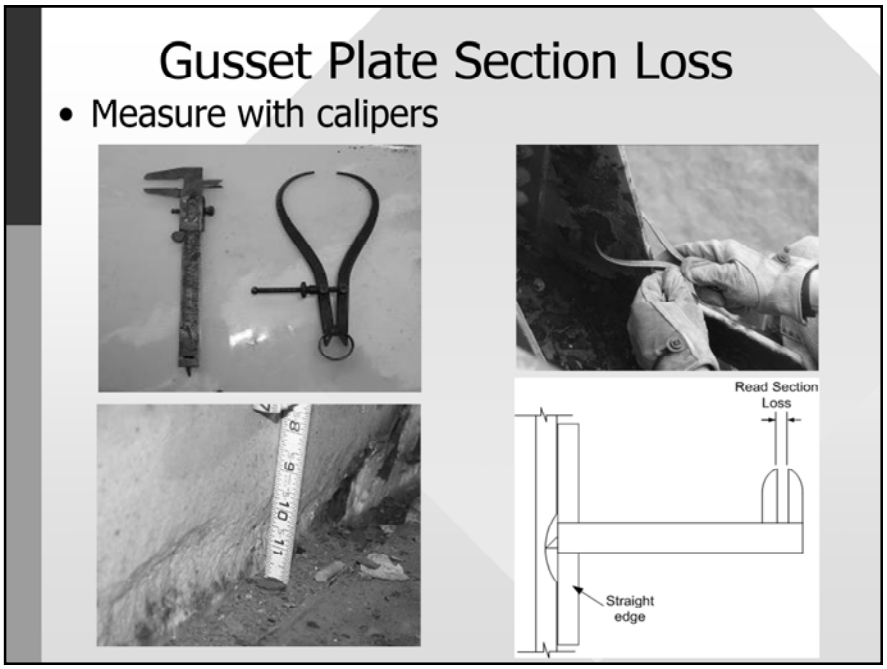
Areas that trap debris or hold water should be cleaned adequately in order to evaluate the remaining section at these locations. Areas with corrosion should be mechanically cleaned and evaluated.

The use of a chipping hammer (usually a geologist's or masonry hammer) and/or angle grinder or drill fitted with a flexible paint stripping wheel is recommended. Necessary safety precautions (gloves, glasses/goggles, respirator) should be taken when hazardous coatings (lead) or debris (pigeon droppings) are disturbed. Exposed steel should be recoated to prevent further corrosion.

All deterioration of the gusset plate must be thoroughly documented in the inspection report using notes, photographs and sketches.

Compare the measured thickness with the original thickness determined from as-built drawings or a portion of the gusset plate with no section loss.

Reference to previous inspection documented remaining section is required.



Participant Notes:

Background Information

NA

Participant Workbook

At locations or situations where a D-meter cannot be used or is not available, a vernier caliper with a depth probe is another tool that can be utilized to determine section loss. A straight edge is required in conjunction with the probe to obtain the amount of section loss.

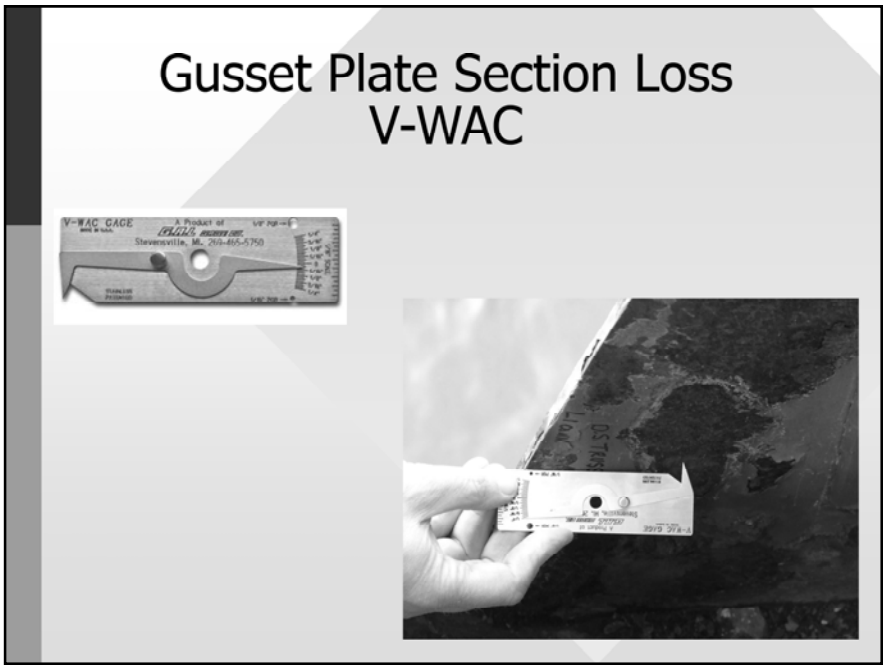
The heel of the caliper shaft is placed against the edge of the straightedge and the probe is advanced until it touches the deteriorated steel.

In this case it is not the remaining section being measured, but rather the section loss. The remaining section is obtained from subtracting measured loss from the original plate thickness – also obtainable by using a caliper.

Record the actual readings and clearly note whether it is remaining section or section loss.

The use of the caliper/depth probe and a straightedge can be cumbersome. In lieu of this method, a tape measure can be used - measuring the amount of section loss by measuring the distance from the steel to the straight edge.

Multiple measurements along the line of section loss are recommended so that an adequate evaluation of the potential shear and tension failure planes for each connected member can be performed.



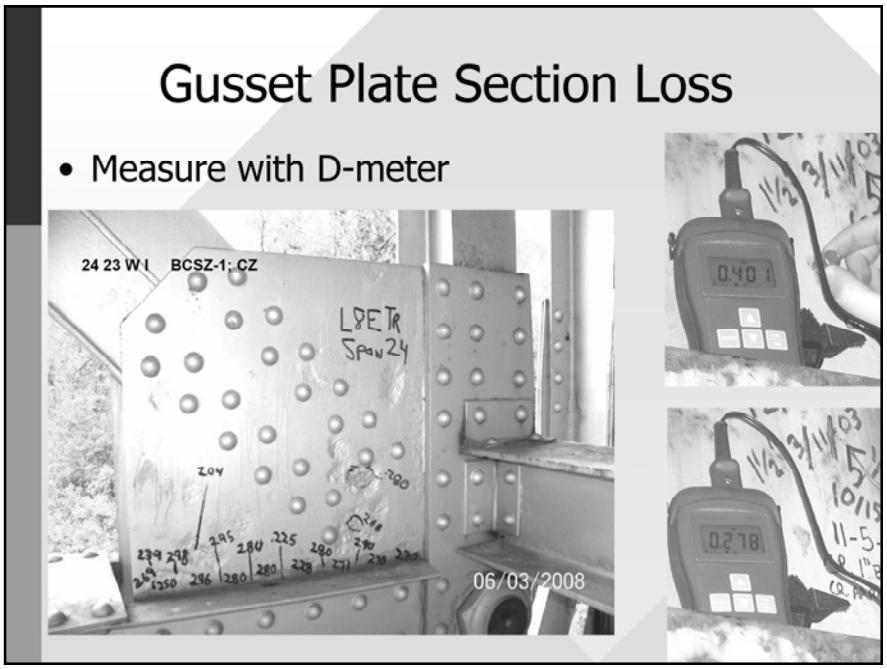
Participant Notes:

Background Information

NA

Participant Workbook

The V-WAC is used to measure section loss and then subtracted from the total thickness to determine the thickness of the plate that is left. It can only measure up to ¼″ section loss. It is also used to determine the severity of pitting undercutting, porosity, and crown height.



Participant Notes:

Background Information

NHI 130078 or BIRM 13.1

"NDT Thickness Measurement of Corroded Weathering Steel Beams," Albrecht, P. and Tinklenberg, G., pg 305-309

Participant Workbook

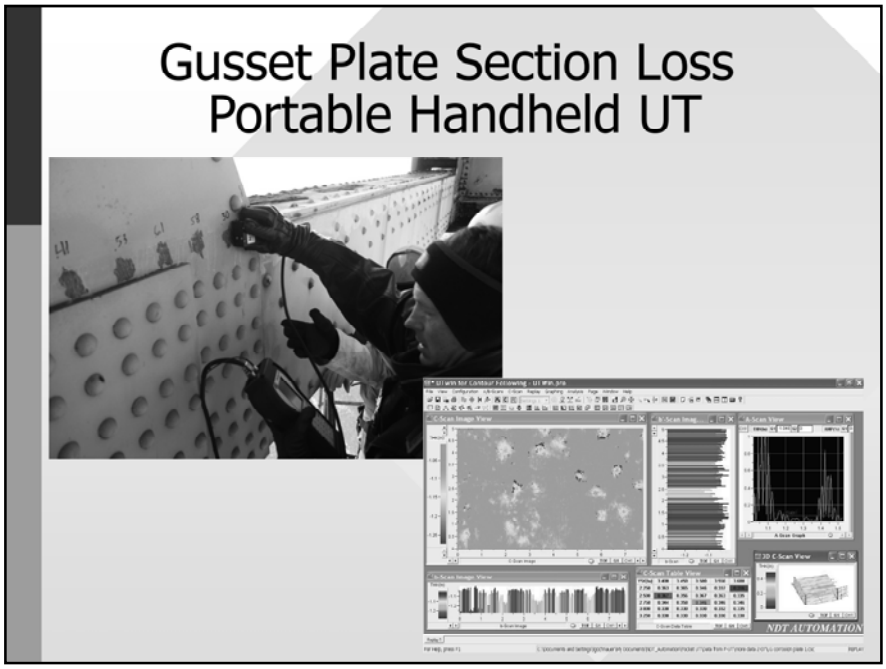
When performing a visual inspection, section losses can be deceiving, therefore the use of ultrasonic thickness gauges (D-meters) is highly recommended to determine the remaining section (remaining plate thickness).

Using a D-meter requires the transducer to be placed on a relatively flat surface. This will generally require the corroded surface to be ground smooth so the D-meter transducer and couplant can obtain an accurate measurement. Paint will generally need to be removed to obtain readings. If not removed, paint thickness must be accounted for because it may be significant.

For major section loss and heavy pitting, the inspector may be required to take measurements from the opposite side of the plate - the "clean" side. For a single transducer UT, measuring from the "clean" side is always recommended.

On the "clean" side of the plate, the inspector must carefully locate the areas of section loss by visual examination, properly prepare the surface, take several readings along the line of corrosion, and thoroughly document the remaining plate thickness using notes, photographs and sketches.

Albrecht and Tinklenberg recommend grinding or sandblasting to determine sound metal in weathering steel. They also recommend moving the transducer to within a ½" to ¾" diameter area to obtain the most accurate results for remaining metal thickness.



Participant Notes:

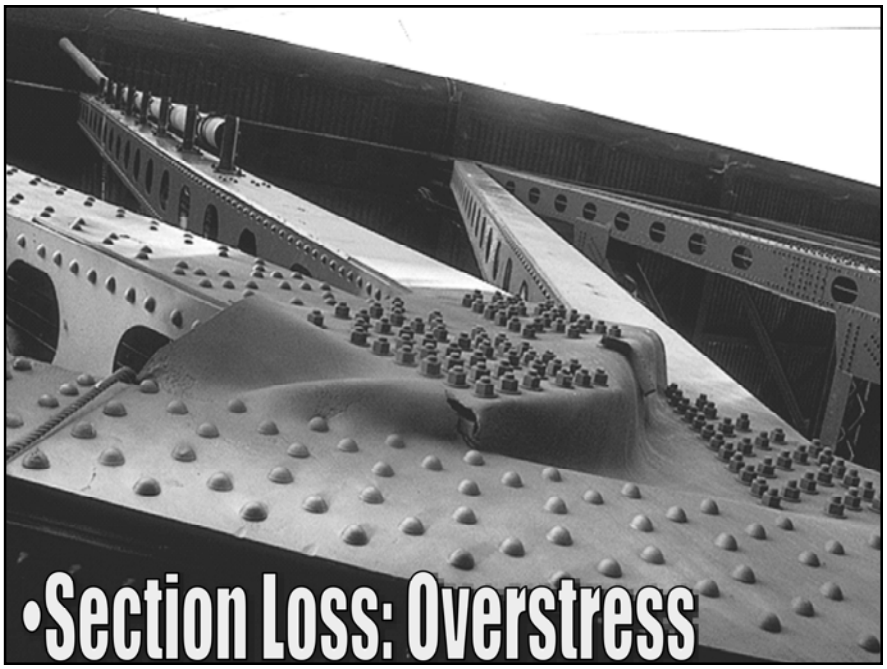
Background Information

NA

Participant Workbook

Portable ultrasonic inspection systems can be used to document cracks, flaws, corrosion and internal anomalies in steel truss gusset plates.

The instrument in the photograph uses phased array data acquisition to display defects. The images can be downloaded and saved in an electronic file.



Participant Notes:

Background Information

NA

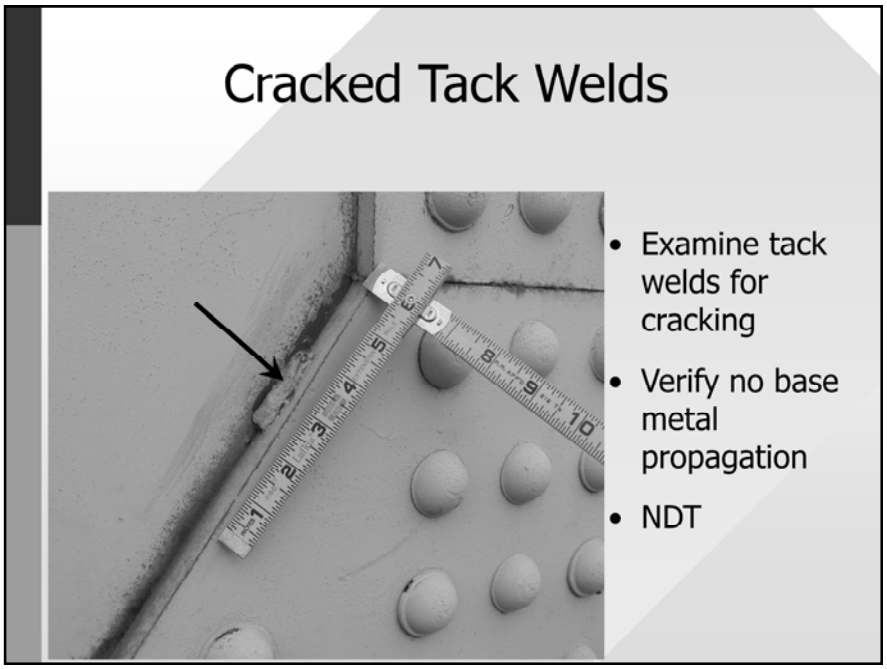
Participant Workbook

This gusset plate failed by buckling (compression) due to section loss.

The plate had a nominal section thickness of 0.4375″. Section loss was estimated along a line through the thinnest section of the buckled area of the plates with most loss occurring on the inside face of the plates.

At the time of failure the gusset plates had a remaining section measured at approximately 0.39″ to 0.28″ thick (10% to 35% section loss due to deterioration), thus increasing the stress in the remaining section and reducing the capacity of the plate to resist buckling.

Section loss on truss gusset plates can lead to overstress.



Participant Notes:

Background Information
NHI Course 130078

Participant Workbook

During the 1950's and 1960's fabricators commonly used tack welds to hold members together during riveting operations. Because this type of weld does not provide structural strength, cracks in these welds do not **directly** represent a problem with respect to the structural integrity of the bridge.

HOWEVER, a tack weld on a tension element is considered a fatigue prone detail because when/if a tack weld cracks, the potential for the crack to propagate into the base metal of the tension element exists.

Tack welds exhibiting a full length crack with no evidence of base metal cracking do not present a problem. Partial length cracked tack welds, however, still have the potential for the crack to propagate into the base metal when exposed to tension. Crack propagation into fracture critical elements, such as gusset plates, has the potential to cause partial or total bridge collapse. The cracks can also propagate into other tension elements such as the chords, verticals, or diagonals as well.

All cracked tack welds should be investigated for crack propagation using techniques such as visual observation, dye penetrant, magnetic particle, eddy current and ultrasonic testing. Results of the investigation should be thoroughly documented. Removal of **partially cracked tack welds** on gusset plates should be considered.

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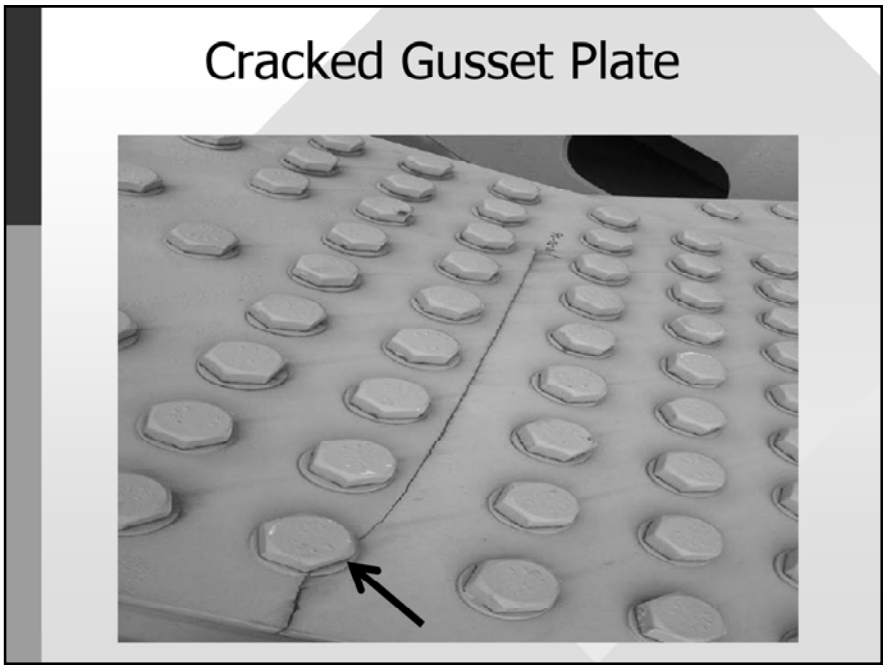


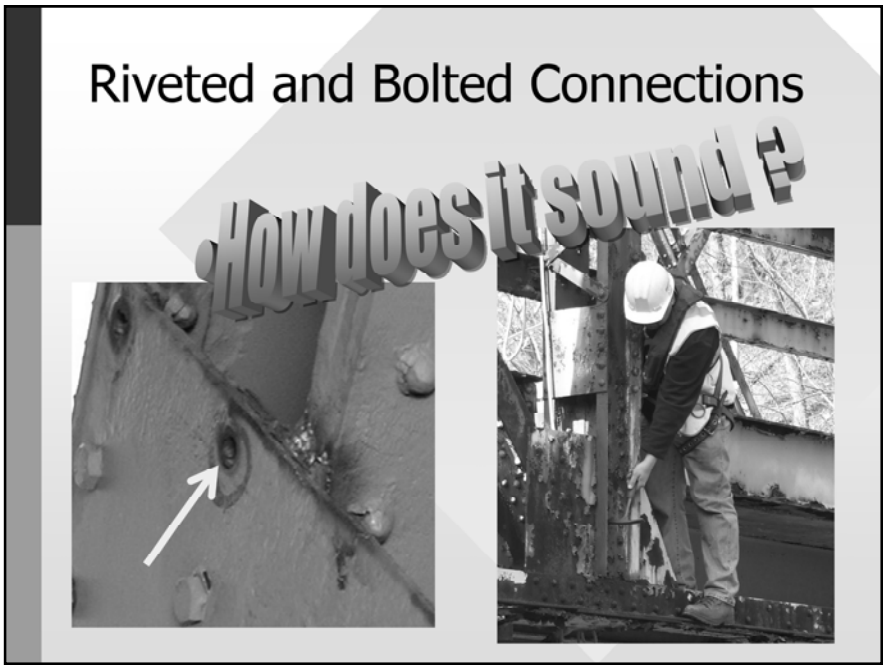
Document exact location and dimensions of cracks in gusset plates.

Try to determine point of crack initiation.

Participant Notes:

Background Information

NHI Course 130078



Participant Notes:

Background Information

NA

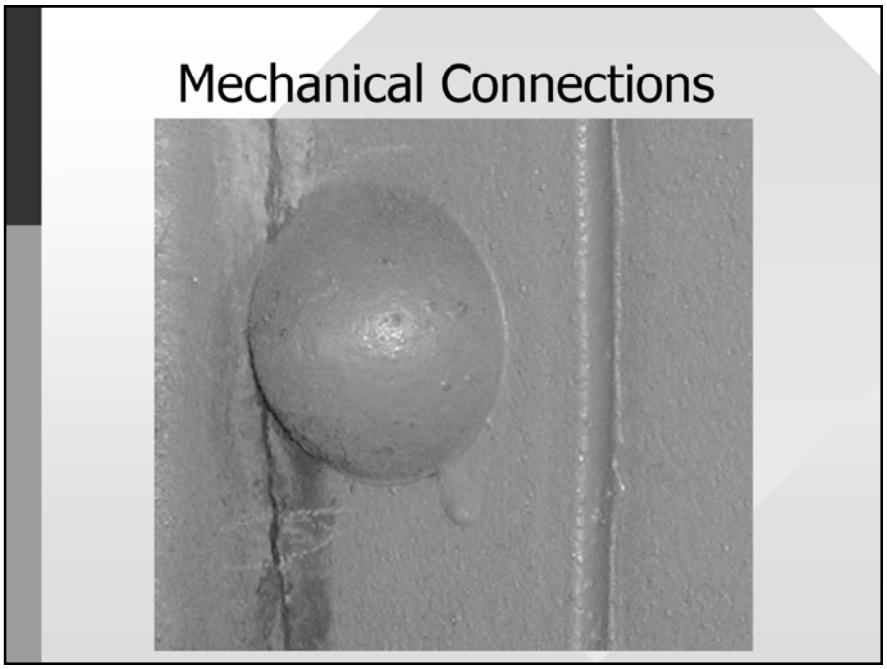
Participant Workbook

Depending on the detail, pack rust causing plate separation can lead to overstressed fasteners.

Loose or broken fasteners can be detected by hammer sounding. Check to assure fastener number and pattern is consistent with as-built/construction plans.

Rivet or bolt heads can "pop" off (tension failure) under the extreme force generated by the pack rust. In extreme situations and if the head is still intact, this overstress can be visually observed as out-of-plane rotation of the rivet head.

Inspect the bolted or rivet connection for slipped surfaces and section loss around the individual bolts and rivets. Slipped surfaces occur when there is a break in the bond between the fastener and gusset plate as exhibited by missing paint or scratched base metal.



Participant Notes:

Background Information

NHI course 130078

Participant Workbook

Inspect the gusset plate for any cracking associated with bolt and rivet holes.

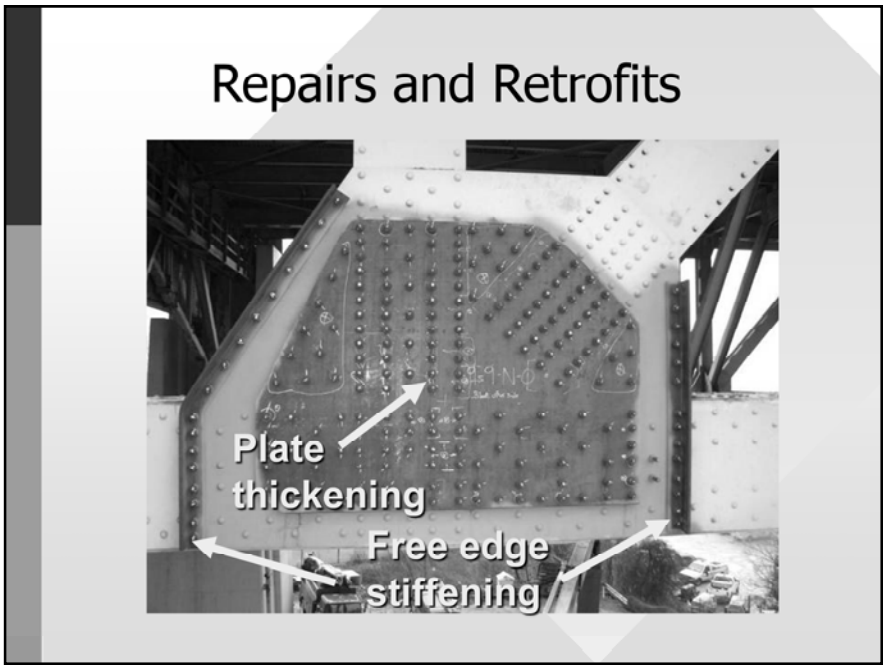
If the rivet holes were not properly reamed after punching during the fabrication process, the rough edges are sources for crack initiation points in tension members due to stress concentrations.

Cracking of gusset plates should be thoroughly documented using notes (location, length, width, and growth history), sketches and photos.

Cracking of tension members is of particular concern. Any crack found in a gusset plate should be considered critical.

The Bridge owner should be notified immediately.

Note: If bolts are loose, they should be replaced and tightened to High Strength bolt specifications. They should not be retorqued.



Participant Notes:

Background Information

NA

Participant Workbook

Structural steel repairs and retrofits are used to strengthen deteriorated and distorted gusset plates.

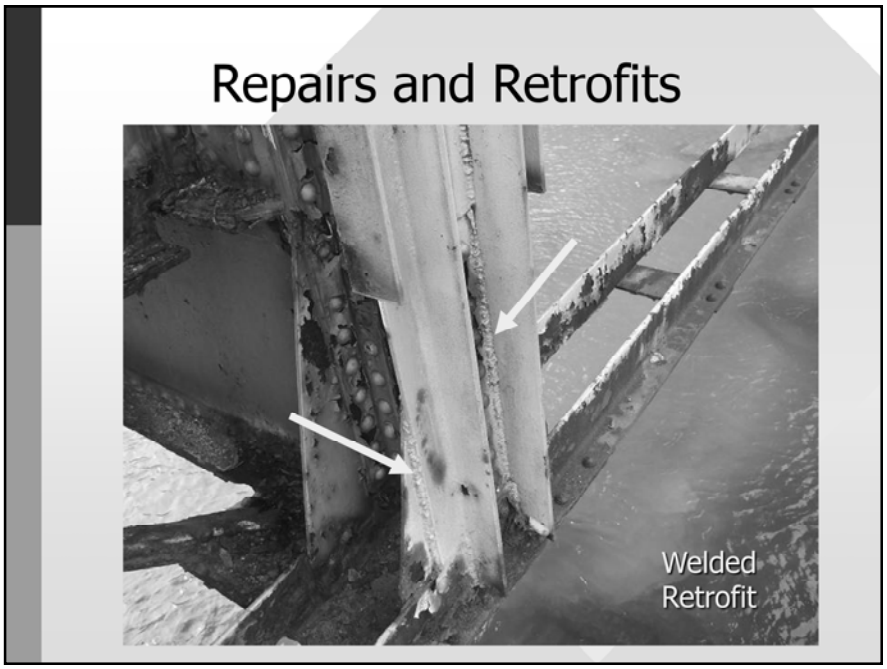
Repairs are normally made by bolting or welding. Riveting has been used in rare instances.

All repairs/retrofits should be inspected for distortion, deterioration, pack rust, tack welds, etc. as a means to verify the repairs/retrofits are functioning as they were intended.

Any repair or retrofit plan should be prepared or checked by a professional engineer and approved by the owner.

Measure repairs and retrofits as described on page 8.6A.6.

Gusset connections with multiple plate layers, whether retrofits or original construction, will complicate inspection and evaluation. Extra care should be taken with D-meter readings and distortion documentation.



Participant Notes:

Background Information

NA

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Welded retrofits are considered to be very fatigue prone. Many trusses older than 1970 are constructed with steel that is brittle. It is difficult to achieve durable and high quality welds in these steels. CVN requirements were not enforced generally until the late 1970's.

Closely examine the toe of the weld / base metal for signs of cracking. Visual inspection may not be enough and more in depth inspection with the proper tools may need to be completed on the gusset plate.

Participant Notes:

Background Information

NA

Participant Workbook

The basic requirement for all fracture critical components is visual inspection from within arms length ("hands-on").

Gusset plated connections sometimes require special tools to aid visual inspection. Simple "mirrors and a stick" are good aids. Bore scopes may be needed if internal areas are too confined for physical access and need close evaluation. Remote cameras connected to a viewing screen and a recording device can be used for otherwise inaccessible areas. Video cameras on a pole are the simple version. Proto-type robotic climbers have been developed.

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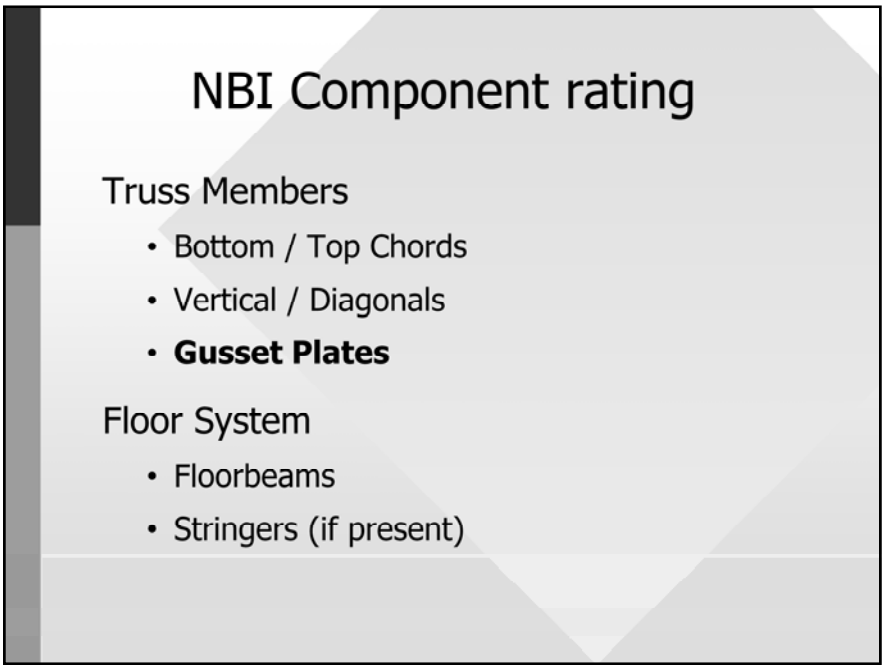


Participant Notes:

The NBI component rating of a truss is based on the condition of the superstructure's primary members:

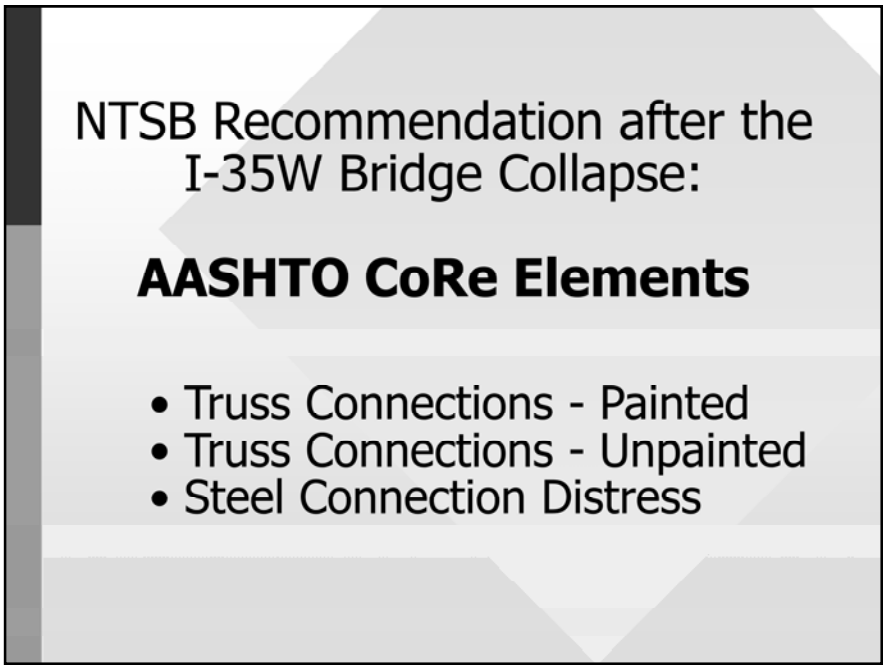
- Truss
- Floor system

It is important to realize gusset plates connect truss members together and are primary members.

The superstructure component rating is based on the overall condition of all truss members including the gusset plates. The component rating may be influenced by the condition of one member, including gusset plates, if that member has deteriorated and is now a safety concern. Please refer to the Bridge Inspector's Reference Manual (BIRM), Topic 4.2 for a detailed explanation of the "weak link" member concept.

Background Information

FHWA Coding and Recording Guide



Participant Notes:

Background Information

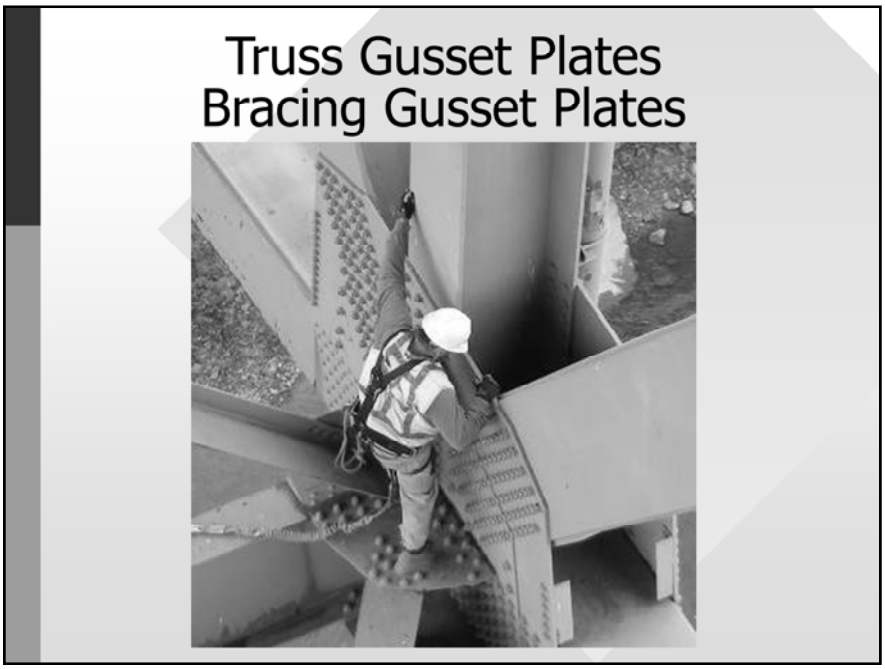
None

Participant Workbook

After the collapse of the I-35W bridge in Minnesota, the National Transportation Board recommended that AASHTO create CoRe Elements and Condition State Language for Steel Truss Gusset Plates.

Recommendations presented to AASHTO members include:

- Truss Connections – Painted CoRe Element
- Truss Connections – Unpainted CoRe Element
- Steel Connection Distress Smart Flag



Participant Notes:

Background Information

NA

Participant Workbook

Gusset plates are used to connect primary members of the truss such as chords, diagonals and verticals. Gusset plates are also used to connect secondary members such as lateral and sway bracing to the truss.

The truss gusset plates are considered more critical since they connect primary members. Failure of this gusset plate type can result in the collapse of the bridge superstructure. The inspection procedure presented in this topic for truss gusset plates can be also used for the inspection of bracing gusset plates.

Input for Gusset Plate Analysis

- Gusset Plate Location
- Plate Thickness
- Distance between outermost centerline of fasteners
- Distance between first and last centerline of fasteners
- Number of fasteners across width
- Number of fasteners along length

Participant Notes:

Background Information

NA

Participant Workbook

Certain information must be collected from the design drawings (as-builts and/or shop drawings) and actual field condition documentation so gusset plates can be analyzed when calculating the structural capacity for the bridge.

Field verification of plan information is desirable even if drawings are available.

Input for Gusset Plate Analysis

- Total number of fasteners
- Angle between a vertical line to the line of action of member
- Unsupported length (along edges)
- Splice plate dimensions (thickness, length, width)
- Edge stiffeners dimensions (if present)

Participant Notes:

Background Information

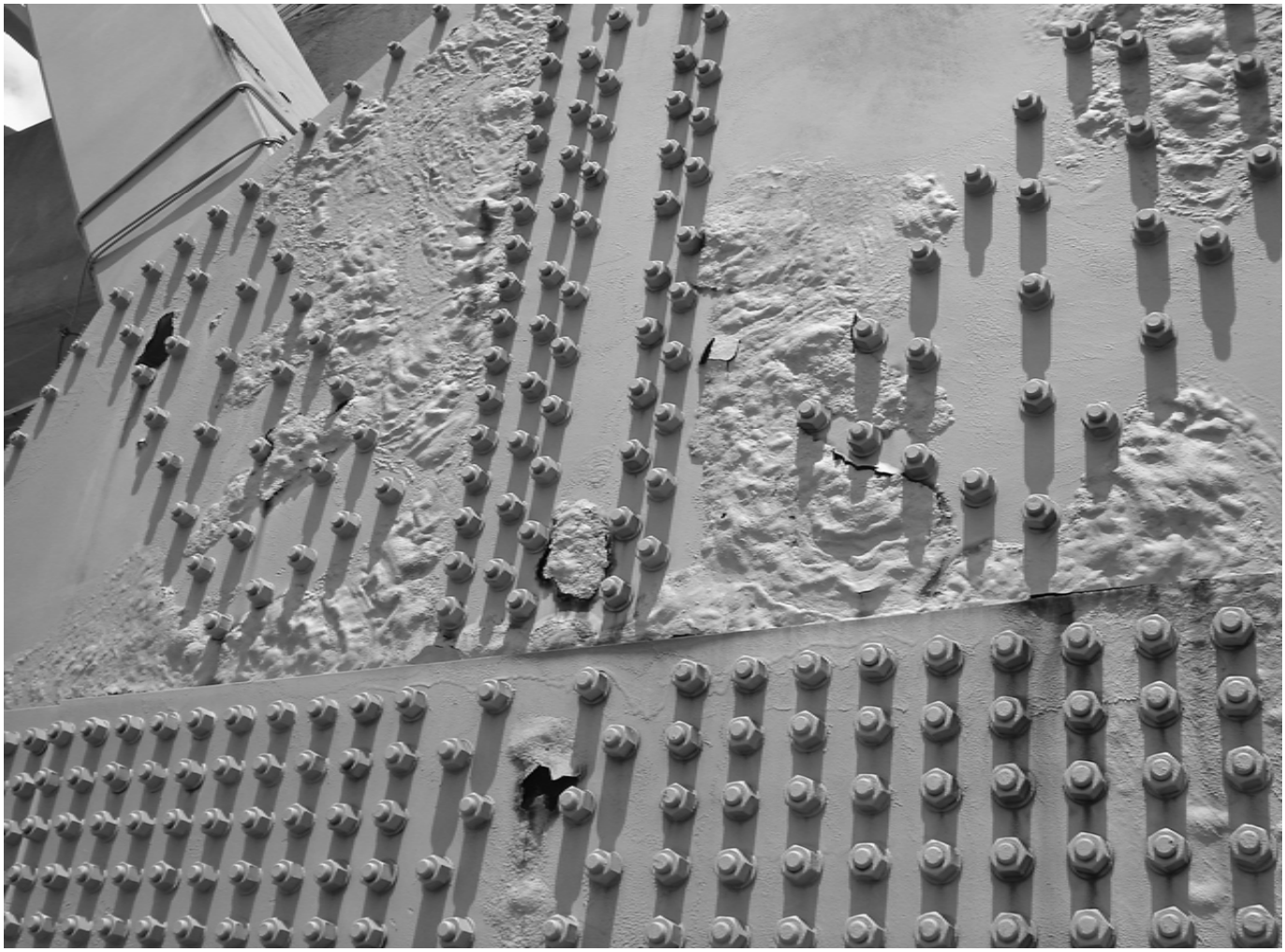
NA

Participant Workbook

Additional information is required to analyze gusset plates.

Next few pages show sample gusset plate configurations and a table that can be used to collect data.

Gusset Plate Documentation



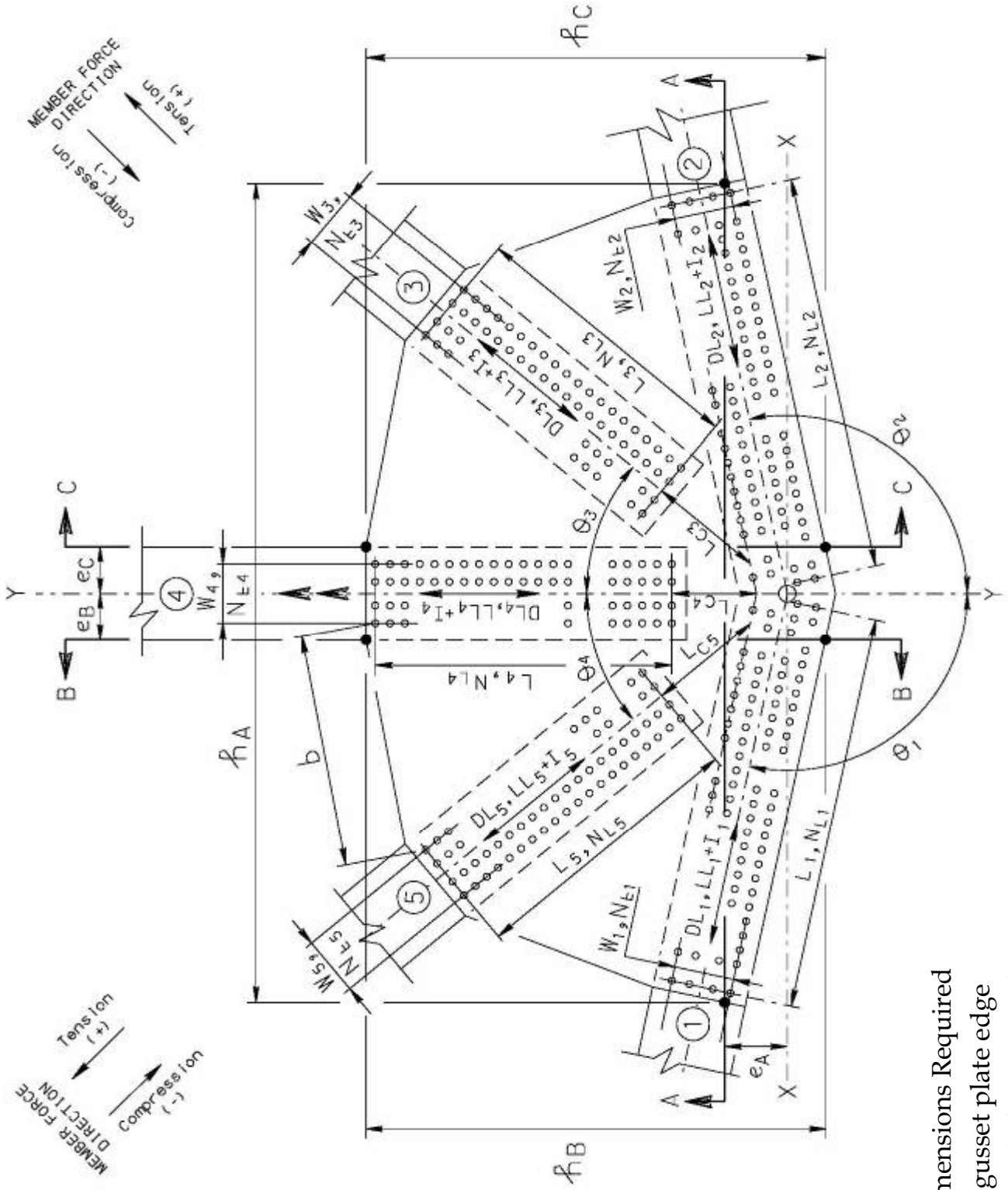


FIGURE 1 - GUSSET PLATE GEOMETRY
(Bottom Chord)

Note:
Additional Dimensions Required
- ℄ fastener to gusset plate edge
- ℄ fastener to end of truss member

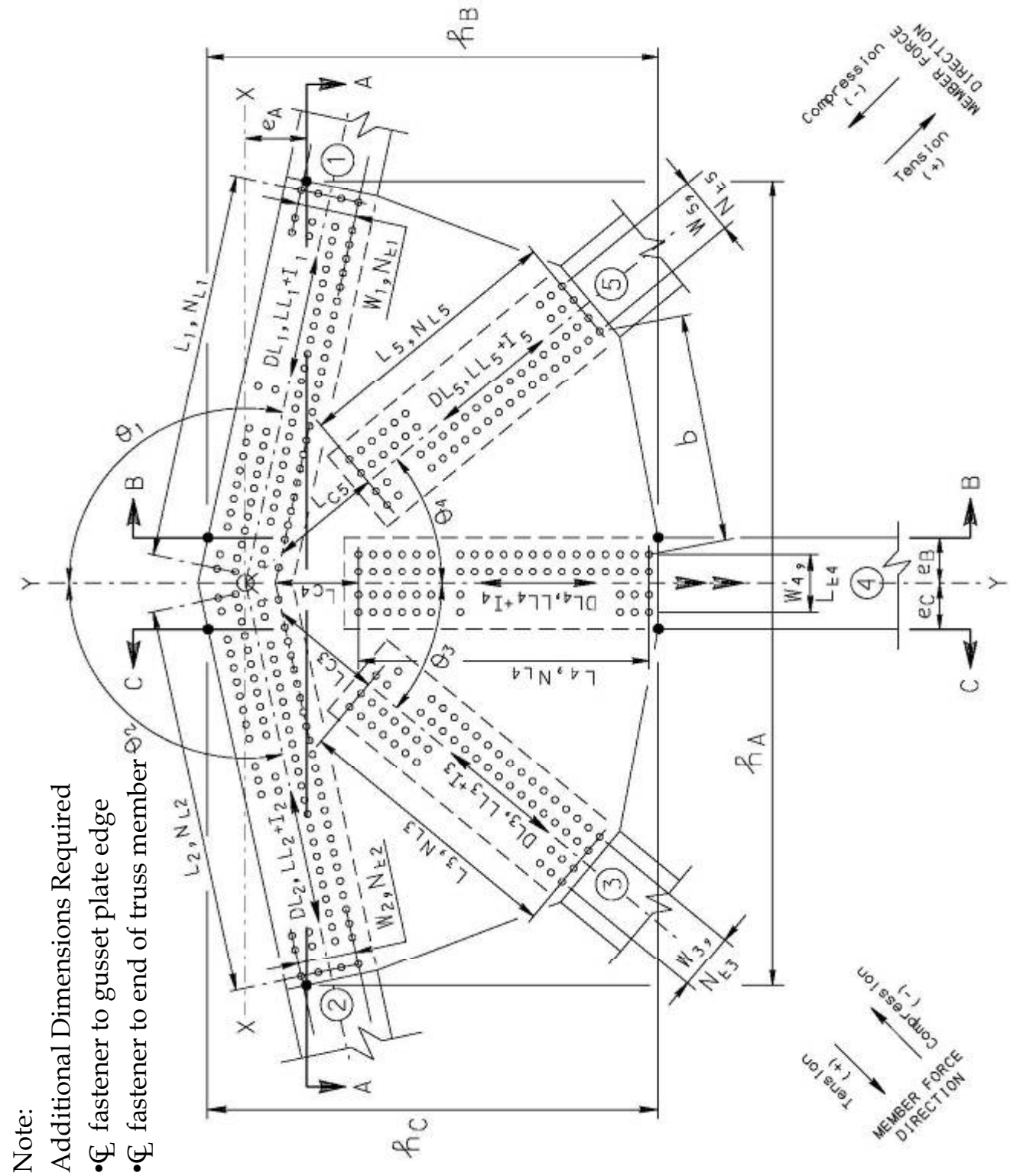


FIGURE 2 - GUSSET PLATE GEOMETRY
(Top Chord)

Note:
Additional Dimensions Required
- ℄ fastener to gusset plate edge
- ℄ fastener to end of truss member

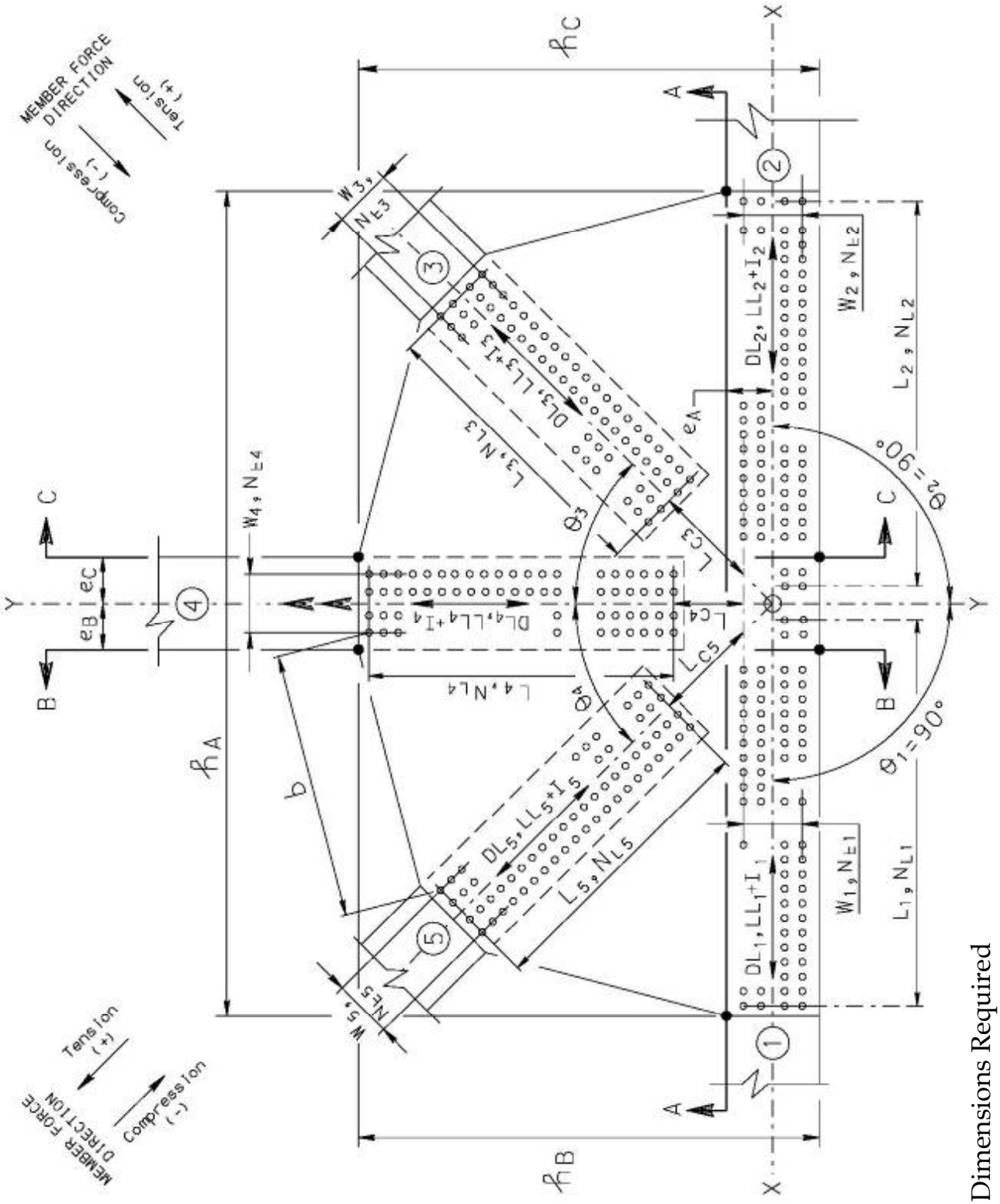


FIGURE 3 - GUSSET PLATE GEOMETRY
(Horizontal Bottom Chord)

Note:
Additional Dimensions Required
- ℄ fastener to gusset plate edge
- ℄ fastener to end of truss member

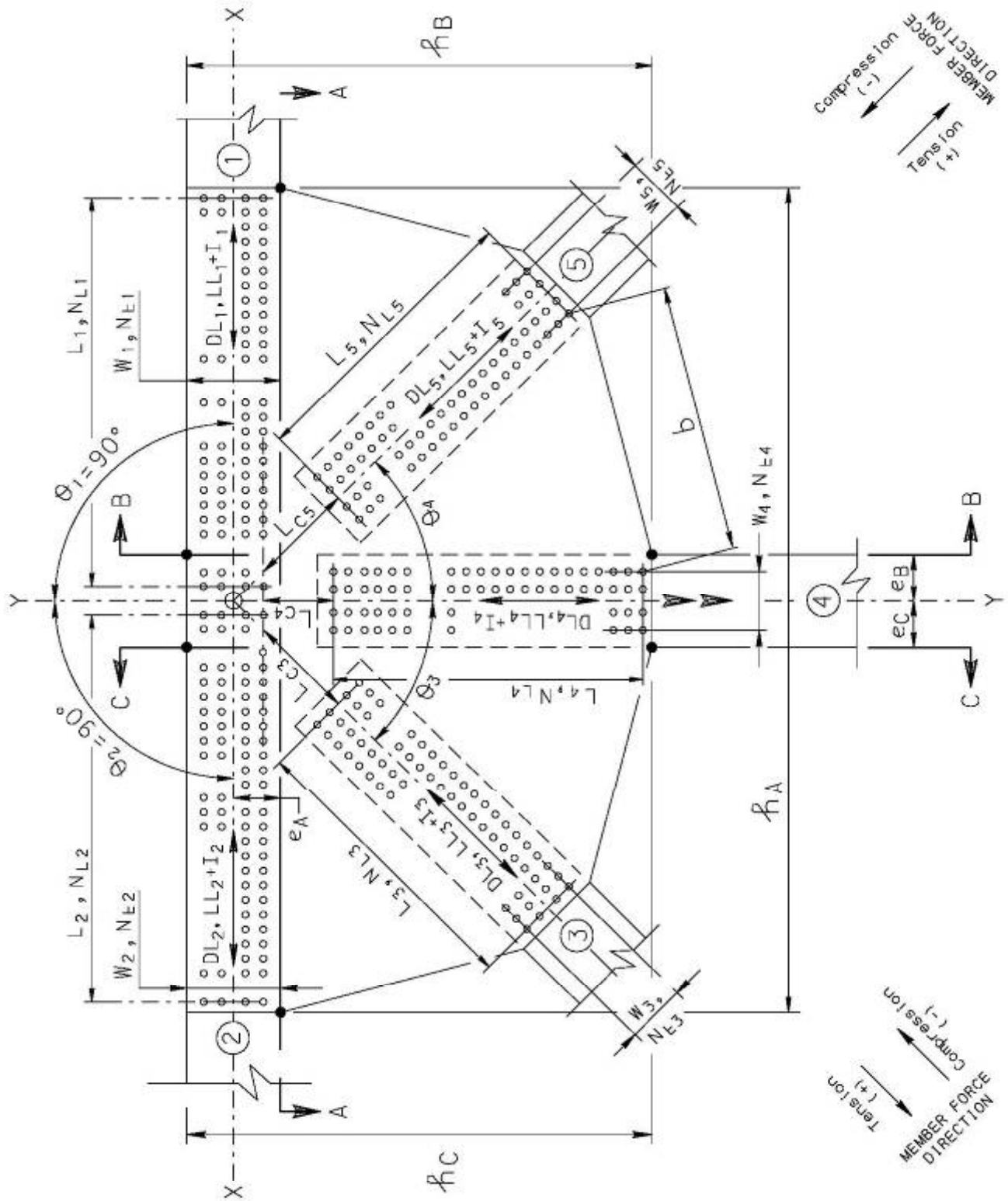


FIGURE 4 - GUSSET PLATE GEOMETRY

(Horizontal Top Chord)

Note:

Additional Dimensions Required

- ℄ fastener to gusset plate edge
- ℄ fastener to end of truss member

GUSSET.DGN

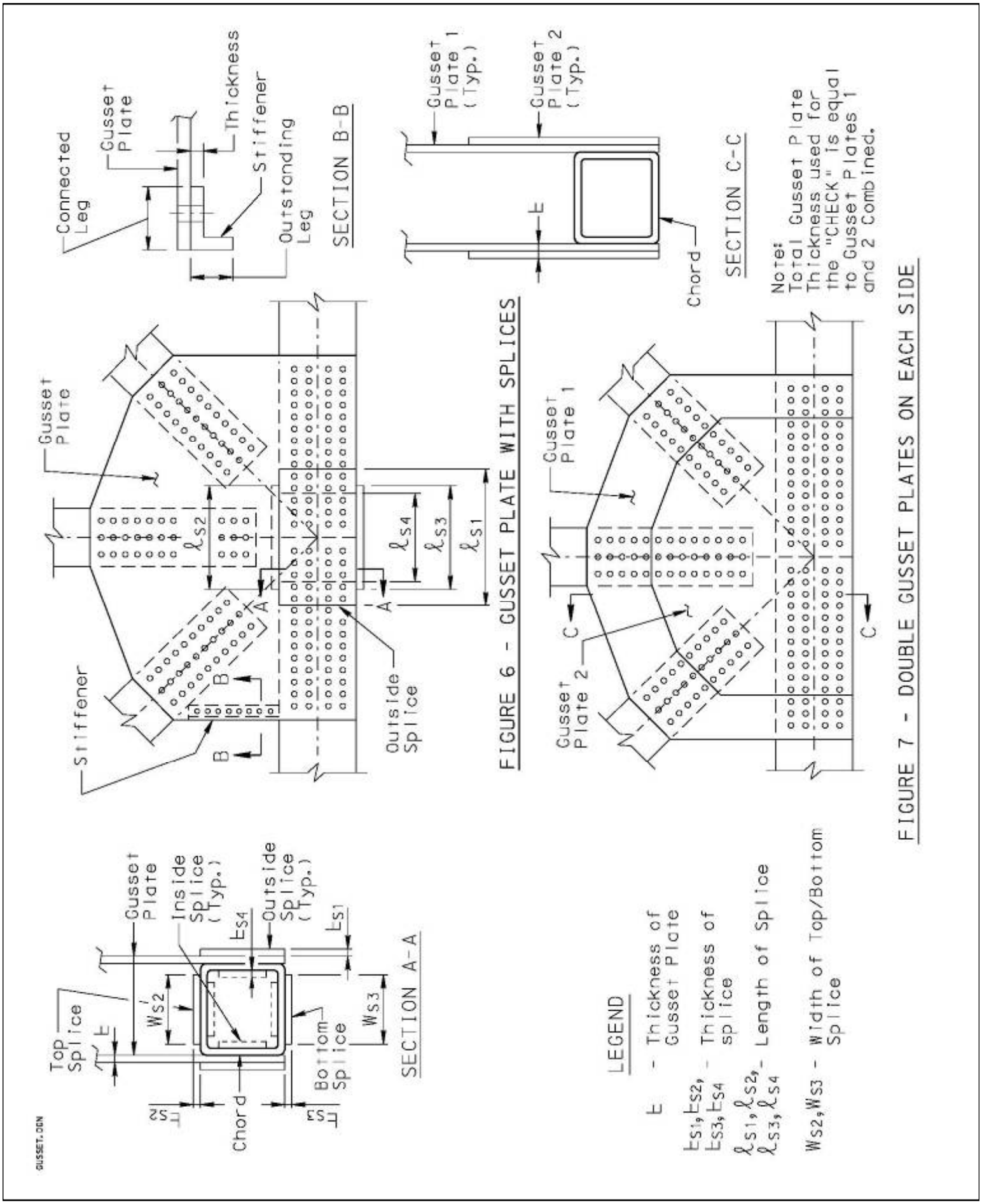
LEGEND FOR FIGURES 1 AND 3

①	-	Left Bottom Chord
②	-	Right Bottom Chord
③	-	Right Diagonal Member
④	-	Vertical Member
⑤	-	Left Diagonal Member
e_A, e_B, e_C	-	Cross Section Eccentricity (in)
h_A, h_B, h_C	-	Cross Section Length (in)
DL, LL+I	-	Member Force Load (k)
$\theta_1, \theta_2, \theta_3, \theta_4$	-	Member Angle (degree)
W_1, W_2, W_3, W_4, W_5	-	Length between first and last row of Fasteners in Longitudinal Direction (in).
L_{C3}, L_{C4}, L_{C5}	-	Length of the Unstiffened Vertical edge in Compression (in).
L_1, L_2, L_3, L_4, L_5	-	Length between first and last row of Fasteners in Transverse Direction (in).
b	-	Maximum Unsupported Length along the edge of Gusset Plate (in).
$N_{E1}, N_{E2}, N_{E3}, N_{E4}, N_{E5}$	-	Number of Fasteners in the Transverse Direction.
$N_{L1}, N_{L2}, N_{L3}, N_{L4}, N_{L5}$	-	Number of Fasteners in the Longitudinal Direction.

LEGEND FOR FIGURES 2 AND 4

①	-	Right Top Chord
②	-	Left Top Chord
③	-	Left Diagonal Member
④	-	Vertical Member
⑤	-	Right Diagonal Member
e_A, e_B, e_C	-	Cross Section Eccentricity (in)
h_A, h_B, h_C	-	Cross Section Length (in)
DL, LL+I	-	Member Force Load (k)
$\theta_1, \theta_2, \theta_3, \theta_4$	-	Member Angle (degree)
W_1, W_2, W_3, W_4, W_5	-	Length between first and last row of Fasteners in Longitudinal Direction (in).
L_{C3}, L_{C4}, L_{C5}	-	Length of the Unstiffened Vertical edge in Compression (in).
L_1, L_2, L_3, L_4, L_5	-	Length between first and last row of Fasteners in Transverse Direction (in).
b	-	Maximum Unsupported Length along the edge of Gusset Plate (in).
$N_{E1}, N_{E2}, N_{E3}, N_{E4}, N_{E5}$	-	Number of Fasteners in the Transverse Direction.
$N_{L1}, N_{L2}, N_{L3}, N_{L4}, N_{L5}$	-	Number of Fasteners in the Longitudinal Direction.

FIGURE 5 - LEGENDS


Connected Leg
Gusset Plate
Thickness
Stiffener
Outstanding Leg
SECTION B-B
Gusset Plate 1 (Typ.)
Gusset Plate 2 (Typ.)
t
Chord
SECTION C-C
Note: Total Gusset Plate Thickness used for the "CHECK" is equal to Gusset Plates 1 and 2 Combined.
Gusset Plate
Stiffener
Outside Splice
FIGURE 6 - GUSSET PLATE WITH SPLICES
Gusset Plate 1
Gusset Plate 2
FIGURE 7 - DOUBLE GUSSET PLATES ON EACH SIDE
Top Splice
Gusset Plate
Inside Splice (Typ.)
Outside Splice (Typ.)
Bottom Splice
Chord
SECTION A-A
LEGEND
t - Thickness of Gusset Plate
ts1, ts2, ts3, ts4 - Thickness of splice
ℓs1, ℓs2, ℓs3, ℓs4 - Length of Splice
Ws2, Ws3 - Width of Top/Bottom Splice
GUSSET.DGN

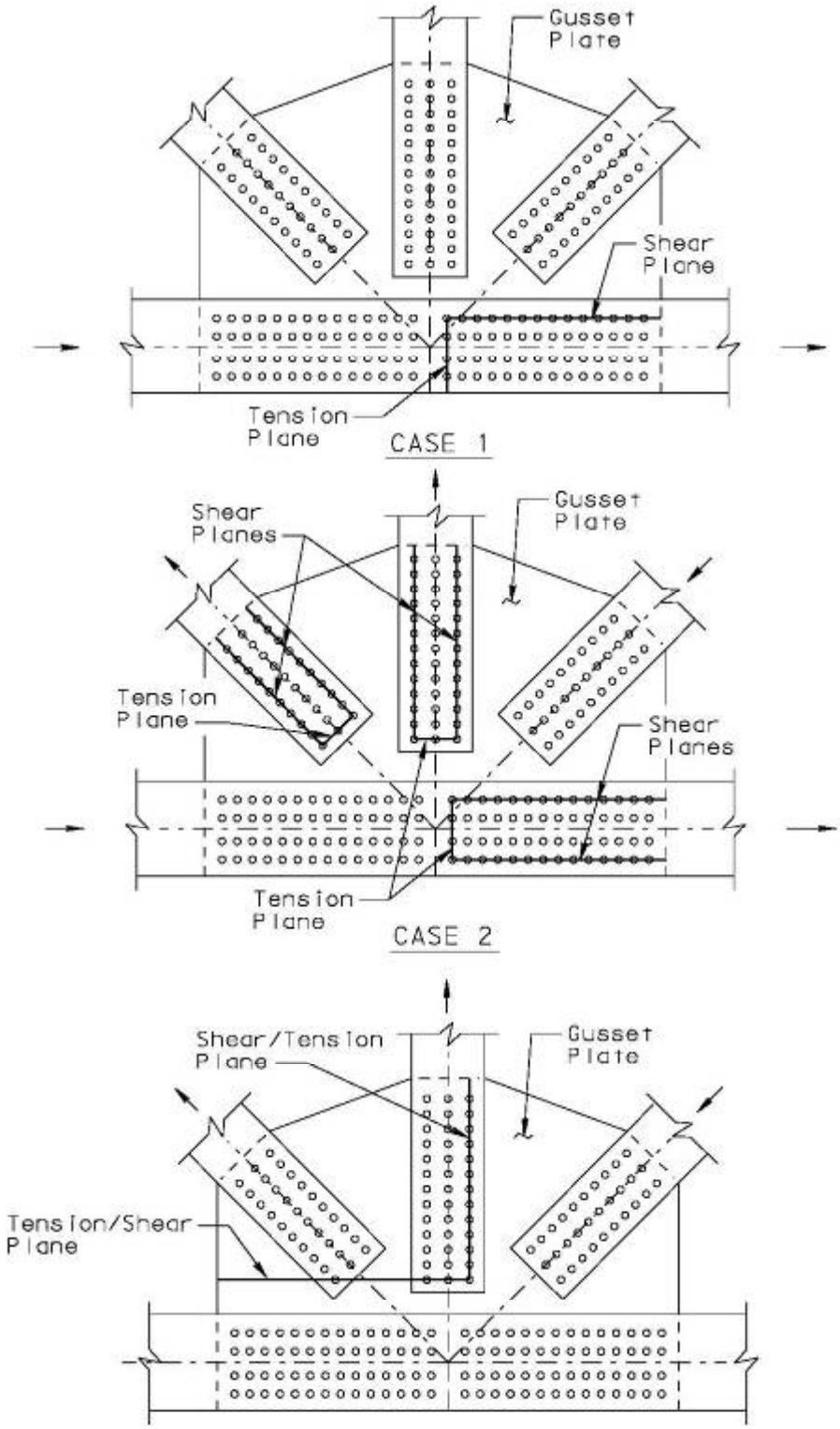
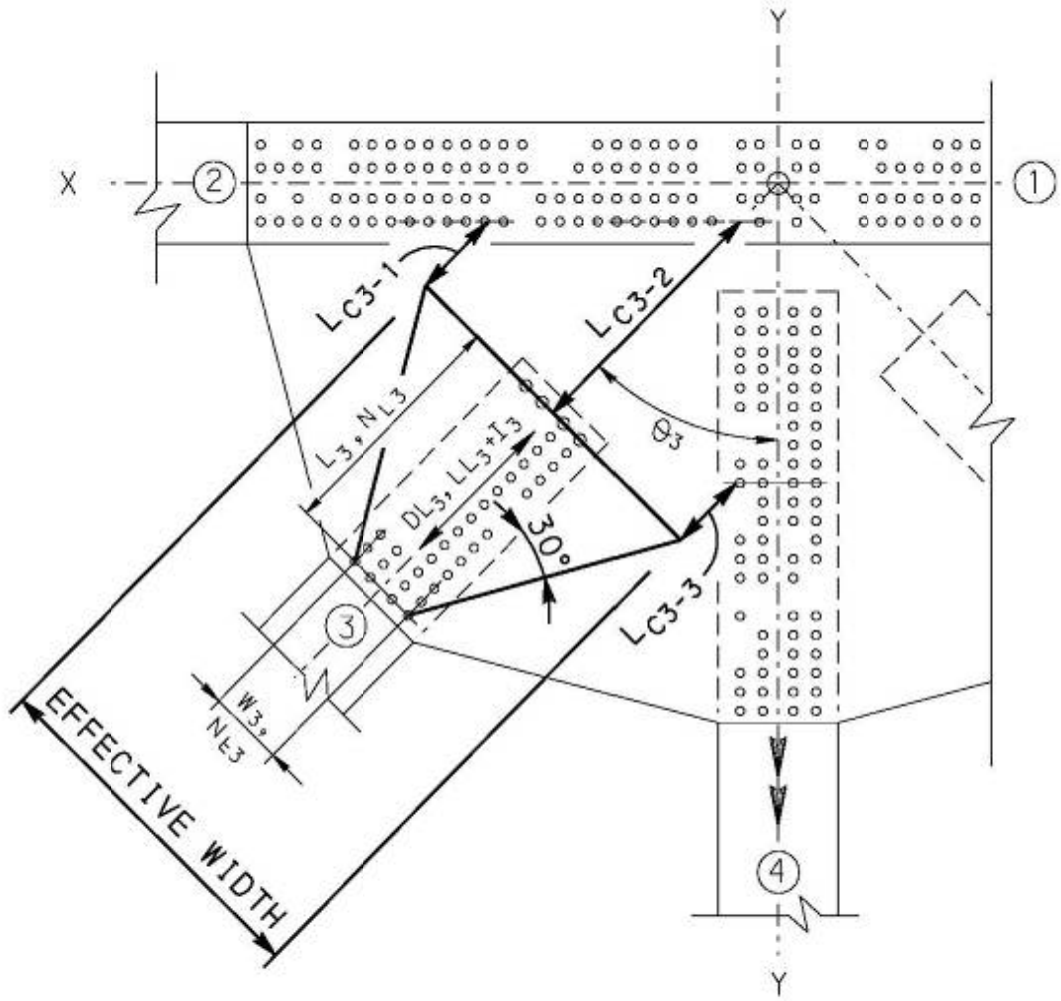


FIGURE 8 - BLOCK SHEAR RUPTURE PLANES IN GUSSET PLATE IN TENSION USED FOR THE "CHECK"

Details shown with only (1) one Gusset Plate for Clarity.

GUSSET.DGN



Gusset plate buckling is a concern when truss members are in **compression**.

Figures 1-4 show only one dimension for unstiffened distance between truss members (L_{CX})

When truss members are in compression, determine the three unsupported lengths shown and use their <u>average</u> for analysis.

FHWA Report No. FHWA-IF-09-014

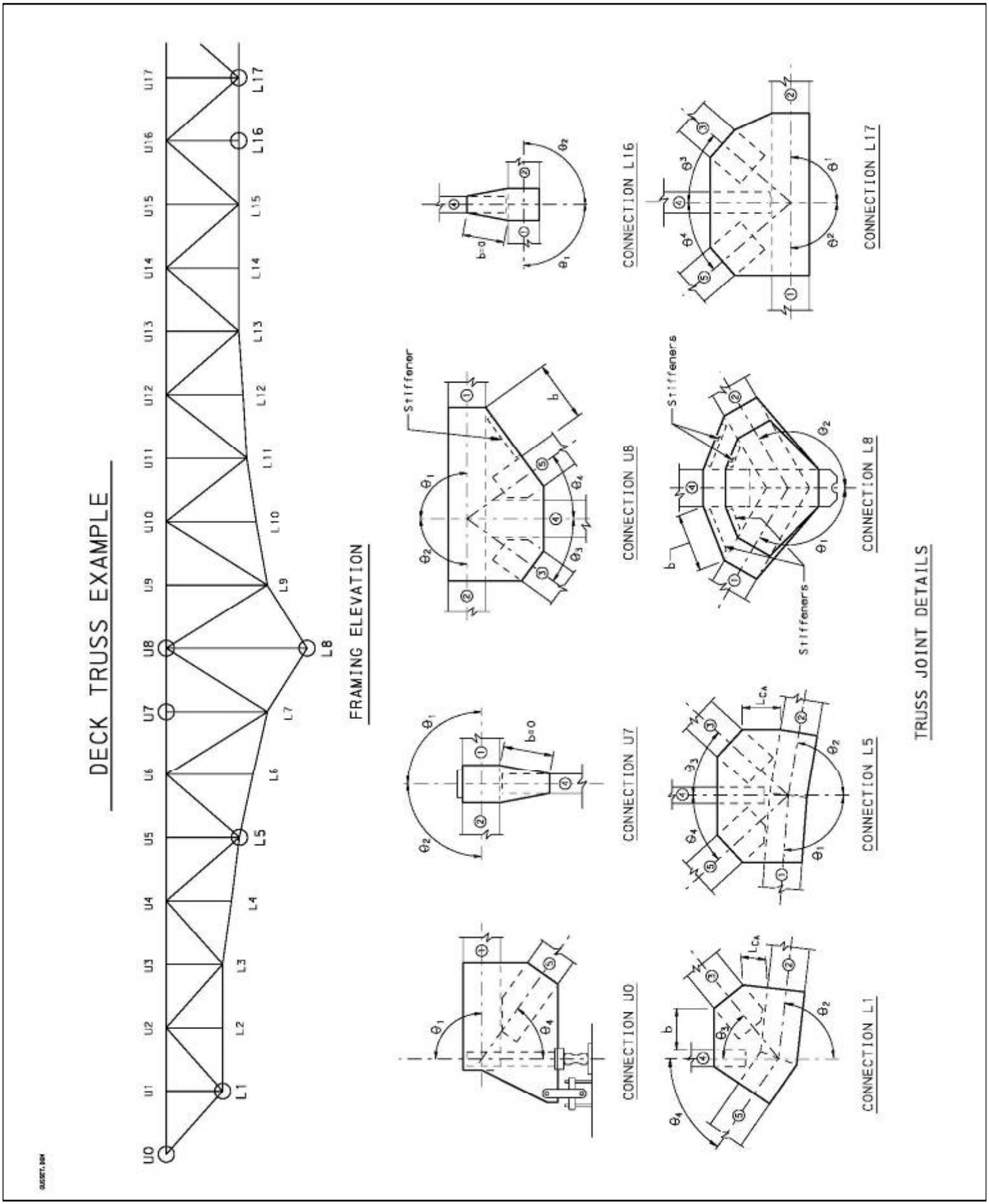
"Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges" page 16

Note:

Additional Dimensions Required

- ℄ fastener to gusset plate edge
- ℄ fastener to end of truss member

FIGURE 9 - EXAMPLES SHOWING L_{C3-1}, L_{C3-2}, L_{C3-3}, AND EFFECTIVE WIDTH FOR A GUSSET PLATE IN COMPRESSION

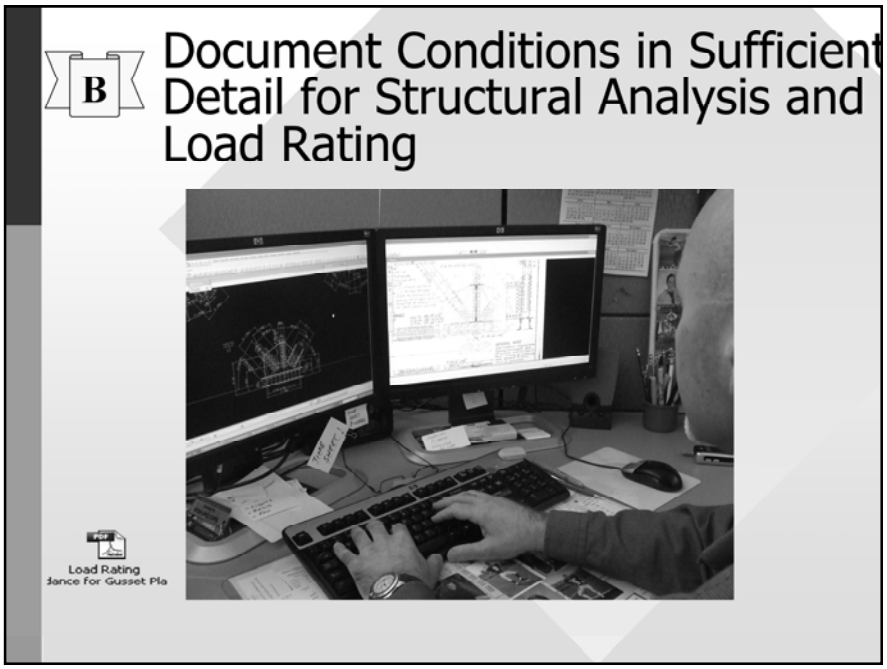

DECK TRUSS EXAMPLE
FRAMING ELEVATION
TRUSS JOINT DETAILS
CONNECTION U0
CONNECTION U7
CONNECTION U8
CONNECTION L16
CONNECTION L1
CONNECTION L5
CONNECTION L8
CONNECTION L17
Stiffener
Stiffeners
b=0

Bridge No.: XYZ Joint: L3 DS/US (Fig. 1 used)

	Design	Actual	Comments
①	L_2L_3		
②	L_3L_4		
③	L_3U_4		
④	L_3U_3		
⑤	L_3U_2		
e_A	21"	✓	
e_B	16"	15 1/2"	
e_C	16"	15 1/2"	
h_A	276"	✓	
h_B	156"	✓	
h_C	156"	✓	
DL_{Design}			(1) +1008k (2) +1038k (3) −705k (4) −700k (5) +726k
$LL+I_{Design}$			(1) +1512k (2) +1537k (3) −1058k (4) −1050k (5) +1090k
$DL_{Measured}$			(1)___ (2)___ (3)___ (4)___ (5)
$LL+I_{Measured}$			(1)___ (2)___ (3)___ (4)___ (5)
Θ_1	100°	✓	
Θ_2	100°	99°	
Θ_3	40°	41°	
Θ_4	40°	41°	
W_1	20"	19"	
W_2	20"	19"	
W_3	20"	19"	
W_4	20"	19"	
W_5	20"	19"	
L_{C3}	39"	✓	
L_{C4}	29"	✓	
L_{C5}	39"	✓	
L_1	137"	✓	
L_2	137"	✓	
L_3	96"	✓	
L_4	101"	✓	
L_5	96"	✓	
b	80"	✓	
N_{t1}	4	✓	7/8" Ø Bolts (typ. N_{t1} - N_{t5})
N_{t2}	4	✓	
N_{t3}	4	✓	(1/16" loss on nut, last 4 bolts)
N_{t4}	4	✓	med surface rust - typ.
N_{t5}	4	✓	(1/16" loss on nut, last 4 bolts)
N_{L1}	28	✓	
N_{L2}	28	✓	
N_{L3}	20	✓	
N_{L4}	21	✓	
N_{L5}	20	✓	
t	1 1/2"	✓	1/16" x 1" loss along bottom edge (inside gusset plate)
t_{S1}	—	—	
t_{S2}	—	—	
t_{S3}	—	—	
t_{S4}	—	—	
ℓ_{S1}	—	—	
ℓ_{S2}	—	—	
ℓ_{S3}	—	—	
ℓ_{S4}	—	—	
W_{S2}	—	—	
W_{S3}	—	—	

Bridge No.:_____ Joint:_____ DS/US (Fig. _____ used)

	Design	Actual	Comments
①			
②			
③			
④			
⑤			
e_A			
e_B			
e_C			
h_A			
h_B			
h_C			
DL_{Design}			(1)_____ (2)_____ (3)_____ (4)_____ (5)
$LL+I_{Design}$			(1)_____ (2)_____ (3)_____ (4)_____ (5)
$DL_{Measured}$			(1)_____ (2)_____ (3)_____ (4)_____ (5)
$LL+I_{Measured}$			(1)_____ (2)_____ (3)_____ (4)_____ (5)
Θ_1			
Θ_2			
Θ_3			
Θ_4			
W_1			
W_2			
W_3			
W_4			
W_5			
L_{C3}			
L_{C4}			
L_{C5}			
L_1			
L_2			
L_3			
L_4			
L_5			
b			
N_{t1}			
N_{t2}			
N_{t3}			
N_{t4}			
N_{t5}			
N_{L1}			
N_{L2}			
N_{L3}			
N_{L4}			
N_{L5}			
t			
t_{S1}			
t_{S2}			
t_{S3}			
t_{S4}			
ℓ_{S1}			
ℓ_{S2}			
ℓ_{S3}			
ℓ_{S4}			
W_{S2}			
W_{S3}			



Participant Notes:

Background Information

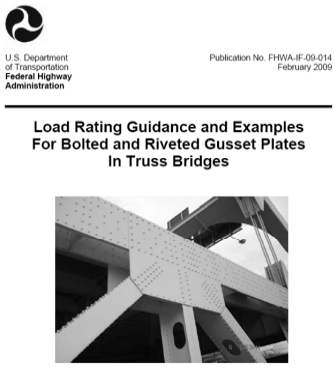
Publication No. FHWA-IF-09-14, "Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges", February 1, 2009

Participant Workbook

The following observations during inspection can trigger the need to perform a structural analysis and load rating.

1. Actual gusset plate dimensions different from original drawings
2. Out-of-plane distortion of gusset plates
3. Coating system failures
   - Lead to corrosion of plate then eventually to section loss
4. Gusset plate corrosion and section loss
5. Cracked gusset plates and tack welds
6. Loose, missing, or deteriorated fasteners
7. Repairs and/or retrofits have been added that may change the AASHTO Fatigue Categories

Publication No. FHWA-IF-09-14, "Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges", February 1, 2009


U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-IF-09-014
February 2009

Load Rating Guidance and Examples For Bolted and Riveted Gusset Plates In Truss Bridges

Participant Notes:

Background Information

NA

Participant Workbook

The safety of the traveling public must be protected at all times.

Verify with the bridge owner specific established policies and the procedures to close the bridge. It is suggested these policies be known prior to any bridge inspection.

Possible procedures include:

- Decreased inspection interval
- Immediate bridge closure
- Lane restrictions
- Monitoring
- Structural analysis
- Load posting after structural analysis

Case Study

Gusset Plate Inspection

Moffit Mill Run Bridge

Participant Notes:

Background Information

NA

Participant Workbook

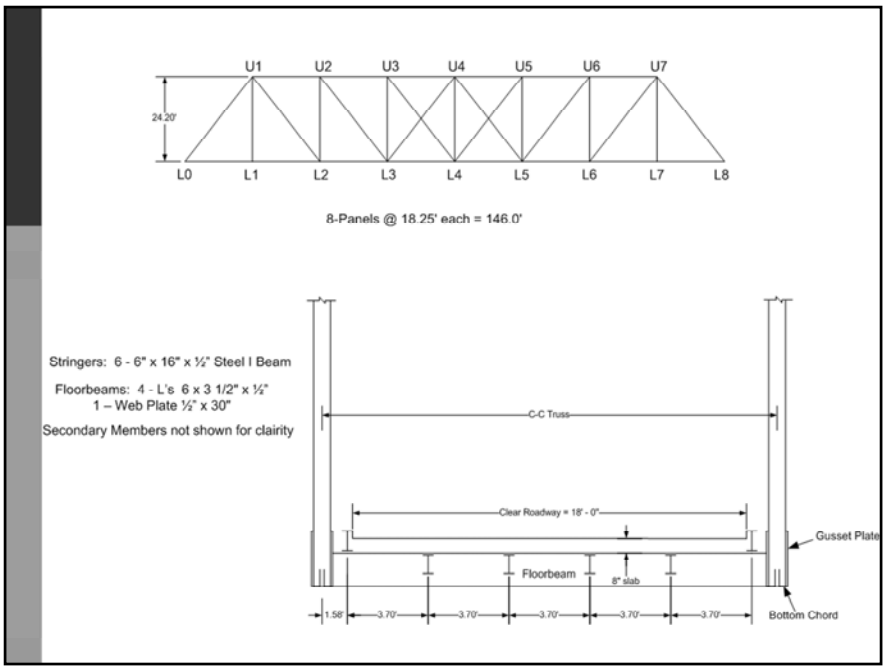
A special inspection was requested to examine the gusset plates. Inspection using visual procedures concluded the following two gusset plates appeared to be in the worst condition:

L_7 Downstream Truss

L_6 Downstream Truss

Based on the above visual observations, determine the 1st two steps to complete this special gusset plate inspection.

Participant Workbook



Participant Notes:

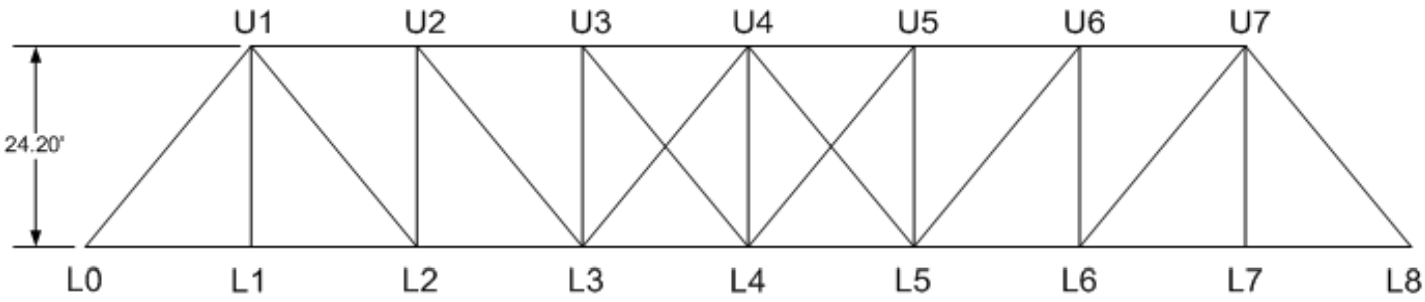
Typical Truss elevation and cross section used by inspectors in the field.

Use the inspection sketches, photos, and video to complete the inspection documentation of gusset plates L_7 on page 8.6A.67.

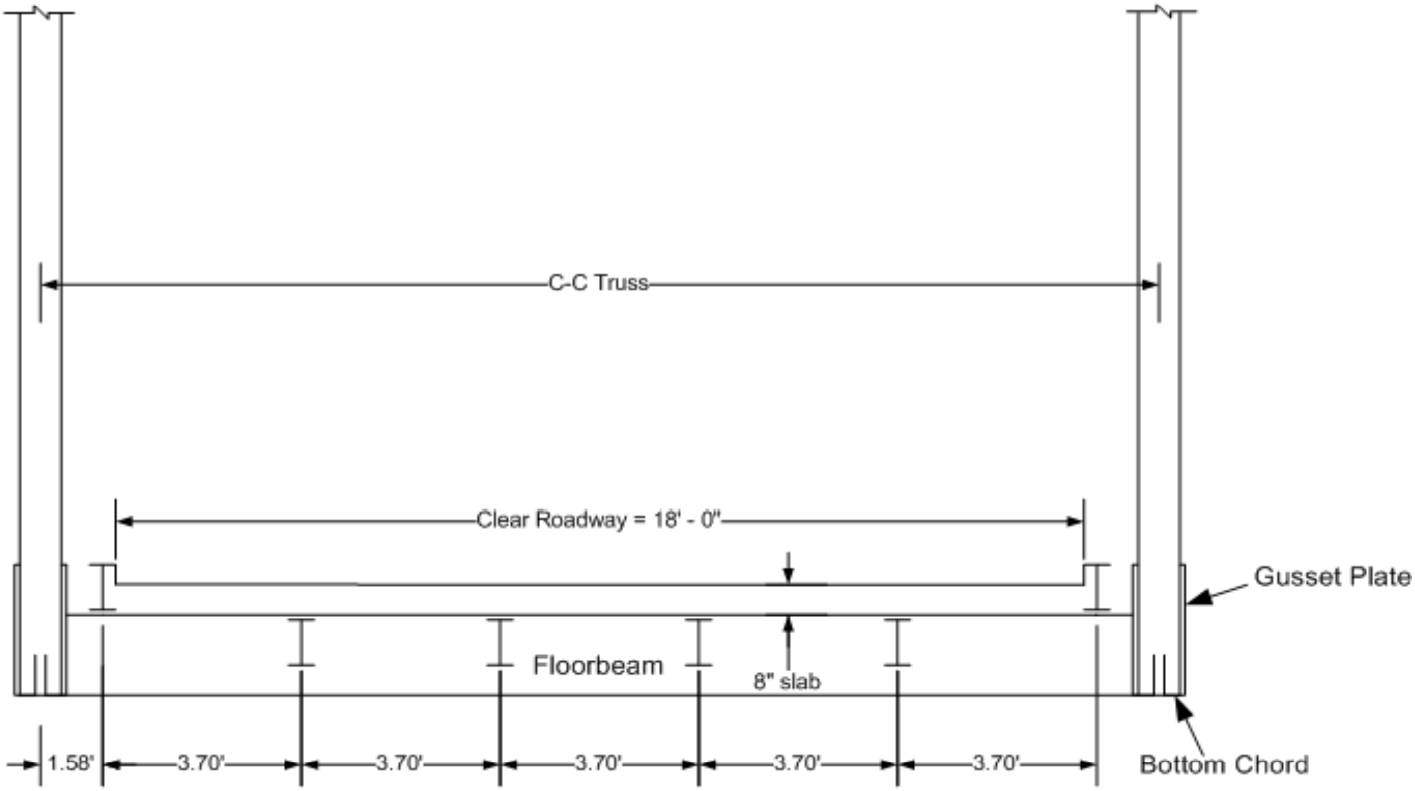
Use the inspection sketches, photos, and video to complete the inspection documentation of gusset plates L_6 on page 8.6A.78.

Background Information

NA



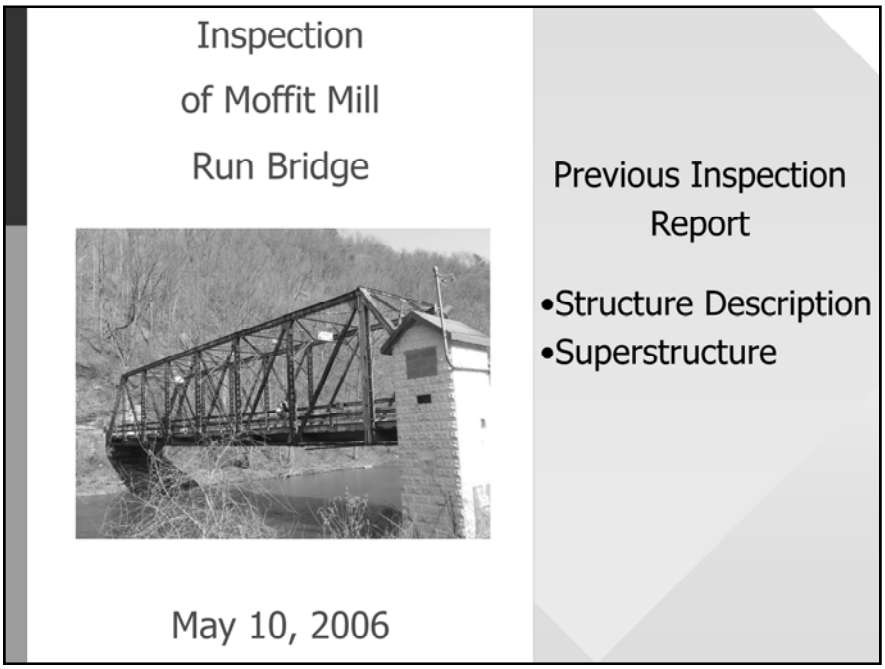
8-Panels @ 18.25' each = 146.0'



Stringers: 6 - 6" x 16" x ½" Steel I Beam

Floorbeams: 4 - L's 6 x 3 1/2" x ½"
1 – Web Plate ½" x 30"

Secondary Members not shown for clairity



Participant Notes:

Background Information

NA

Participant Workbook

Excerpts from previous Moffit Mill Run Bridge Inspection Report

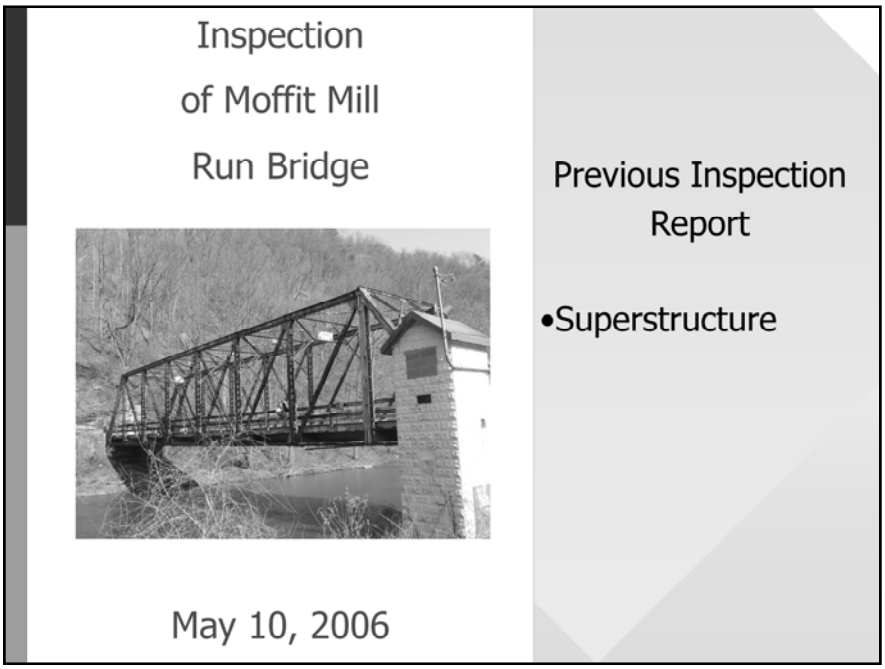
Structure Description

The bridge, built in 1929, is a single span riveted steel through-truss measuring 146′-0″ in length. The 8″ reinforced concrete bridge deck with 1″ bituminous wearing surface measures 18′-5″ between the fascia stringers and 18′-0″ curb-to-curb. The roadway carries two lanes of bi-directional traffic and is protected by steel angle and post railings along each side. The superstructure consists of four rolled steel interior stringers, two rolled steel fascia stringers, and seven built-up riveted steel floorbeams supported by two built-up riveted steel through-trusses. The substructure consists of two stone masonry abutments.

Superstructure

Truss: The truss bottom chords, verticals, and diagonals are in poor-to-serious condition. The bottom chord members typically exhibit moderate surface rust with minor section loss throughout. The following bottom chord members exhibit advanced section loss and corrosion holes:

- Right Truss Member L0-L1
- Right Truss Member L5-L6
- Right Truss Member L6-L7
- Right Truss Member L7-L8



Participant Notes:

Background Information

NA

Participant Workbook

Superstructure, continued

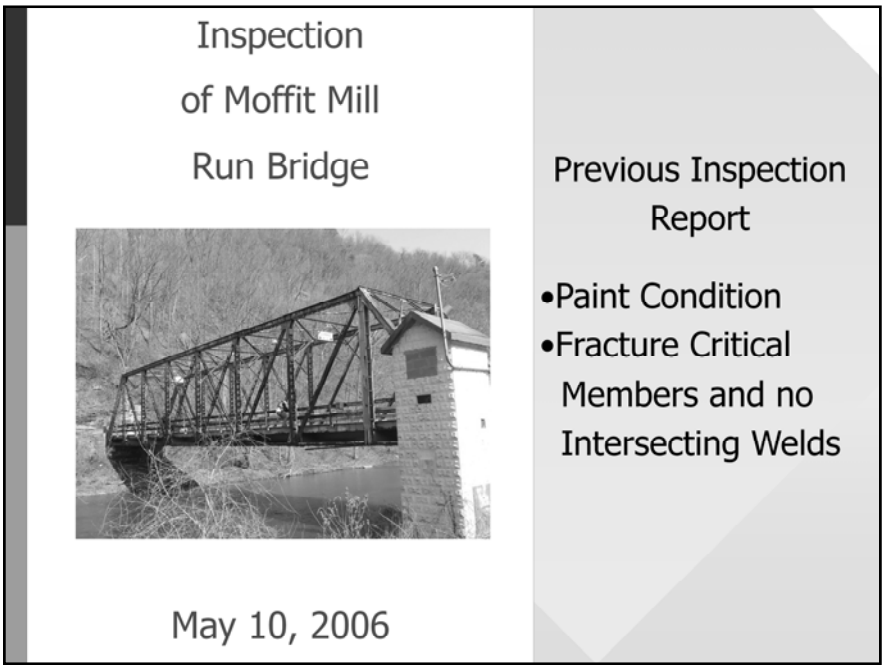
Bottom chord member L0-L1 and L7-L8 for both trusses exhibit horizontal sweeps and deflected flange angle vertical legs. There has been no change in the sweeps or deflections since the previous inspection.

The truss verticals and diagonals typically exhibit moderate surface rust with minor section loss in the splash zone. The following verticals and diagonals exhibit advanced section loss and corrosion holes:

- Left Truss Member L3-U4
- Left Truss Member U4-L5
- Right Truss Member L3-U4
- Right Truss Member L4-U4
- Right Truss Member U4-L5
- Right Truss Member L6-U7
- Right Truss Member L7-U7

A small hole is present in the right truss as a result of the collision damage. Left Truss Member L1-U1 has been retrofitted with welded angles and bars at the top and bottom chord connections (see Field Notes).

The top chord members are in fair condition with Paint failure and moderate surface rust throughout.



Participant Notes:

Background Information

NA

Participant Workbook

Paint Condition

The paint system has failed throughout all components of the bridge. Moderate-to-heavy surface rust is typical throughout the bridge, with isolated areas of advanced section loss, corrosion holes, and failed bracing members

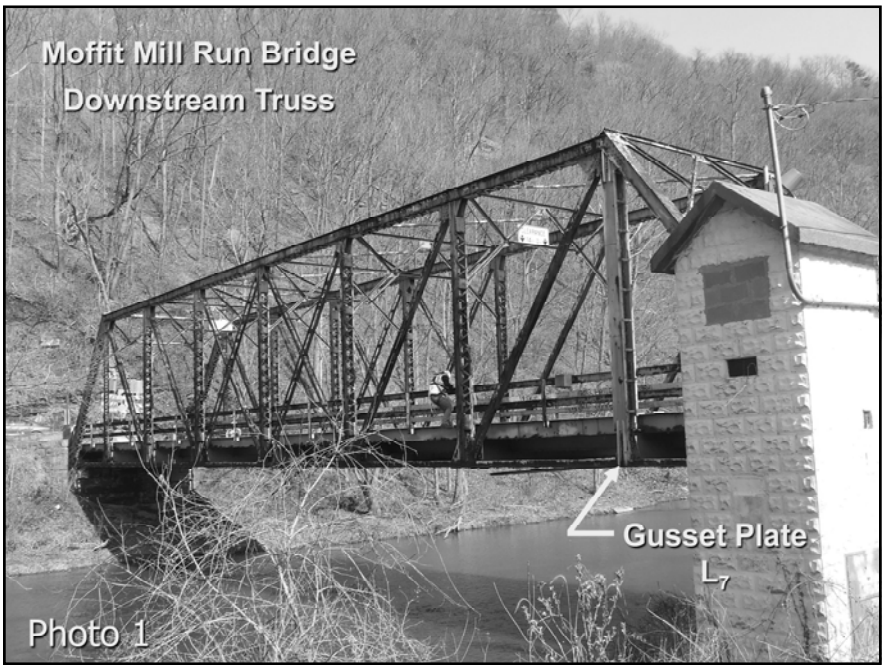
Fracture Critical Members and Intersection Welds

The fracture critical truss members are in serious-to-poor condition. Several truss diagonals and bottom chord members exhibit advanced section loss. The floorbeams are in poor condition with advanced section loss and corrosion holes in the bottom flange angles at the truss connections.

There are no intersecting welds on the bridge.

Note for Case Study:

There are no comments specifically on the condition of the truss gusset plates in the latest inspection report.



Participant Notes:

Background Information

NA

Participant Workbook

Gusset Plate L_7

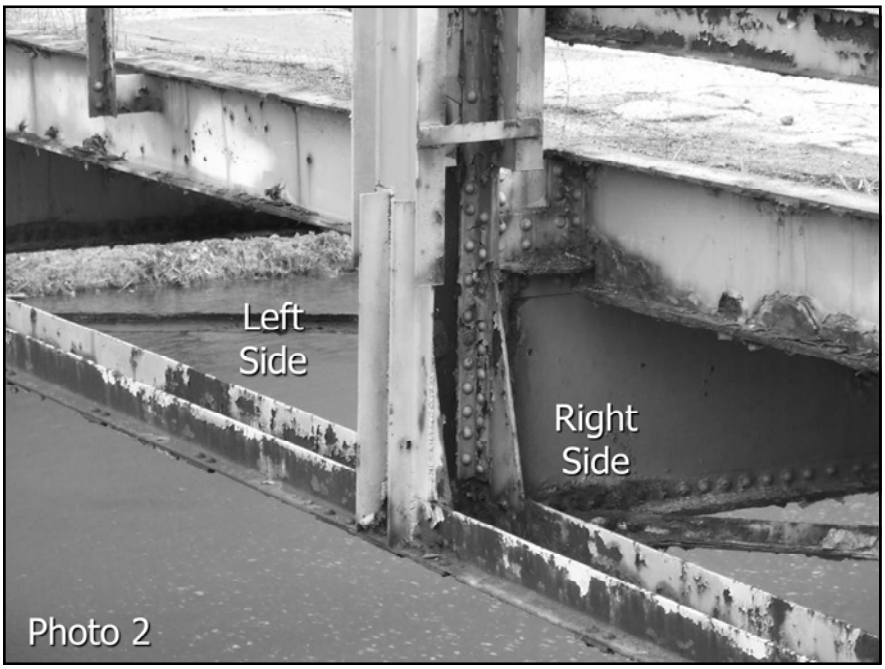
Photos 1-15 were taken during the special in-depth inspection of the gusset plates. Use the photos to determine the condition of the **Gusset Plate L_7** for this exercise.

Photo 1

Location: Moffit Mill Run Bridge. Downstream truss, Gusset Plate L_7 shown.

Gusset Plate L_6 will be shown later.

Use the photos and video to complete the inspection documentation on page 8.6A.67.



Participant Notes:

Background Information

NA

Participant Workbook

Photo 2

Location: Downstream truss.

Description: Close-up of Gusset Plate at L_7.

Participant Notes:

Background Information

NA

Participant Workbook

Photo 3

Location: Downstream truss.

Description: Right elevation of L7.

Note the rusted horizontal plate between the gusset plates.

Participant Workbook

Participant Notes:

Background Information

NA

Photo 4

Location: Downstream truss.

Description: Right elevation of L_7. Typical condition of the paint peeling on both gusset plates.

There appears to be section loss at mid plate of down stream plate.

Participant Workbook

Photo 5

Location: Downstream truss, L_7.

Description: Left elevation of L_7. Typical condition with corrosion and paint peeling.

Participant Notes:

Background Information

NA

Participant Notes:

Background Information

NA

Participant Workbook

Photo 6

Location: Gusset Plate L_7.

Description: Measuring the gusset plate dimensions:

- Height of gusset plate from bottom to top of the plate is 30.5″
- Diagonal distance is 26″
- Vertical depth is 6″
- Horizontal distance along the bottom chord is 21″
- Horizontal distance along the top is 6″

Participant Workbook

Participant Notes:

Background Information

NA

Photo 7

Location: Gusset plate L_7.

Description: There were no drawings available to determine the gusset plate dimensions. The dimensions of the gusset plate was measured in areas where there were no section loss. The measured thickness of the gusset plate:

- Thickness of gusset plate is 3/8″

Participant Workbook

Photo 8

Location: Gusset plate L_7.

Description: Measuring for out-of-plane distortion with a straight edge.

The plate is distorted along the edge and there is 3/16″ pack rust as shown by the arrow on the photo.

Participant Notes:

Background Information

NA

Participant Workbook

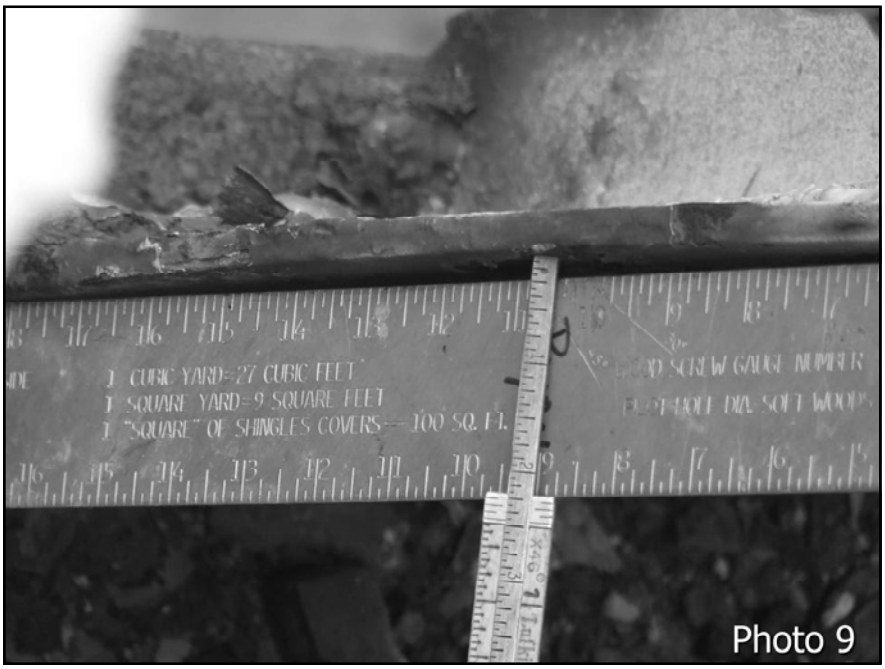


Photo 9

Participant Notes:

Photo 9

Location: Gusset plate L_7.

Description: Measuring for out-of-plane distortion with a straight edge.

- Out-of-plane distortion was measured to be 3/16″ on the downstream gusset plate
- The plate is bowed away from deck
- Maximum distortion is at the center of the free edge distance

Background Information

NA

Participant Workbook

Participant Notes:

Background Information

NA

Photo 10

Location: Downstream truss, gusset plate L_7.

Description: Using a grinder to clean the gusset plate of any loose rust and paint so an accurate measurement can be taken for the plate thickness.

Participant Notes:

Background Information

NA

Participant Workbook

Photo 11

Location: Gusset plate L_7.

Description: Measuring for section loss with the use of a D-meter.

- D-meter measured 0.251″ section remaining of the gusset plate. The original thickness was 3/8″.

Area with section loss

- 6″ vertical.
- 2 ½ ″ horizontal.
- 2 ½″ above horizontal plate

Participant Workbook

Photo 12

Location: Gusset plate L_7.

Description: Measuring section loss of the gusset plate with calipers.

Participant Notes:

Background Information

NA

Participant Workbook

Participant Notes:

Background Information

NA

Photo 13

Location: Gusset plate L_7.

Description: Measuring section loss of the gusset plate with calipers.

- Section remaining was found to be ¼″. The original thickness was 3/8″.

Participant Notes:

Background Information

NA

Participant Workbook

Photo 14

Location: Gusset plate L_7.

Description: Use of a hammer to clear debris off the gusset plate and check soundness of rivets.

40 to 100% section loss is estimated for the four interior rivet heads on the bottom right side of Gusset Plate L_7.

There are no tack welds connecting the gusset plates to the truss chord members.

Participant Notes:

Background Information

NA

Participant Workbook

Photo 15

Location: Gusset plate L_7.

Description: Retrofit angles placed on the gusset plate. Total height of the 3 ½″ x 3 ½″ x 3/8″ angles is 39″. The distance between the back of the angles is 5″

The retrofits are attached with field welds which have an irregular surface profile.

Using information from the photograph and video, provide gusset plate dimensions and noted defects for Gusset Plate L_7.

Notes:

- Out-of-plane distortion _____
- Gusset plate section loss _____
- Tack welds _____
- Connections _____
- Repair and retrofits _____

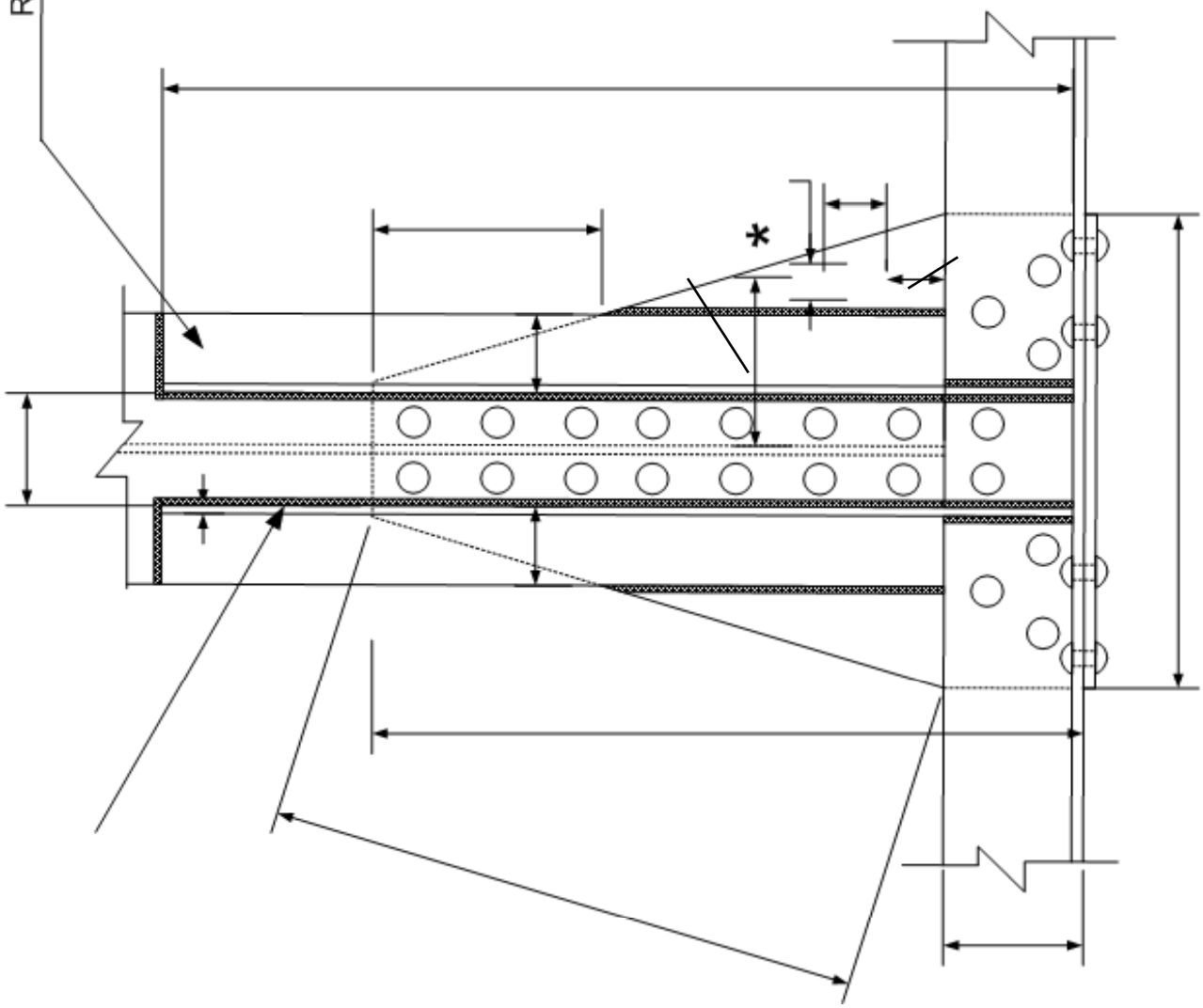


Figure
Downstream L7 Gusset Plate

Participant Workbook

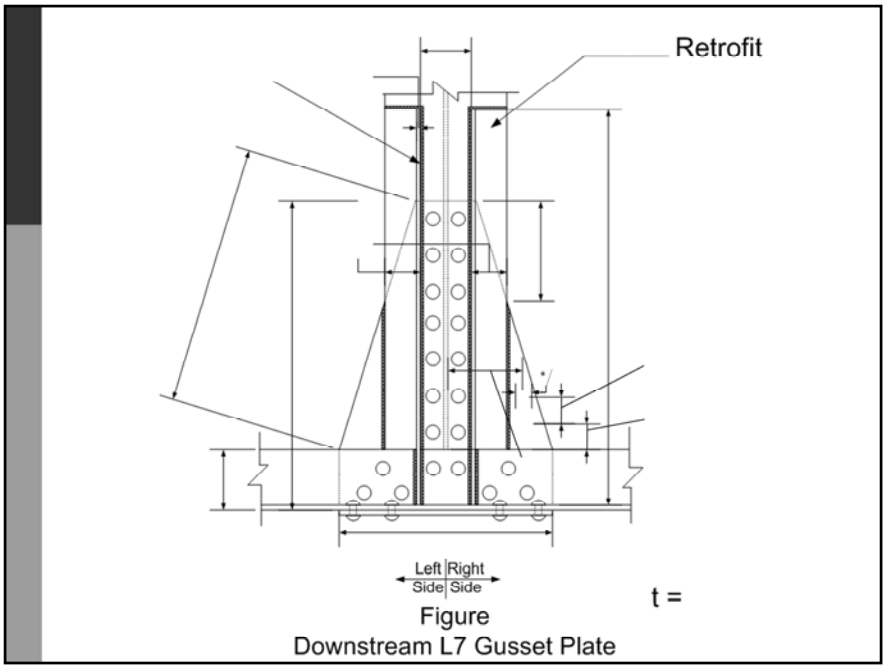


Figure
Downstream L7 Gusset Plate

L_7 gusset plate dimensions.

Participant Notes:

Background Information

NA

Notes

- Out-of-plane distortion
- Gusset plate section loss
- Tack welds
- Connections
- Repair and retrofits

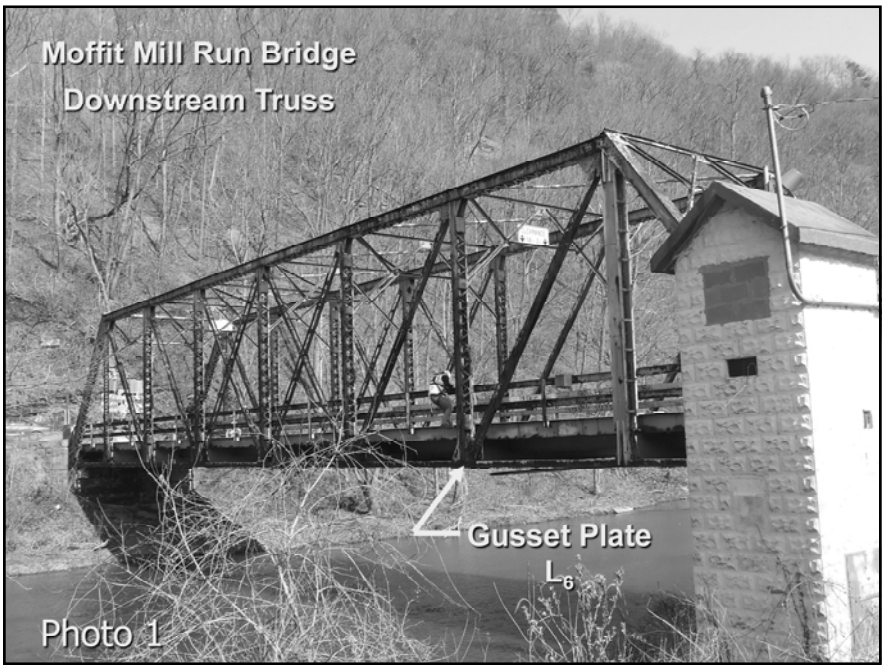
Participant Notes:

Background Information

NA

Participant Workbook

Complete the inspection notes for Gusset Plate L_7.



Participant Notes:

Background Information

NA

Participant Workbook

Gusset Plate L_6

Photos 1-8 were taken during the special in-depth inspection of the gusset plates. Use the photos to determine the condition of the **Gusset Plate L_6** for this exercise.

Photo 1

Location: Moffit Mill Run Bridge. Downstream truss, gusset plate L_6.

Description: Through truss bridge, downstream elevation.

Use the photos and video to complete the inspection documentation on page 8.6A.78.

Participant Workbook

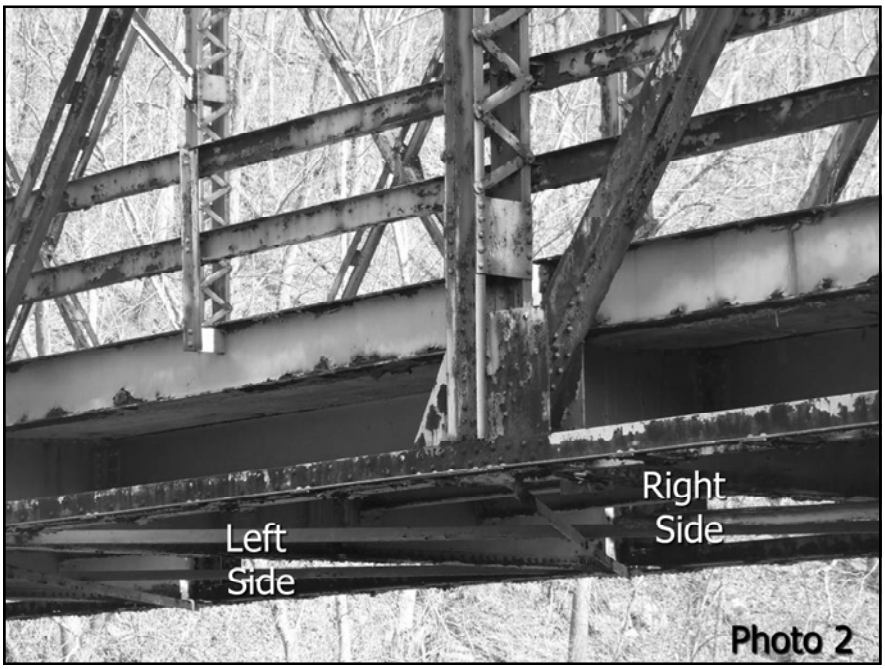


Photo 2

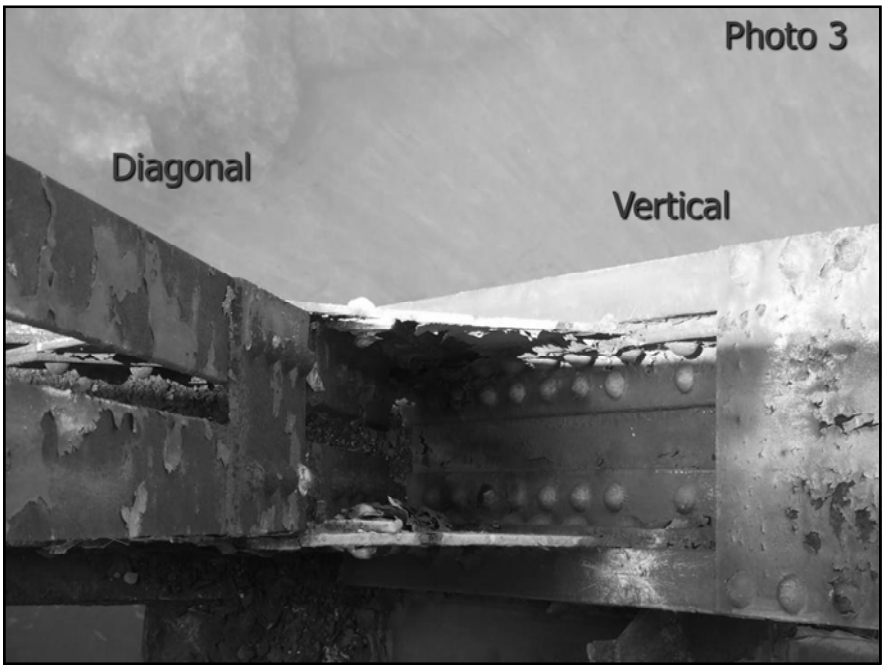
Location: Downstream truss.

Description: Close-up of L_6.

Participant Notes:

Background Information

NA



Participant Notes:

Background Information

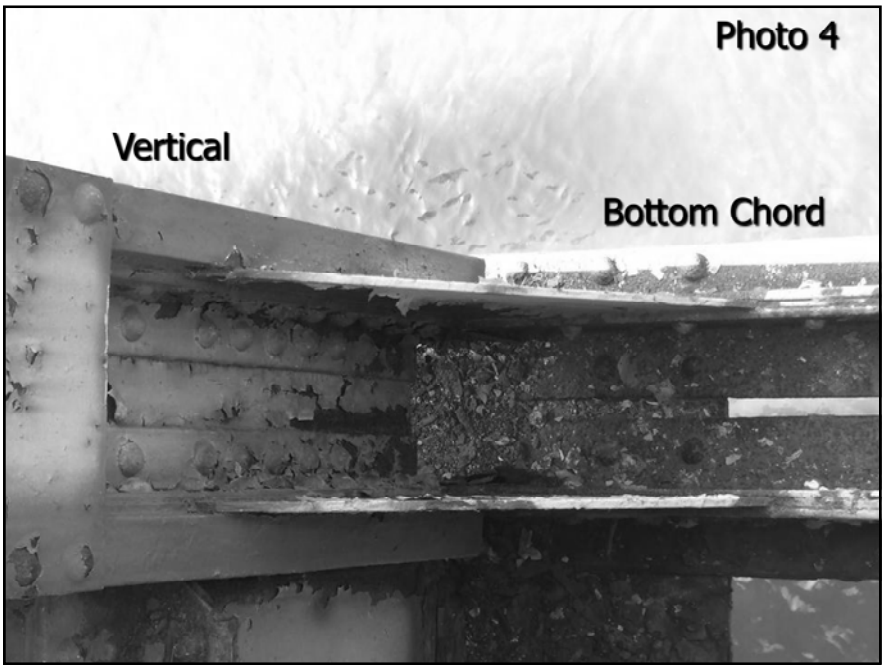
NA

Participant Workbook

Photo 3

Location: Gusset plate L_6.

Description: Looking down the diagonal member on the right side of Gusset Plate L_6 connection. There was no measureable section loss on either gusset plate.



Participant Notes:

Background Information

NA

Participant Workbook

Photo 4

Location: Gusset plate L_6.

Description: Looking down on the left side of Gusset Plate L_6 connection. Notice the flaking and rust, however there was no measureable section loss on either plate.

Participant Notes:

Background Information

NA

Participant Workbook

Photo 5

Location: Gusset plate L_6.

Description: Measuring the gusset plate dimensions:

- Diagonal distance on the left side is 28.5″
- Height of gusset plate from bottom to top of the plate is 30″
- Horizontal distance along the bottom chord is 40″
- Horizontal distance along the top is 25.875″
- Bottom channel height is 6″
- Vertical channel width is 9″
- Thickness is 0.375″

Participant Notes:

Background Information

NA

Participant Workbook

Photo 6

Location: Gusset plate L_6.

Description: Front elevation of gusset plate L_6. Rust and corrosion is typical throughout all the gusset plates along the bottom chord.

There are no tack welds between the gusset plates and truss members.

There are no retrofits of the gusset plates.

Minor surface corrosion is present but no section loss.

Participant Notes:

Background Information

NA

Participant Workbook

Photo 7

Location: Gusset plate L_6.

Description: Gusset plate out-of-plane distortion was checked. No out-of-plane distortion was found along the edge or middle of the gusset plates.

There was some pack rust found on the right side of the gusset plate, measuring at 3/16″.

Participant Notes:

Background Information

NA

Participant Workbook

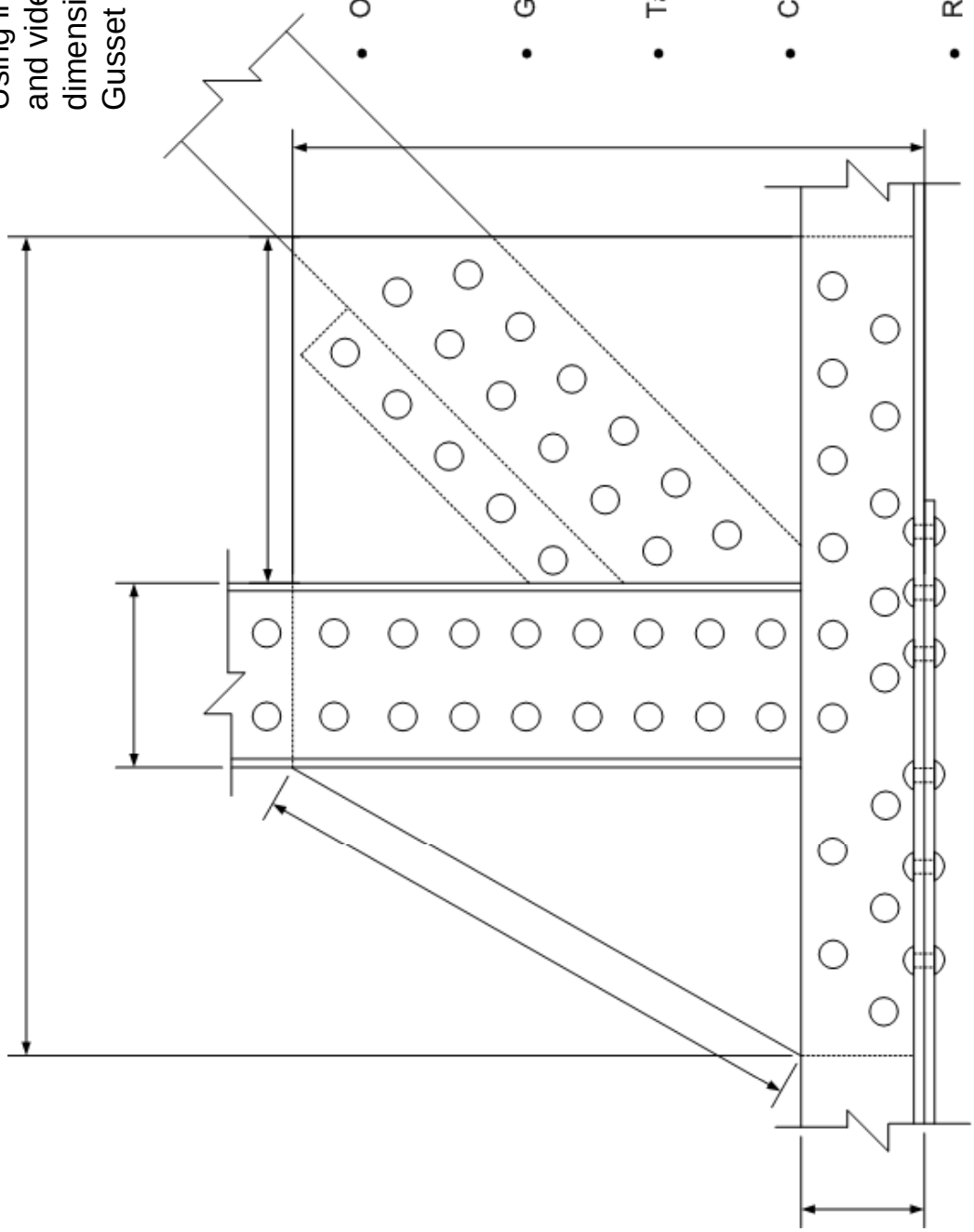
Photo 8

Location: Gusset plate L_6.

Description: Inspecting the fasteners by using a hammer to listen for any fasteners that may be loose.

All connectors were tight with only surface corrosion.

Using information from the photograph and video, provide gusset plate dimensions and noted defects for Gusset Plate L_6.



Notes:

- Out-of-plane distortion _____
- Gusset plate section loss _____
- Tack welds _____
- Connections _____
- Repair and retrofits _____

t =

Figure
L6 Gusset Plate

Participant Workbook

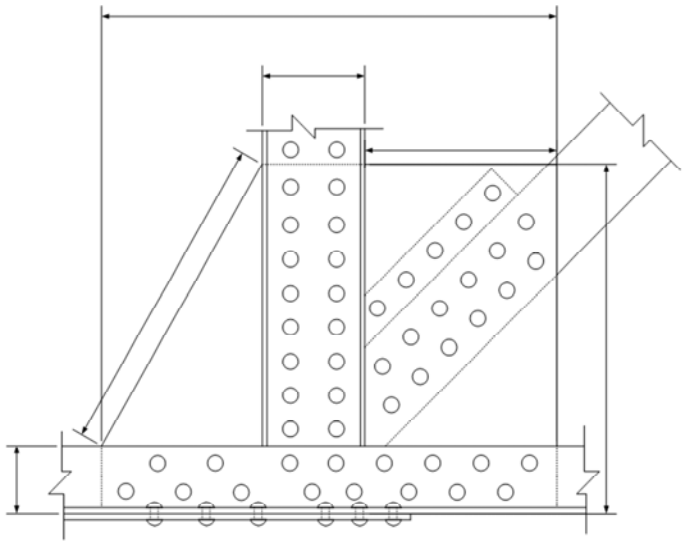


Figure
L6 Gusset Plate

t =

Complete documentation for L_6 Gusset Plate dimensions.

Participant Notes:

Background Information

NA

Notes

- Out-of-plane distortion
- Gusset plate section loss
- Tack welds
- Connections
- Repair and retrofits

Participant Notes:

Background Information

NA

Participant Workbook

Complete documentation for L_6 Gusset Plate defect descriptions.

Document Conditions in Sufficient Detail for Structural Analysis and Load Rating

	L_7	L_6
1. Planned vs. In-Field gusset plate findings	___	___
2. Out-of-plane distortions	___	___
3. Coating system failure	___	___
4. Corrosion / Section Loss	___	___
5. Cracks	___	___
6. Connections	___	___
7. Repairs / Retrofits	___	___
Final Recommendation	___	___

Participant Notes:

Background Information

NA

Participant Workbook

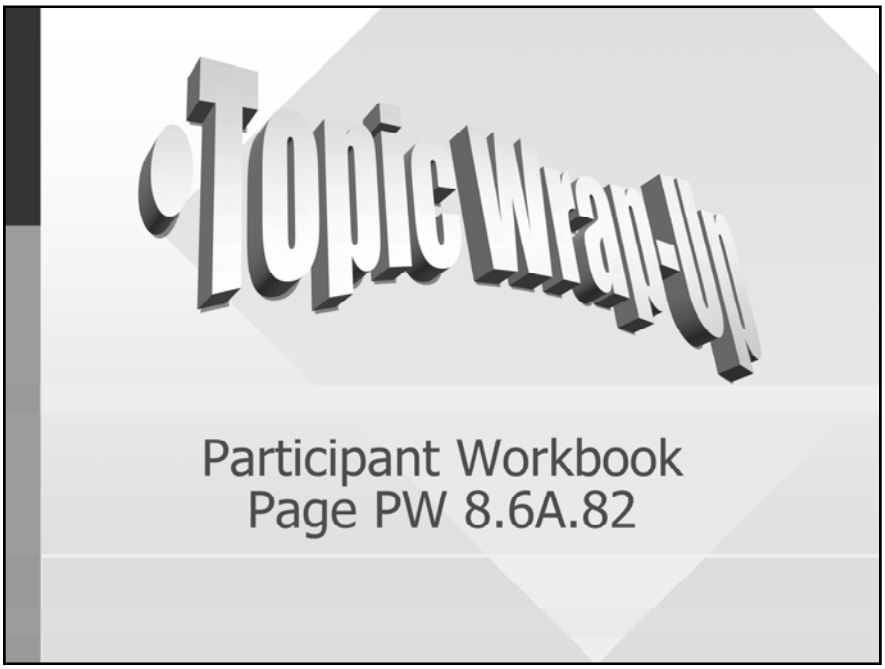
Are there any findings (1-7 in the slide) that would make you recommend structural analysis?

Y- Yes: Condition warrants analysis of Gusset Plate

N – No: Condition does NOT warrant analysis of Gusset Plate

P – Possibly: Condition may warrant a structural analysis of Gusset Plate

Participant Workbook

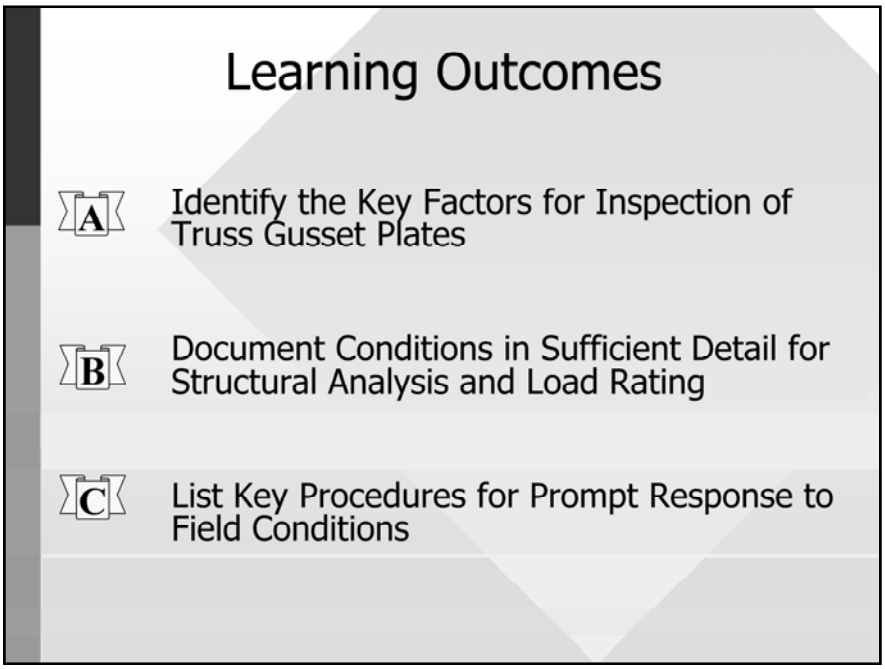


Participant Notes:

Background Information

NA

Participant Workbook



Participant Notes:

Background Information

NA

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