George Sellar Bridge No 285/10

Strengthening a Riveted Truss for Added Lane and Sidewalk

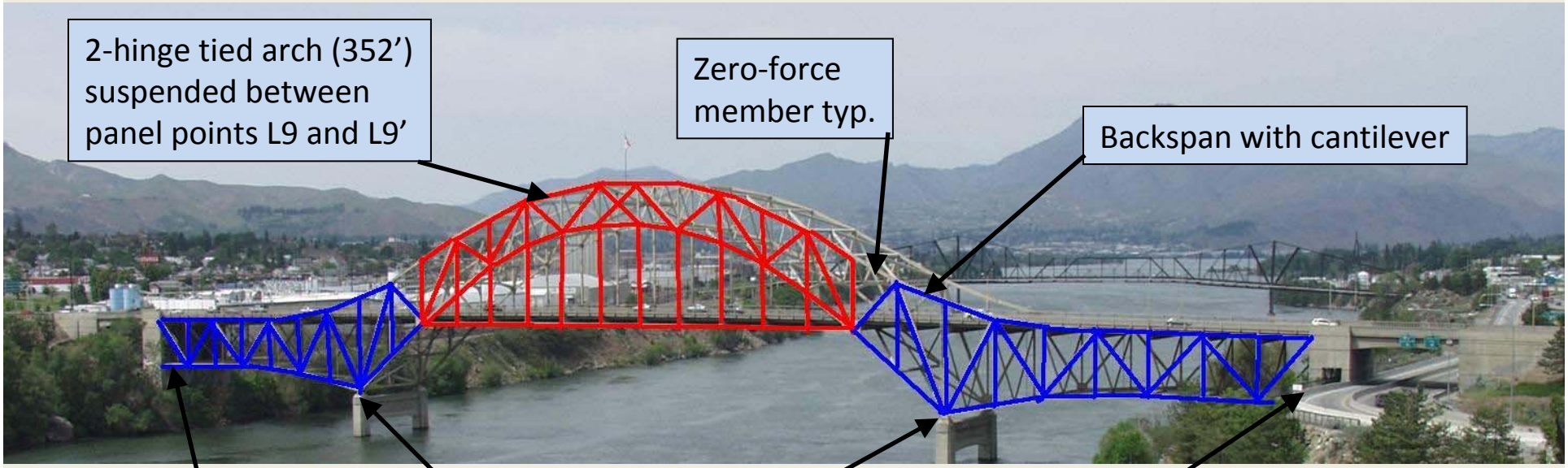
Geoff Swett, PE, SE
WSDOT Bridge & Structures

George Sellar Bridge - Location

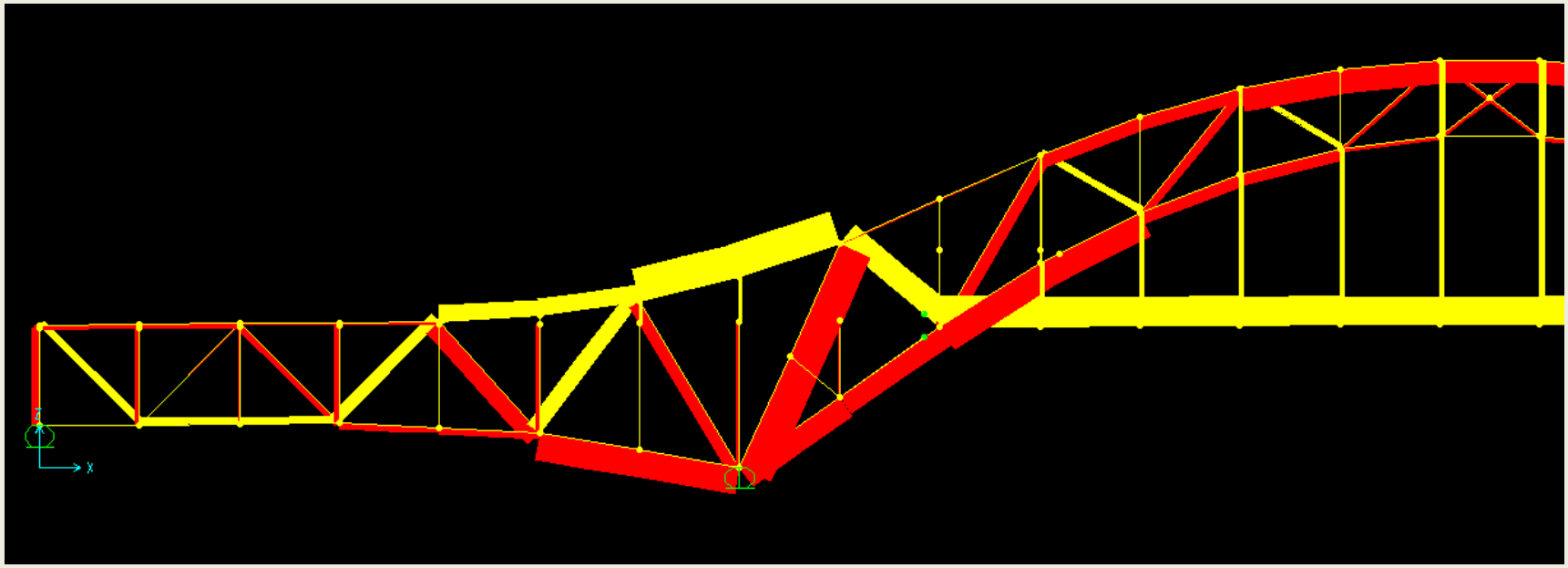
George Sellar Bridge

- Total Bridge Length = 1208 feet
- 3 Span Truss with Concrete Approaches
  - 480 foot main span
  - 223 foot back spans
- Original Completion Date – 1950
- 60,000 ADT

George Sellar Bridge - Truss Span Structural System



Truss: Typical Dead Loading

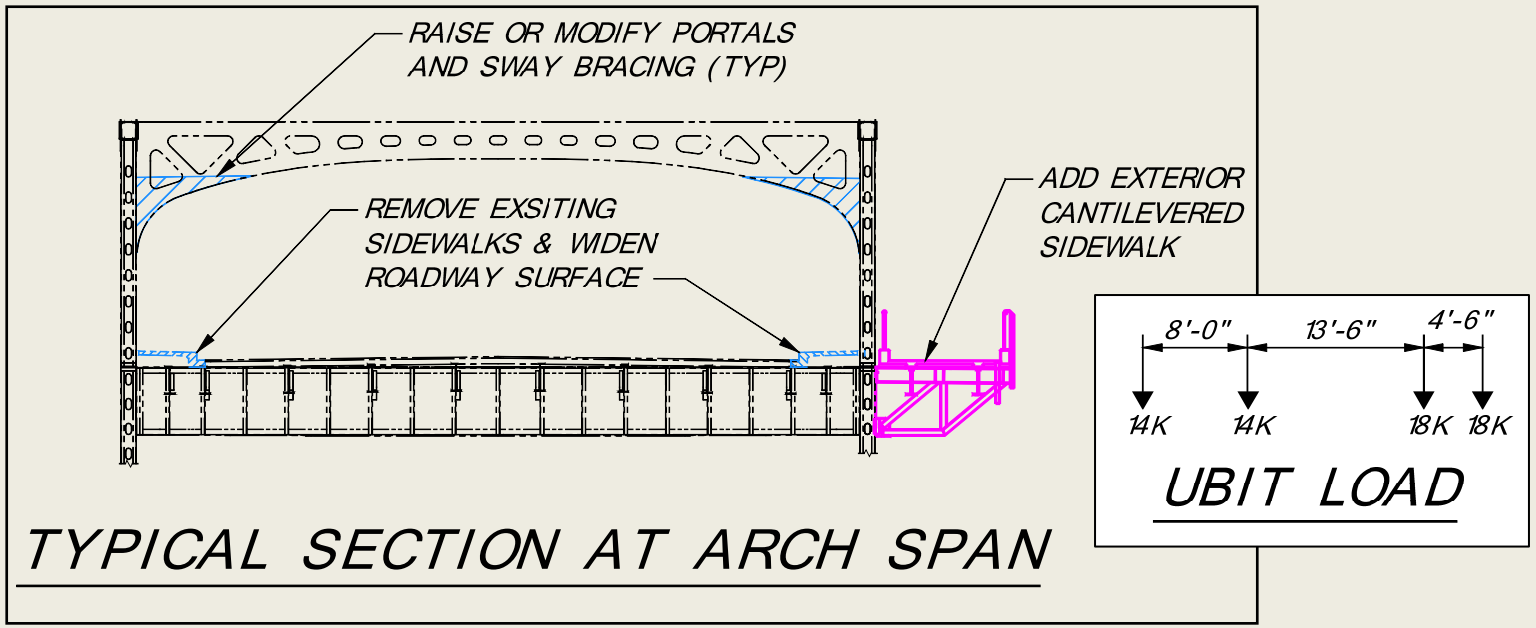


- Yellow = Tension Member
- Red = Compression Member
- Several members reverse load under Live Load

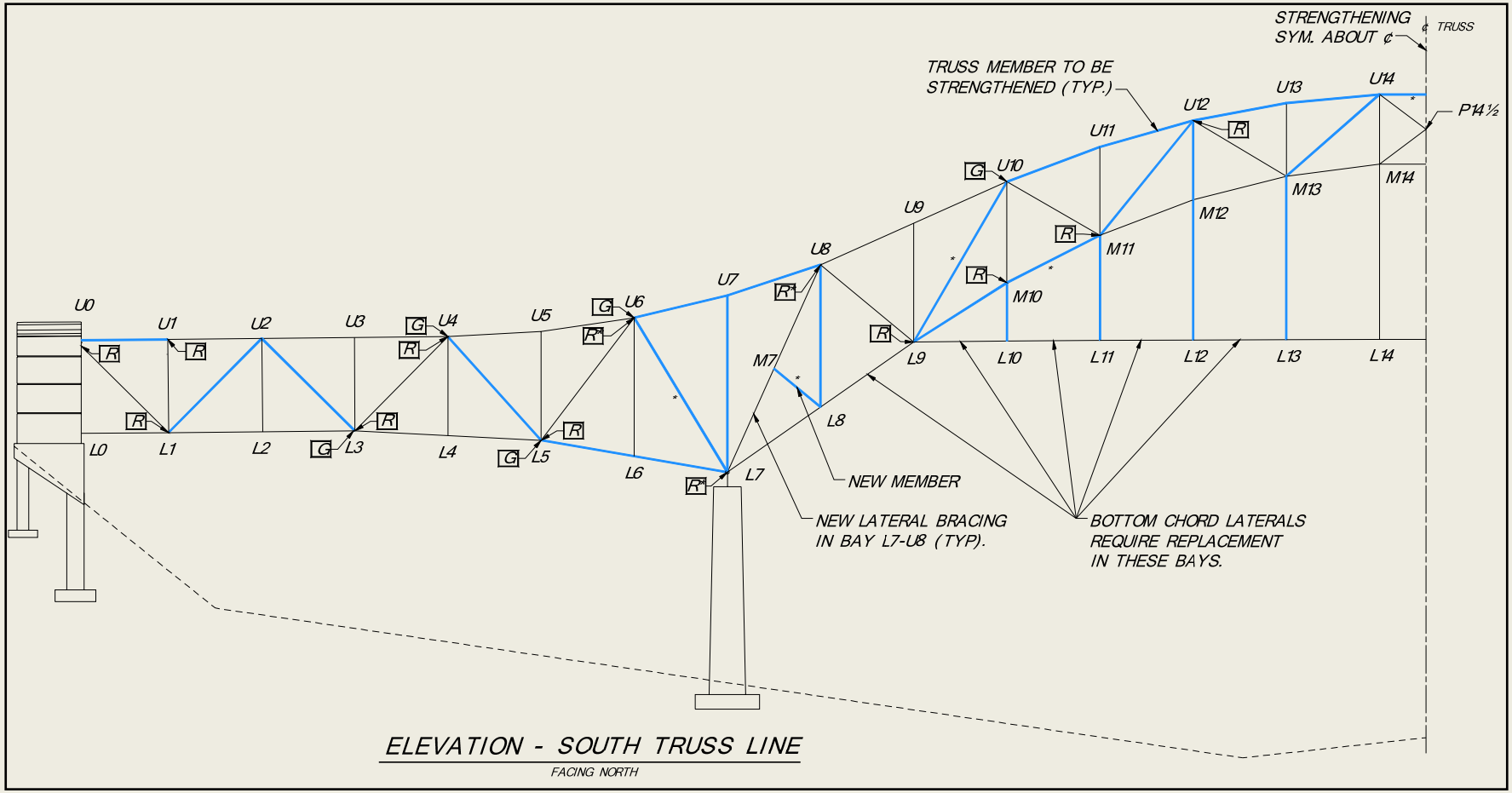
- Design requirements vary depending on loading

Project Scope

- Remove sidewalks on truss and widen roadway for additional traffic lane
- Raise/modify/replace portals and sways to provide proper vertical clearance
- Add sidewalk exterior to truss for pedestrians and maintenance vehicles (UBIT)
- Widen concrete approach structures for additional roadway and sidewalk
- RESULTS – Additional Dead, Live and Pedestrian Load = **MAJOR TRUSS REHAB**



Scope of Truss Strengthening



- **Total of 94 members strengthened or replaced**
- **Total of 10 gusset plates strengthened**

All under traffic

Analysis & Design Approach

Primary Truss Members

- Determine new demands with additional DL + LL
- Check C/D ratios of existing members – members were analyzed for combined axial and moment
- If member is overstressed design strengthening retrofit

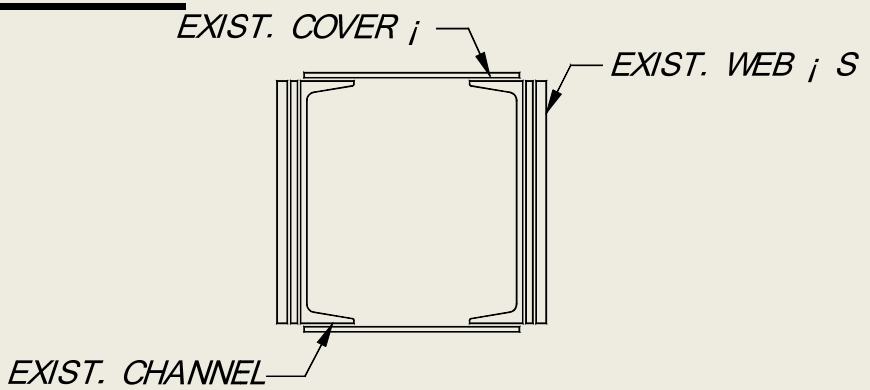
Secondary Members

- Determine new demands with additional DL + LL
- Check C/D ratios
- If member is overstressed - replace

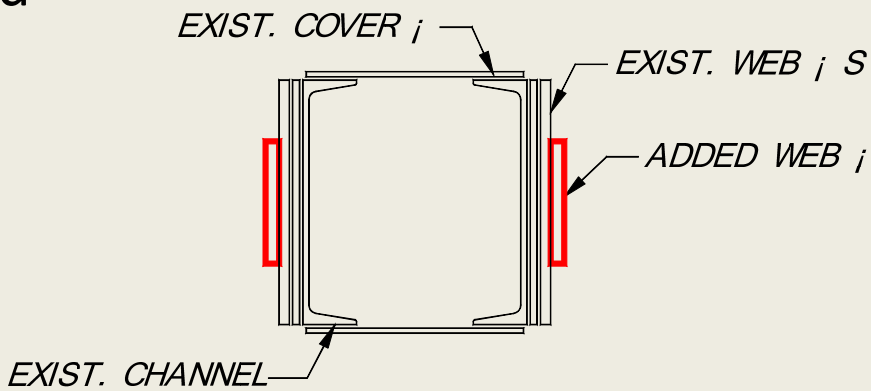
Retrofit Analysis for Overstressed Members

Investigate at stress level and consider sequence of loading

1. Compute demand from existing DL
2. Add plates and check demand on existing member for DL_add + Total_LL
3. Check demand on existing member for combination of steps 1 and 2



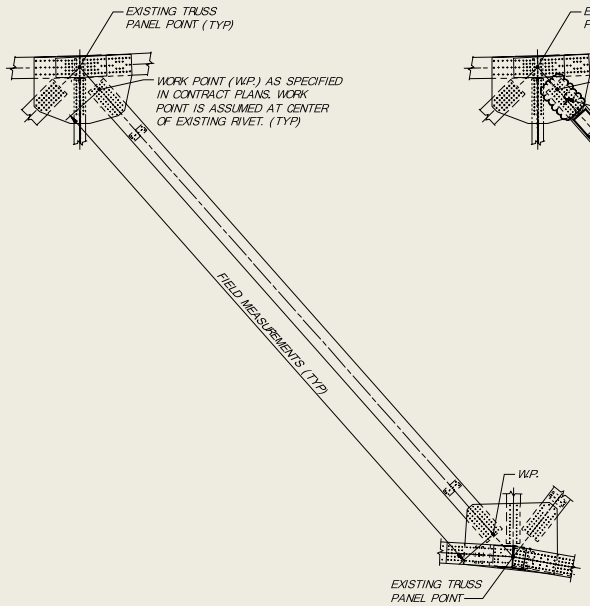
TYPICAL EXISTING BUILT-UP MEMBER

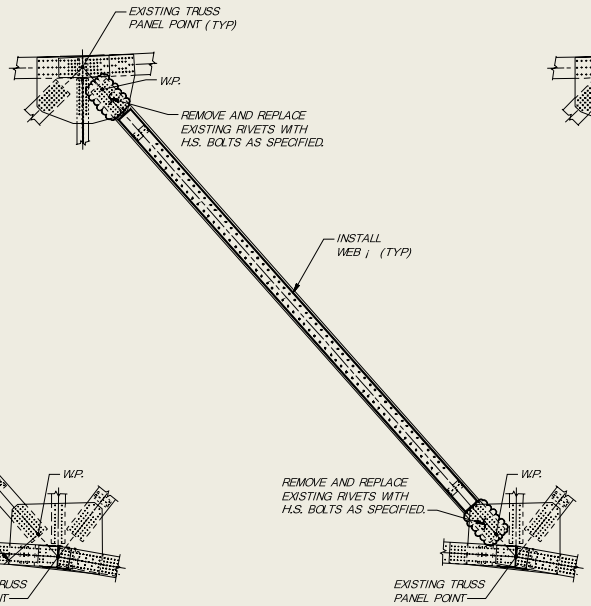


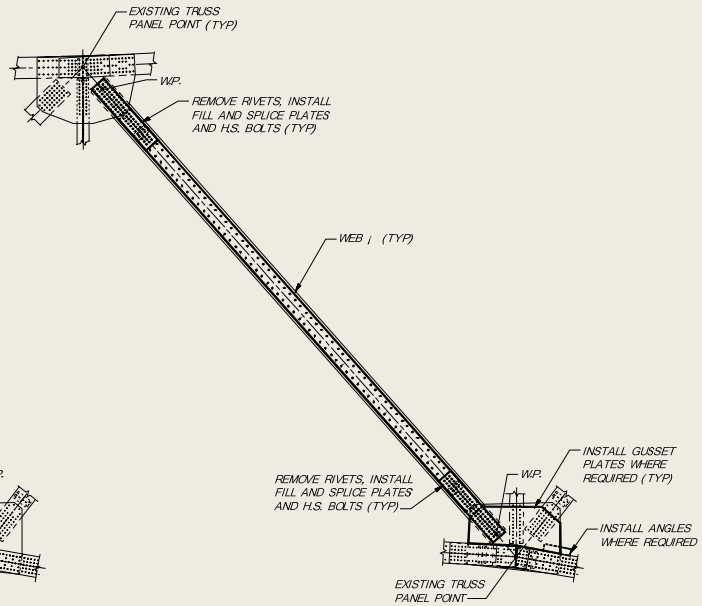
TYPICAL RETROFIT BUILT-UP MEMBER

Steel = either Carbon (33ksi/60ksi) or Silcon (45ksi/80ksi)

General Strengthening Scheme







Step 1

- Field measurements
- Develop *Shop Plans*
- Develop *Truss Strengthening Plan*

Step 2

Increase capacity of existing connections

Install plates between gussets

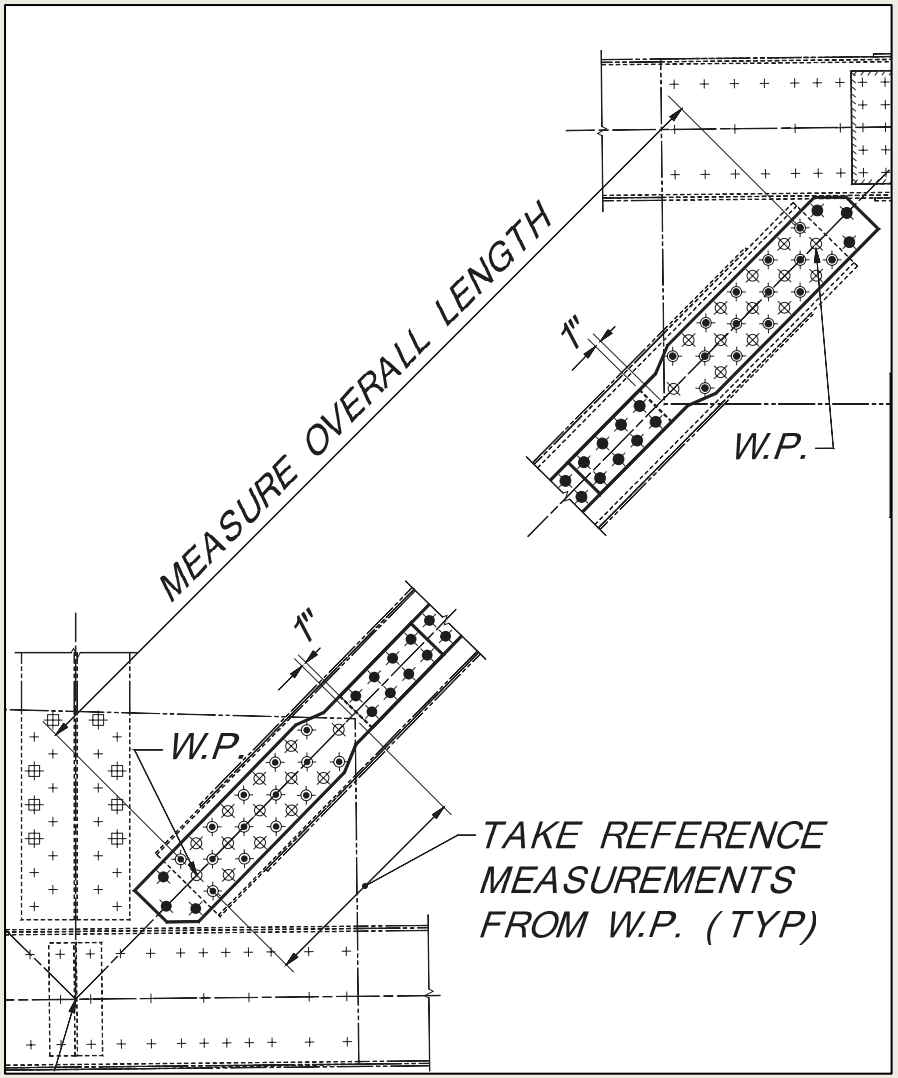
Step 3

Remove rivets and install splice, fill, web, and gusset plates.

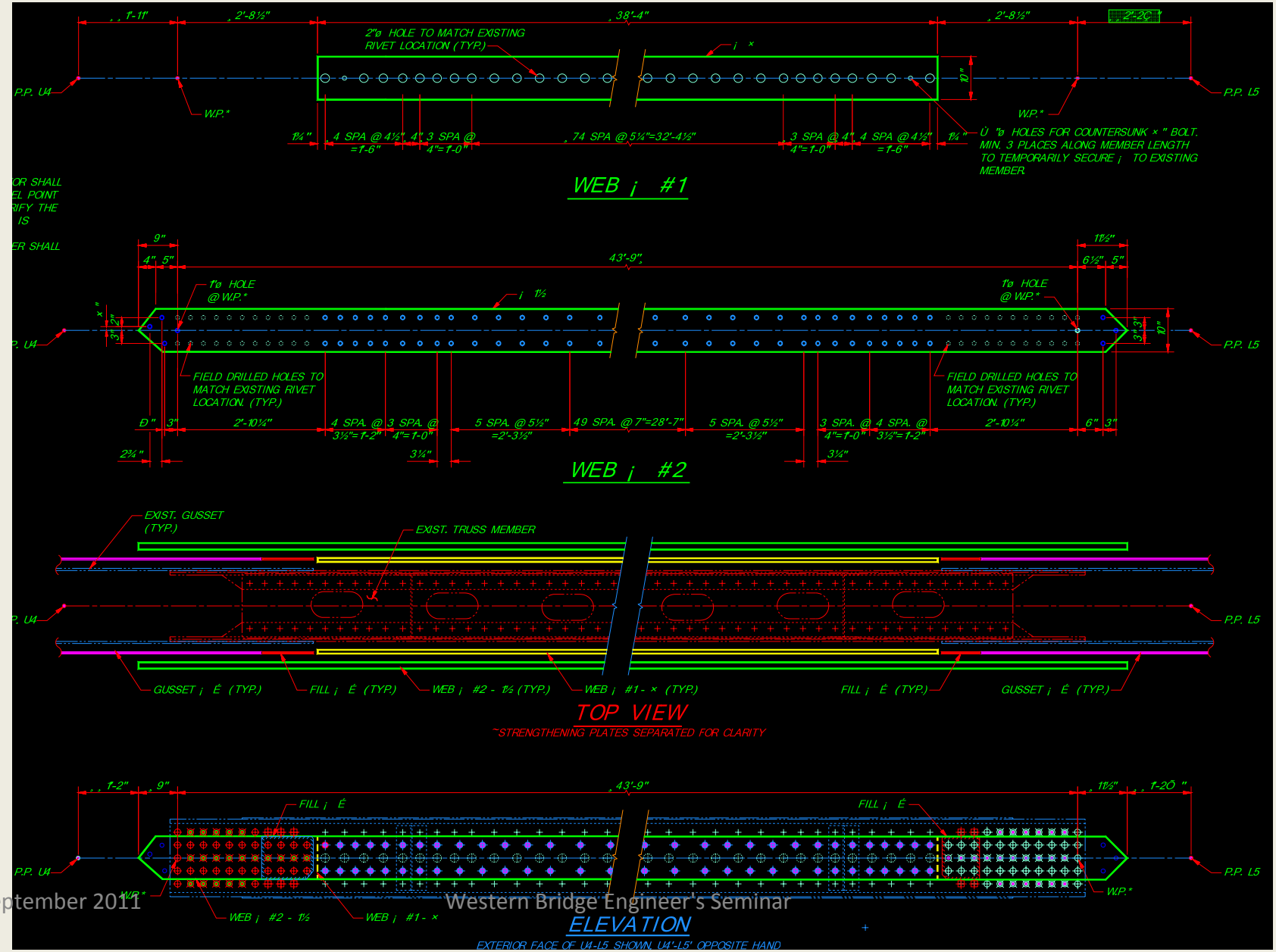
Work 1 side of joint at a time

Step 1

- Field measurements
- Develop *Shop Plans*
- Develop *Truss Strengthening Plan*

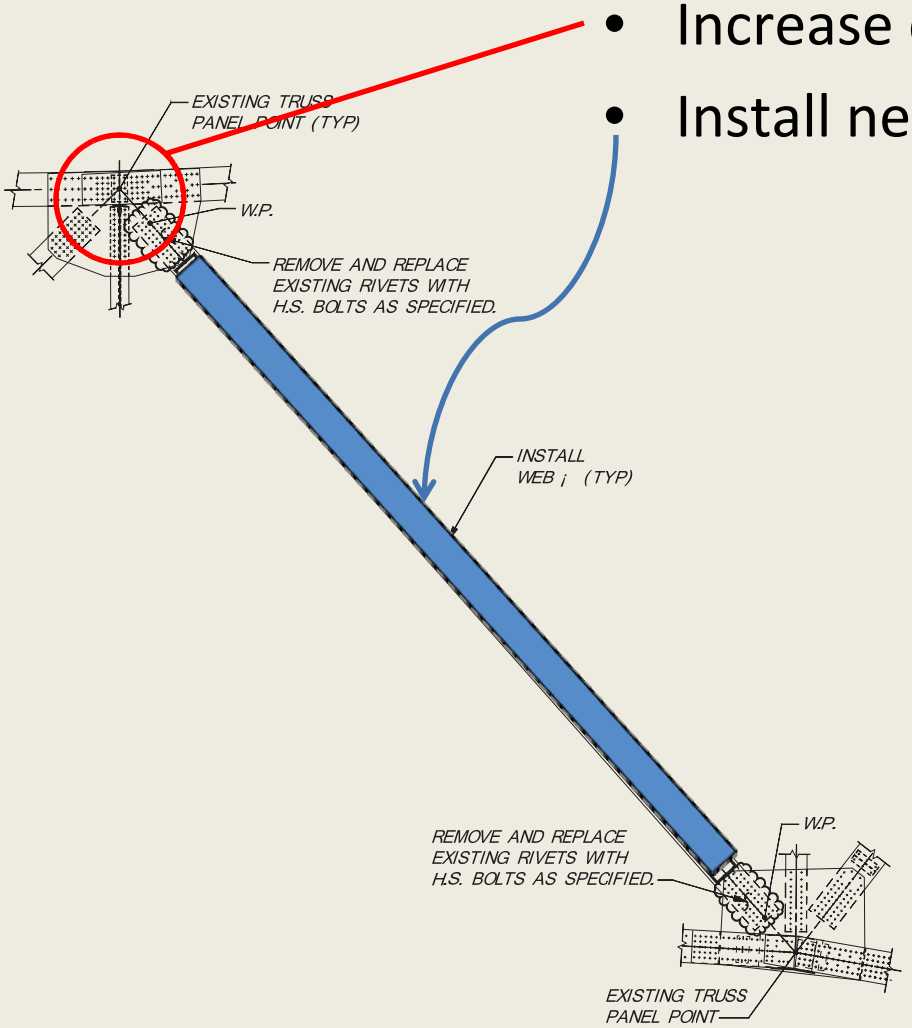


Example: U4-L5 Beam – Contract Plans nearly equivalent to Shop Plans



Step 2

- Increase capacity of existing connections
- Install new web plates between gussets



Each Member and Connection had a Specified Strengthening Sequence

CRITICAL TO FOLLOW SEQUENCE

Step 2

STRENGTHENING SEQUENCE @ U2

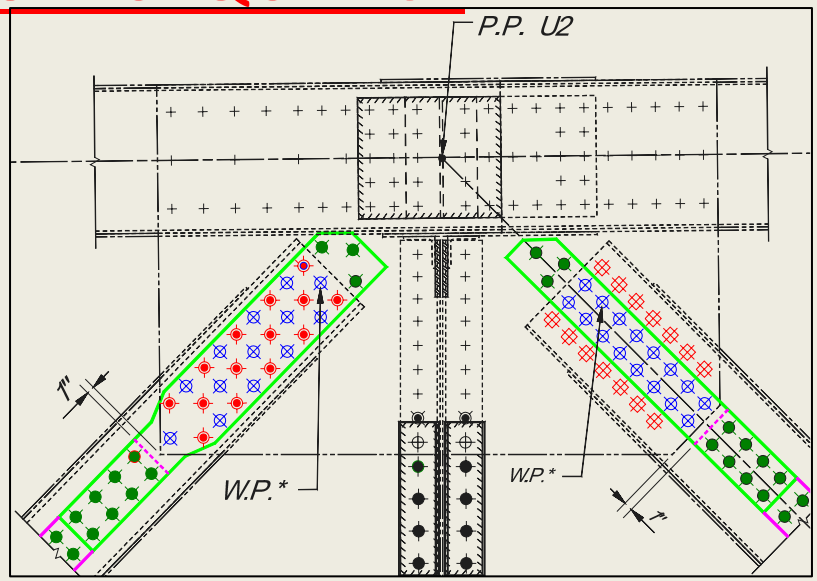
1A. MEMBER L1-U2 & U2-L3: INSTALL WEB PLATES FULL LENGTH OF MEMBER BETWEEN EXISTING GUSSET PLATES.

1B. MEMBER CONNECTIONS OF L1-U2 & U2-L3 TO U2 GUSSET PLATES: REMOVE AND REPLACE EXISTING RIVETS AND REPLACE WITH COUNTERSUNK H.S. BOLTS ⊙ OR STANDARD H.S. BOLTS ⊕ AT LOCATIONS SPECIFIED IN THE PLANS. AT EACH MEMBER CONNECTION TO THE GUSSET, REMOVE AND REPLACE EXISTING RIVETS WITH H.S. BOLTS (COUNTERSUNK OR STANDARD) ONE AT A TIME UNTIL A MINIMUM OF 5 H.S. BOLTS HAVE BEEN INSTALLED. AT THAT POINT, A MAXIMUM OF 5 EXISTING RIVETS CAN BE REMOVED FOR REPLACEMENT AT ONE TIME.

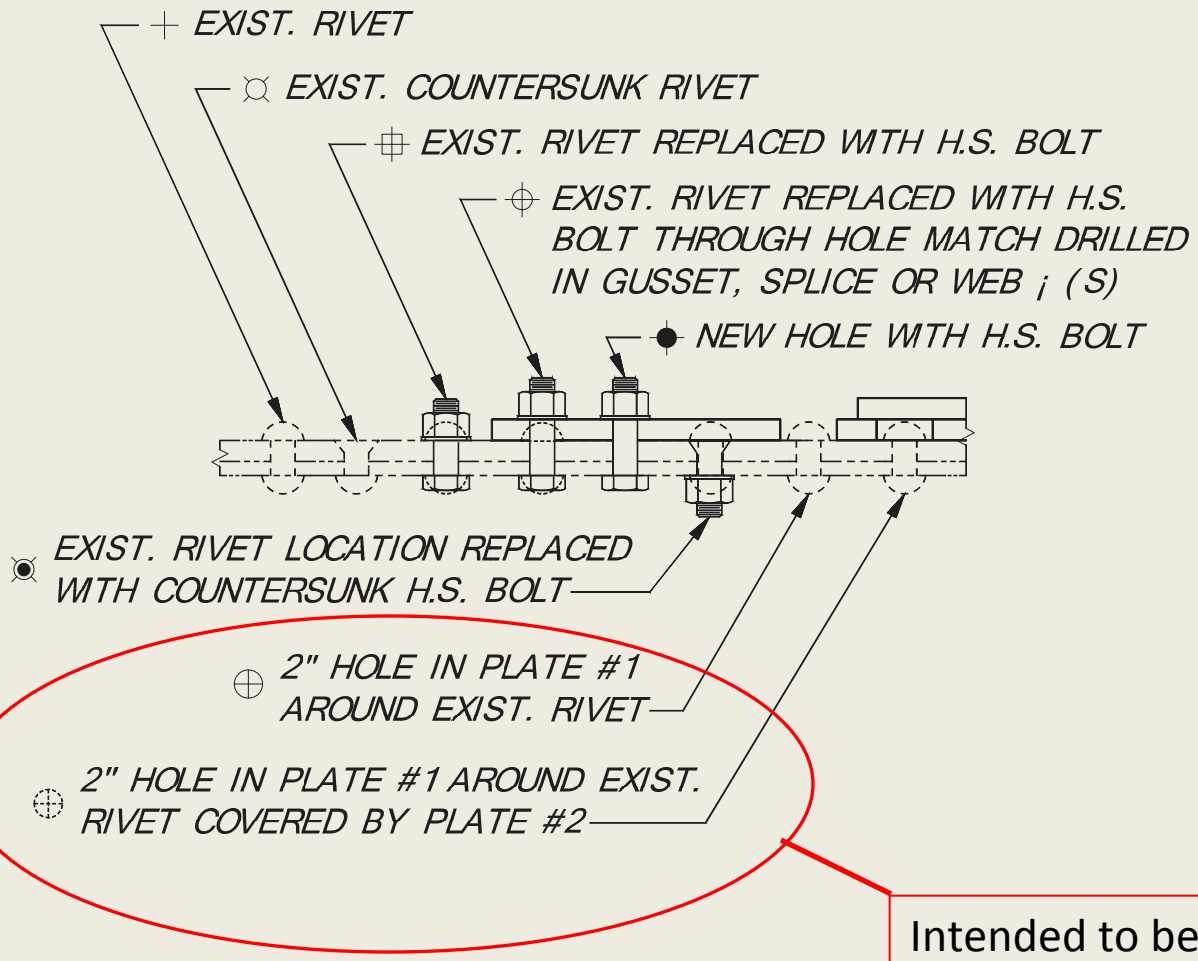
2. AT EACH MEMBER CONNECTION, REMOVE EXISTING RIVETS AT LOCATIONS TO BE COVERED BY NEW SPLICE PLATES AND LEAVE HOLES OPEN.

3. INSTALL SPLICE PLATES IN MEMBER L1-U2 & U2-L3 AND INSTALL ALL REMAINING H.S. BOLTS.

NOTE: STEPS 2 & 3 SHALL BE COMPLETED ON ONE GUSSET/CONNECTION FACE (NS OR FS) PRIOR TO PERFORMING STEPS 2 & 3 ON THE OPPOSITE FACE.



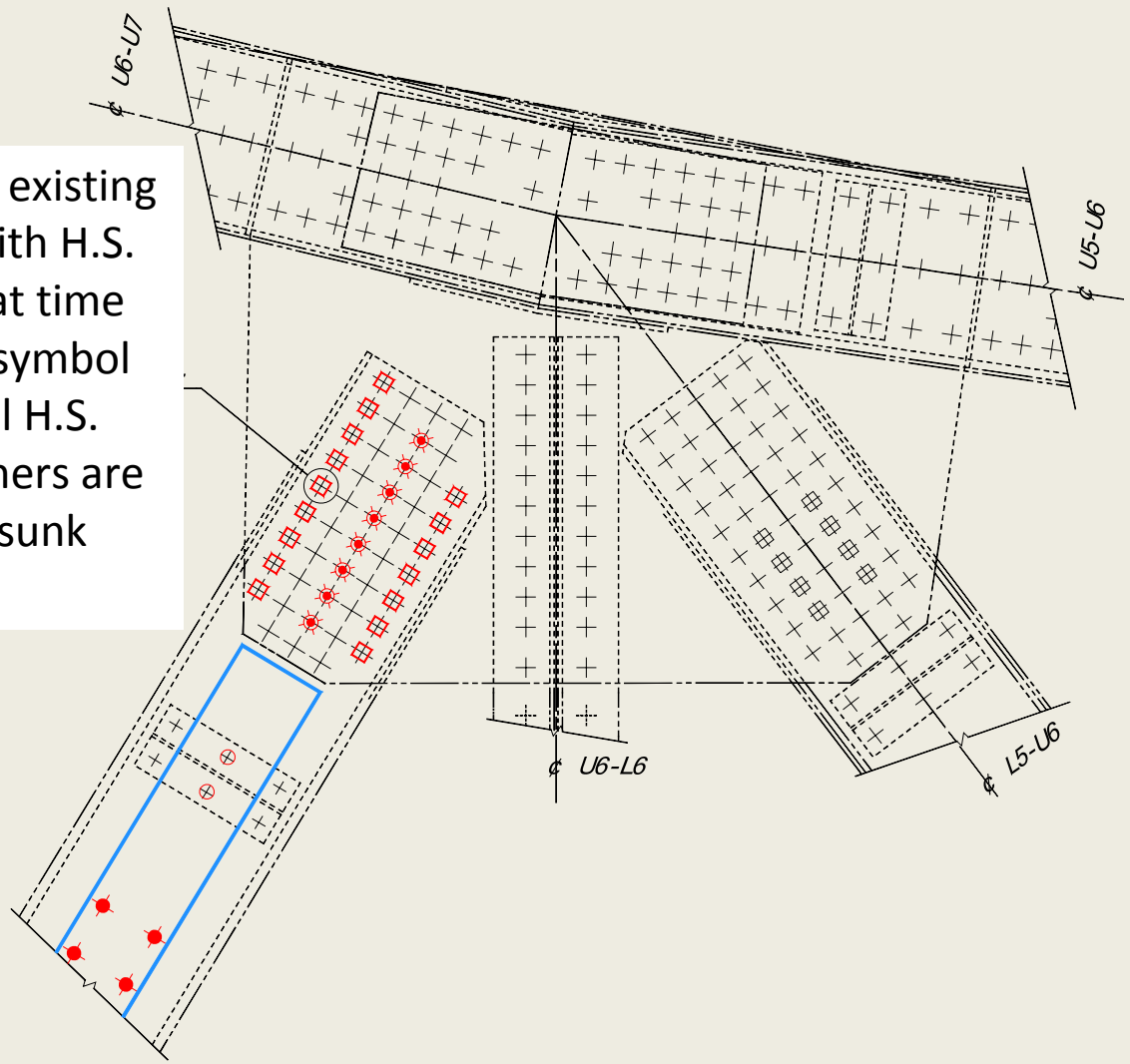
Rivet and High Strength Bolt Symbols



Intended to be shop drilled holes in plates

Typical - Strengthen Existing Connections & Install New Web Plates between Gussets

1. Replace existing rivets with H.S. bolts 1 at time
2. Square symbol is typical H.S. bolt, others are countersunk

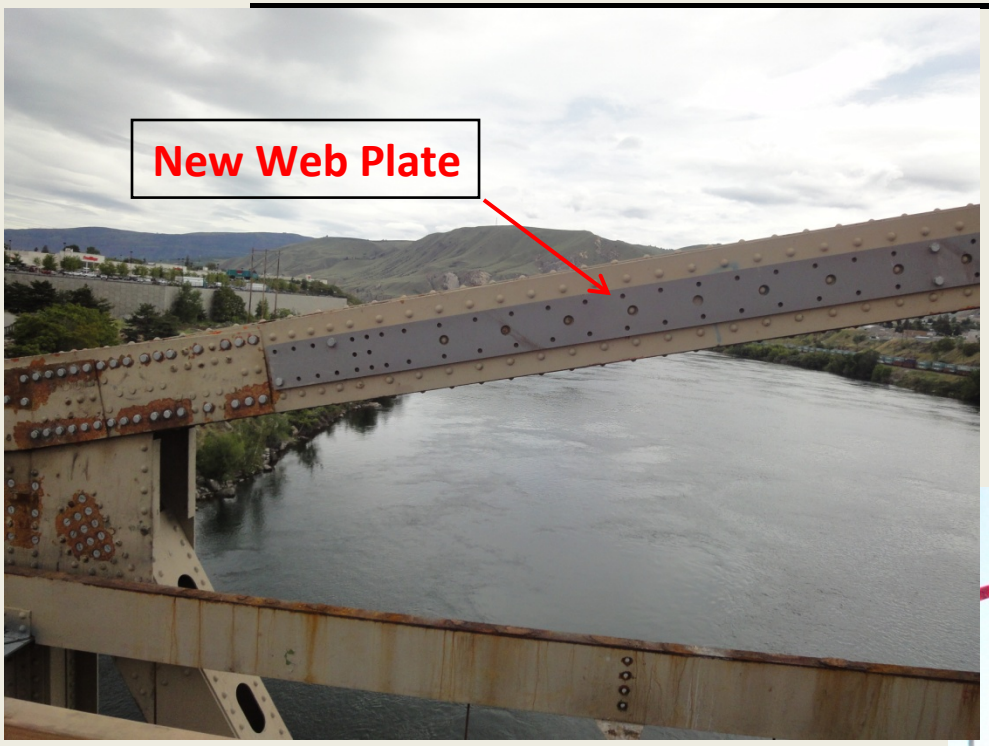


EXISTING MEMBER AND CONNECTION

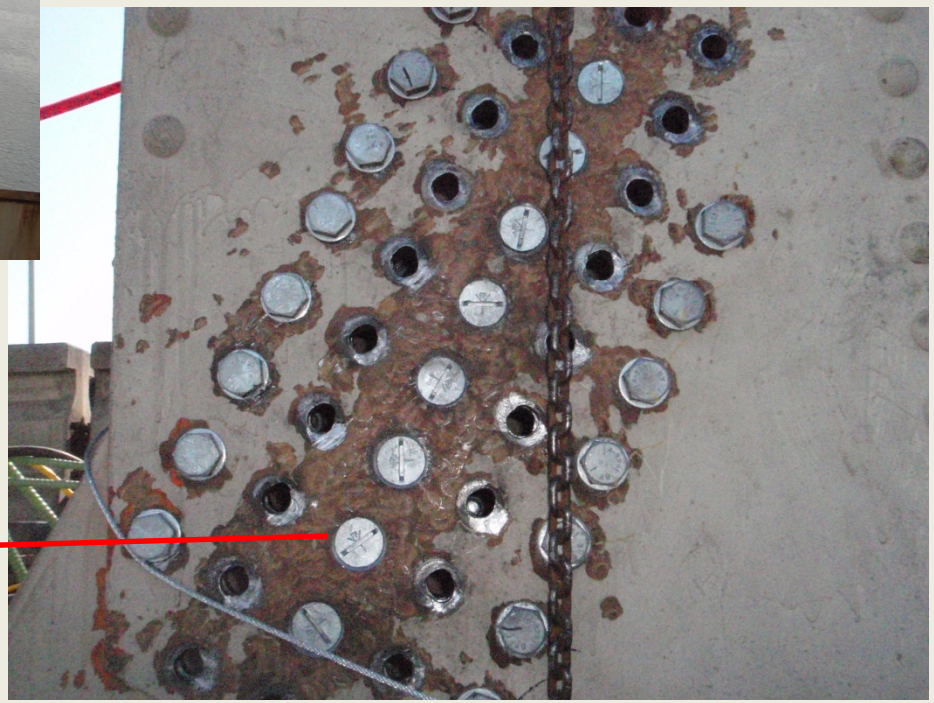
1. Add new web plate.
2. Drill holes in existing members using holes in web plates as templates.
3. Install H.S. bolts along length of plate

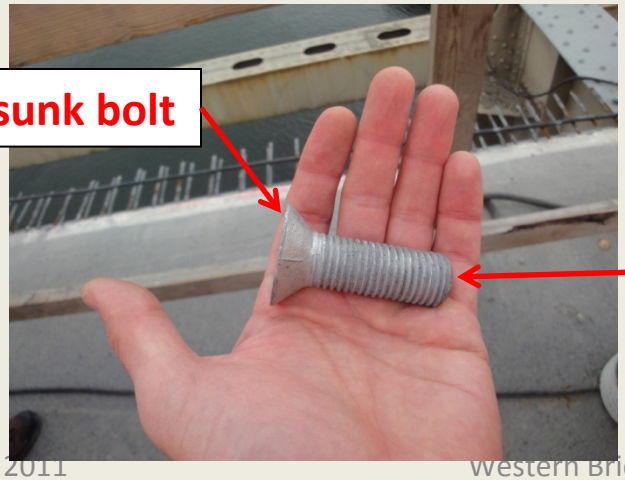
Shear Capacity
Rivet = 12.6 kips
HS bolt = 25 kips

Web Plate & Connection Strengthening



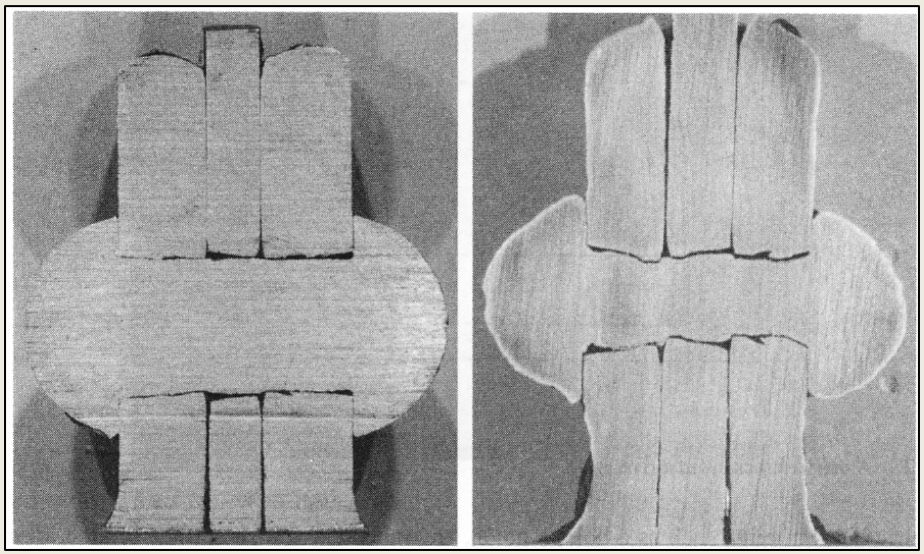
Strengthened Connection



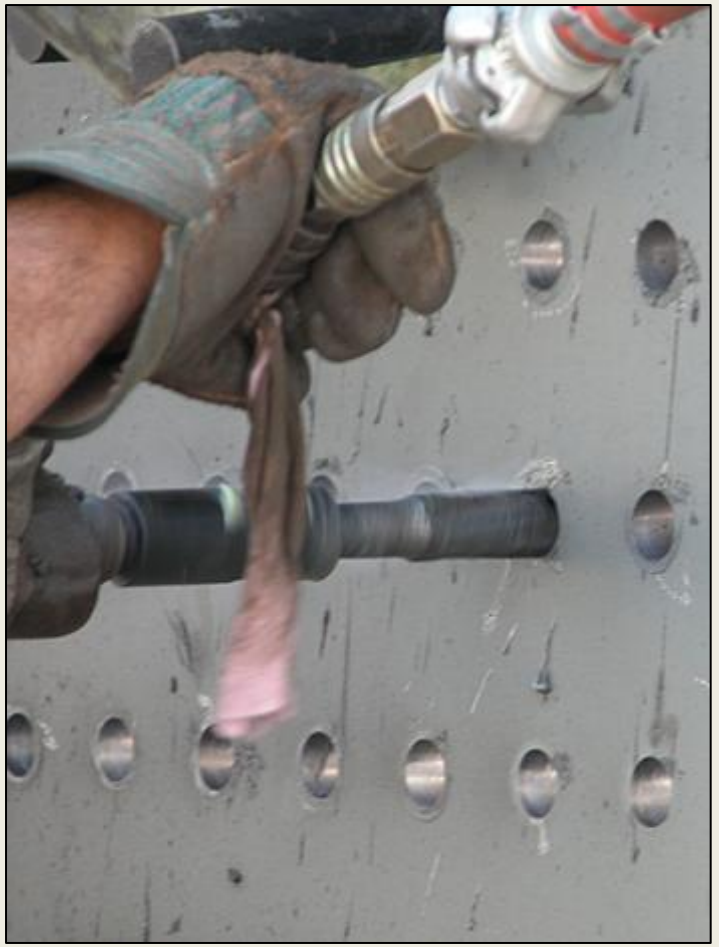


Post-Rivet Removal Hole Preparation

- Reaming may be required to enlarge hole to allow installation of H.S. bolts.
- Limitations on hole size specified in plans (min & max)
  - 7/8" Bolt – 15/16" to 1 1/16"
  - ¾" Bolts – 13/16" to 15/16"



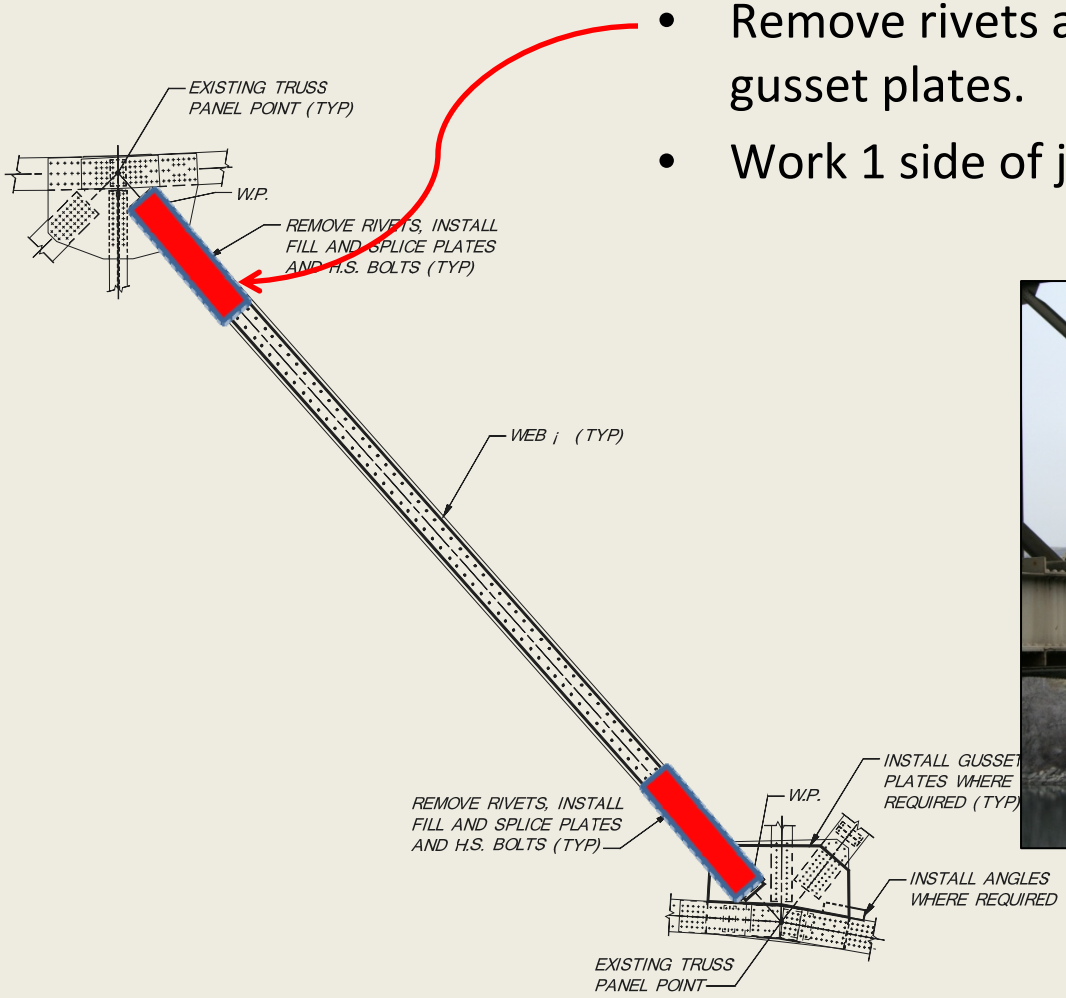
Example of misaligned holes in existing plates – hot rivet forms to shape



Reaming hole

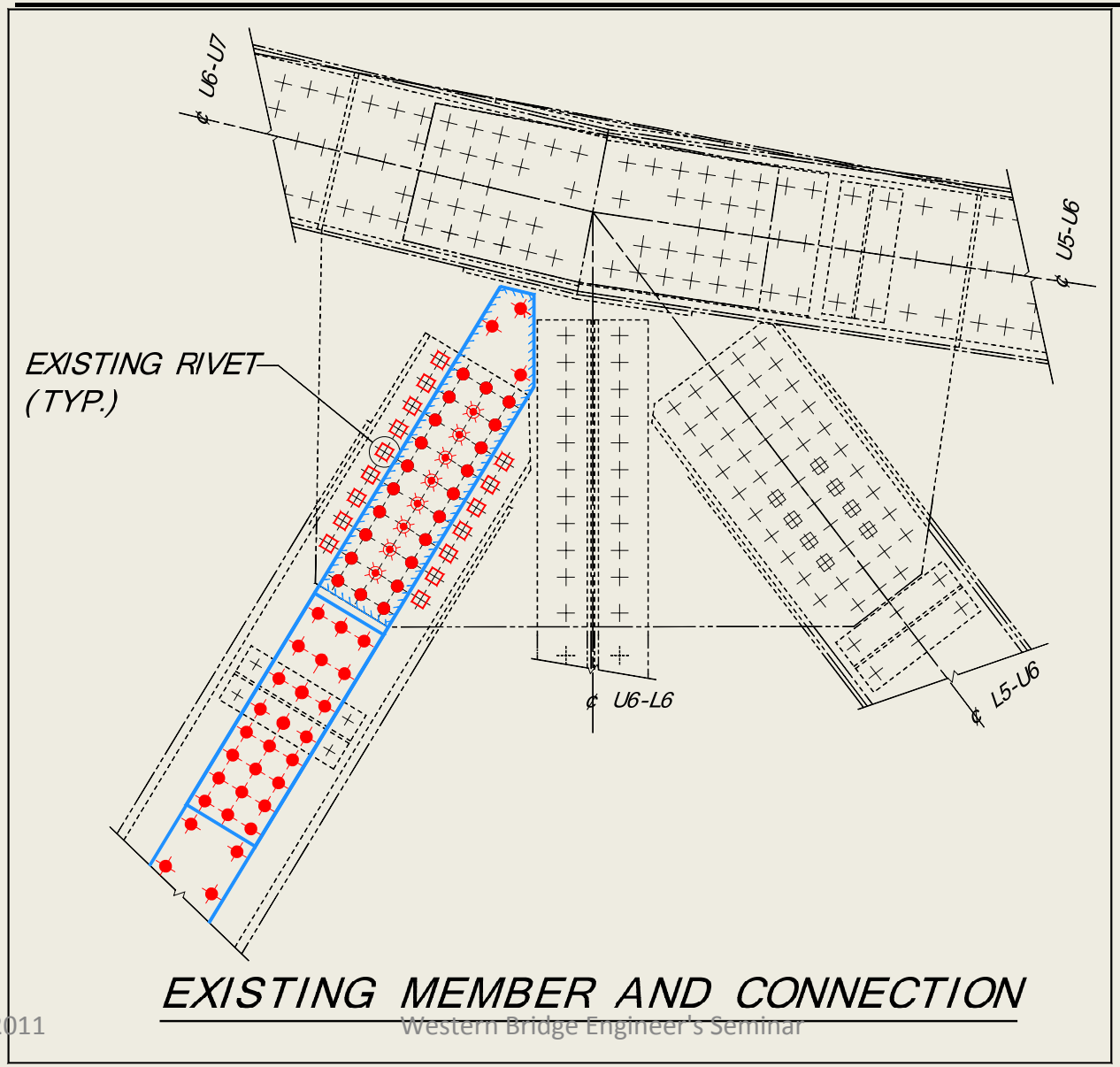
Step 3

- Remove rivets and install splice, fill, web, and gusset plates.
- Work 1 side of joint at a time



Strengthen Existing Connections & Install New Web Plates between Gussets

Install splice plate



Remove all remaining rivets at the connection

Drill holes and install all remaining bolts in connection

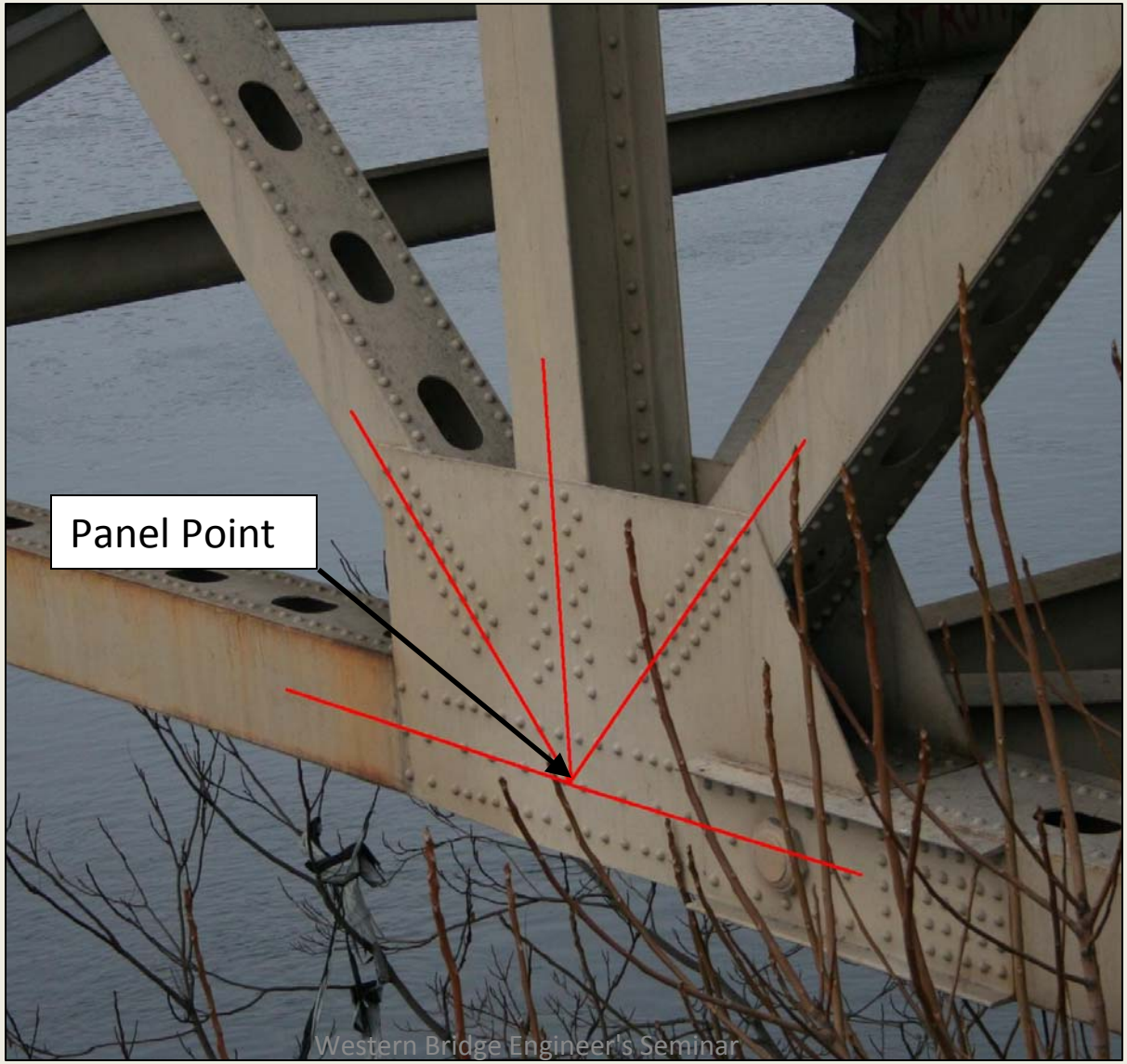
Installing Splice Plates

1. Field measure existing rivet locations

2. Drill holes to match rivet pattern

3. Install splice plates and bolts

Gusset Plates



FHWA Guidance on Evaluation of Gusset Plates Released after I-35W Collapse

FHWA Bridge Design Guidance No. 1
Revision Date: August 28, 2008

Load Rating Evaluation of Gusset Plates in Truss Bridges

By Firas I. Sheikh Ibrahim, PhD, PE

Part – A
Gusset Plate Resistance in Accordance with the Load and Resistance Factor Rating Method (LRFR)

Gusset connections of non-load-path-redundant steel truss bridges shall be evaluated during a bridge load rating analysis. Non-load-path-redundant bridges are those with no alternate load paths and whose failure of a main component is expected to result in the collapse of the bridge

The evaluation of gusset connections shall include the evaluation of the connecting plates and fasteners. The resistance of a gusset connection is determined as the smaller resistance of the fasteners or gusset plates.

The following guidance is intended to provide for life safety and thus the resistance of the connection is required to be checked at the strength limit state only. Owners may require that connections be checked at other limit states such as the service limit state to minimize serviceability concerns.

RESISTANCE OF FASTENERS:

For concentrically loaded bolted and riveted gusset connections, the axial load in each connected member may be assumed to be distributed equally to all fasteners at the strength limit state.

The bolts in bolted gusset connections shall be evaluated to prevent bolt shear and plate bearing failures at the strength limit state. At the strength limit state, the provisions of AASHTO LRFD Article 6.13.2.7 and 6.13.2.9 shall apply for determining the resistance of bolts to prevent bolt shear and plate bearing failures.

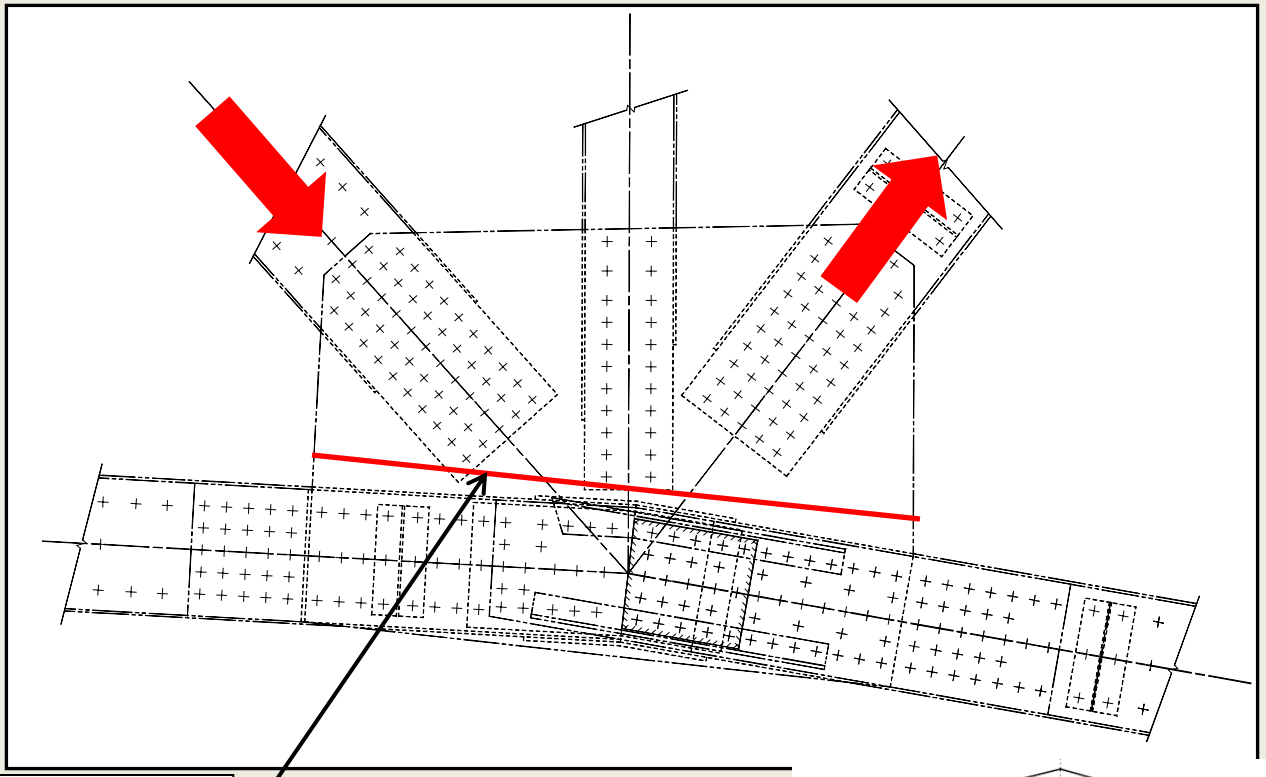
The rivets in riveted gusset connections shall be evaluated to prevent rivet shear and plate bearing failures at the strength limit state. The plate bearing resistance for riveted connections shall be in accordance with AASHTO LRFD Article 6.13.2.9 for bearing at bolt holes.

The factored shear resistance of one rivet shall be taken as:

$$\phi R = \phi F m A, \quad (1)$$

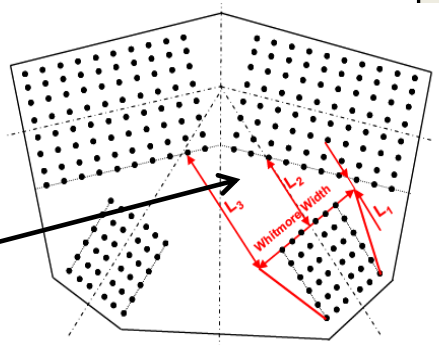
I-35W Bridge Collapse – Minneapolis, MN

Gusset Plates – Typ. Deficiency



Shear capacity deficient along this plane

A few gussets deficient in compression



Examples showing L_1, L_2, L_3, and effective width for a gusset plate in compression.

Similar to Member Strengthening
Each Gusset had Specified Retrofit Sequence

STRENGTHENING SEQUENCE @ L5

1A. MEMBER U4-L5: INSTALL WEB PLATE #1 FULL LENGTH OF MEMBER BETWEEN EXISTING GUSSET PLATES. TEMPORARILY SECURE TO EXISTING MEMBER USING H.S. COUNTERSUNK BOLTS

1B. MEMBER CONNECTIONS OF U4-L5, U5-L5, L5-U6, AND L5-L6 TO L5 GUSSET PLATES: REMOVE AND REPLACE EXISTING RIVETS AND REPLACE WITH COUNTERSUNK H.S. BOLTS ◙ OR STANDARD H.S. BOLTS ⊕ AT LOCATIONS SPECIFIED IN THE PLANS. AT EACH MEMBER CONNECTION TO THE GUSSET, REMOVE AND REPLACE EXISTING RIVETS WITH H.S. BOLTS (COUNTERSUNK OR STANDARD) ONE AT A TIME UNTIL A MINIMUM OF 5 H.S. BOLTS HAVE BEEN INSTALLED. AT THAT POINT, A MAXIMUM OF 5 EXISTING RIVETS CAN BE REMOVED FOR REPLACEMENT AT ONE TIME.

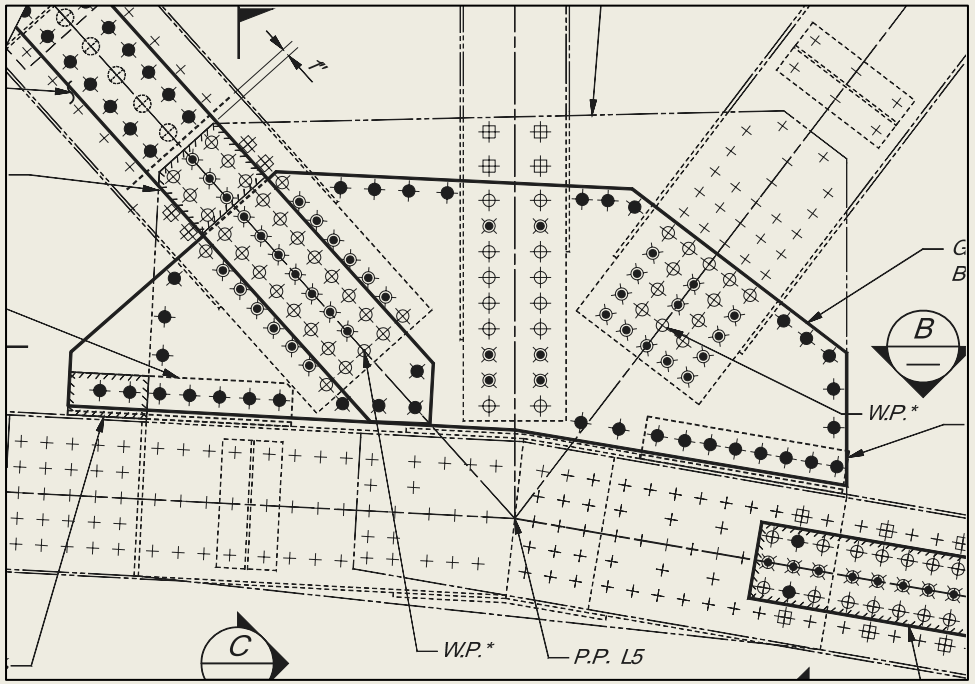
2. AT EACH MEMBER CONNECTION, REMOVE EXISTING RIVETS, NOT PREVIOUSLY REPLACED BY COUNTERSUNK H.S. BOLTS, AT LOCATIONS TO BE COVERED BY A NEW GUSSET OR WEB CONNECTION PLATE AND LEAVE HOLES OPEN.

3. INSTALL NEW GUSSET PLATE AND ALL H.S. BOLTS THAT DO NOT CORRESPOND WITH MEMBER CONNECTIONS TO GUSSET PLATE. USE HOLES IN GUSSET PLATE AS A TEMPLATE FOR DRILLING NEW HOLES.

4. USING WEB PLATE #2 AS A TEMPLATE, DRILL HOLES IN EXISTING MEMBER U4-L5 AND WEB PLATES #1 AND INSTALL WEB PLATES #2. INSTALL ALL REMAINING H.S. BOLTS.

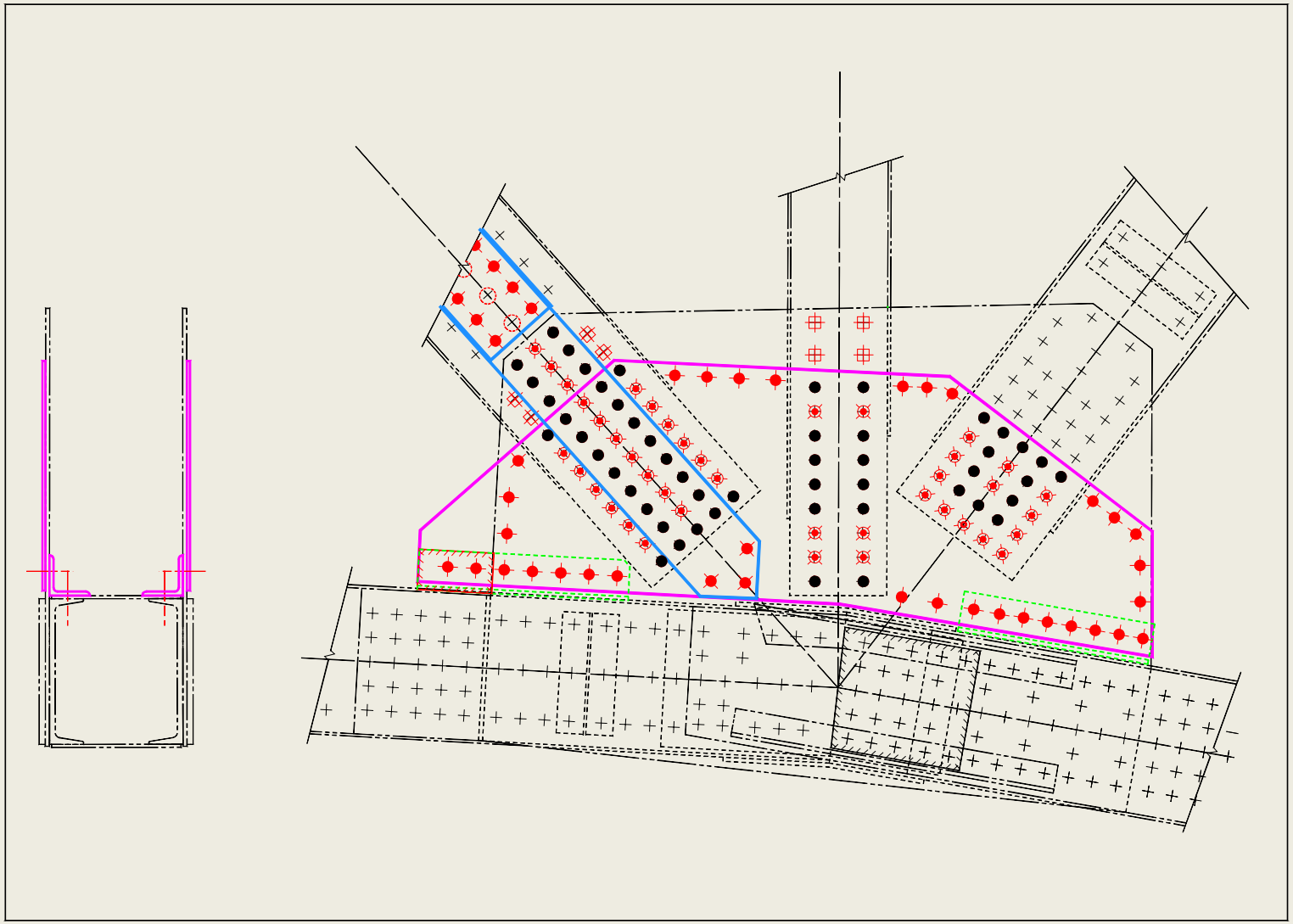
5. INSTALL ANGLES AND ASSOCIATED H.S. BOLTS. INSTALL ONE ANGLE AT A TIME.

NOTE: STEPS 2, 3, & 4 SHALL BE COMPLETED ON ONE GUSSET/CONNECTION FACE (NS OR ES) PRIOR TO PERFORMING STEPS 2, 3 & 4 ON THE OPPOSITE FACE.



Step 3 procedures – One side of connection at a time

Typical Gusset Strengthening

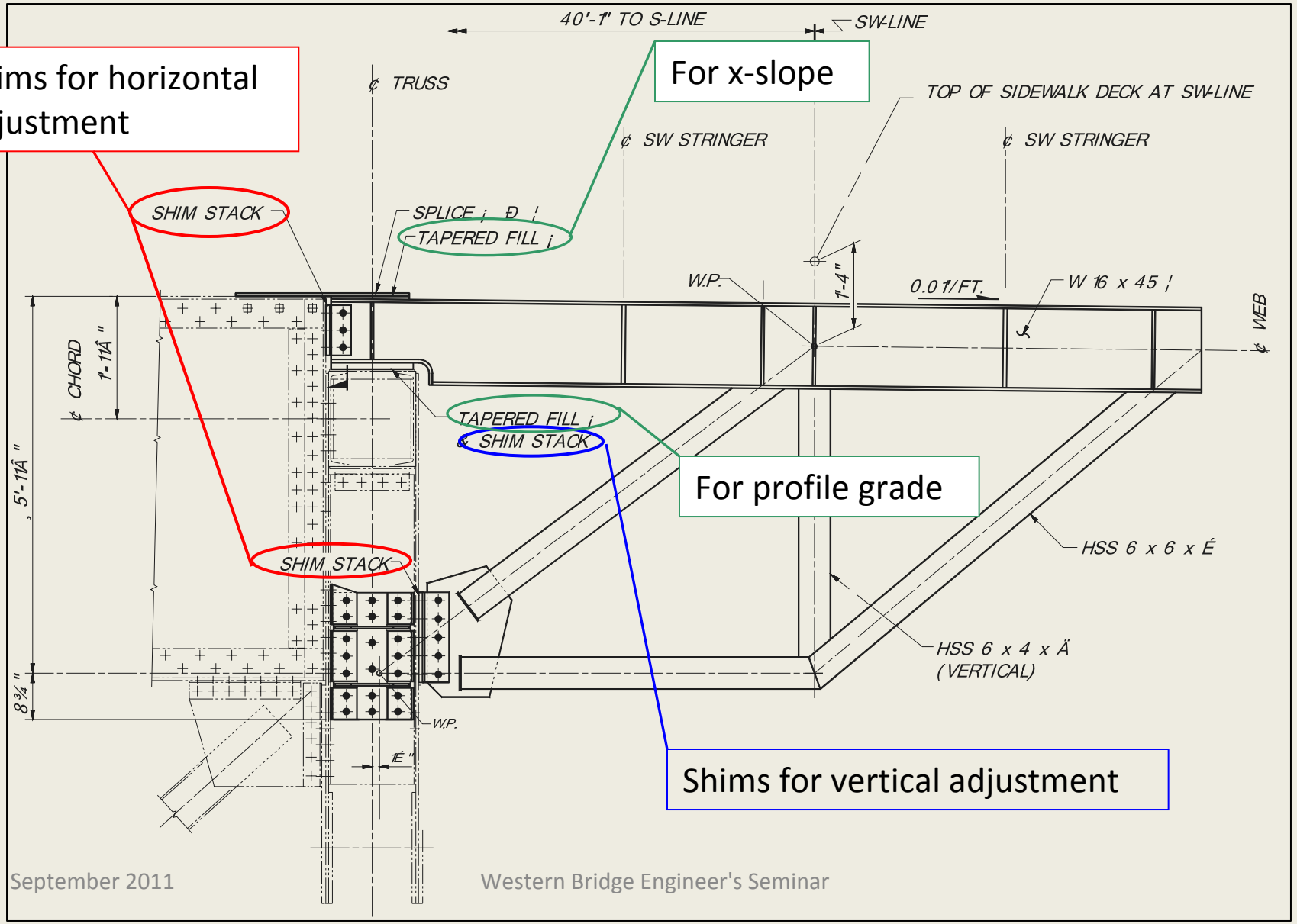


Gusset Plate Strengthening

Gusset strengthened and surface now “flat”
In preparation for additional gusset plate

Gusset plate installed and partially bolted

Sidewalk Floorbeam Frames U0 to U4



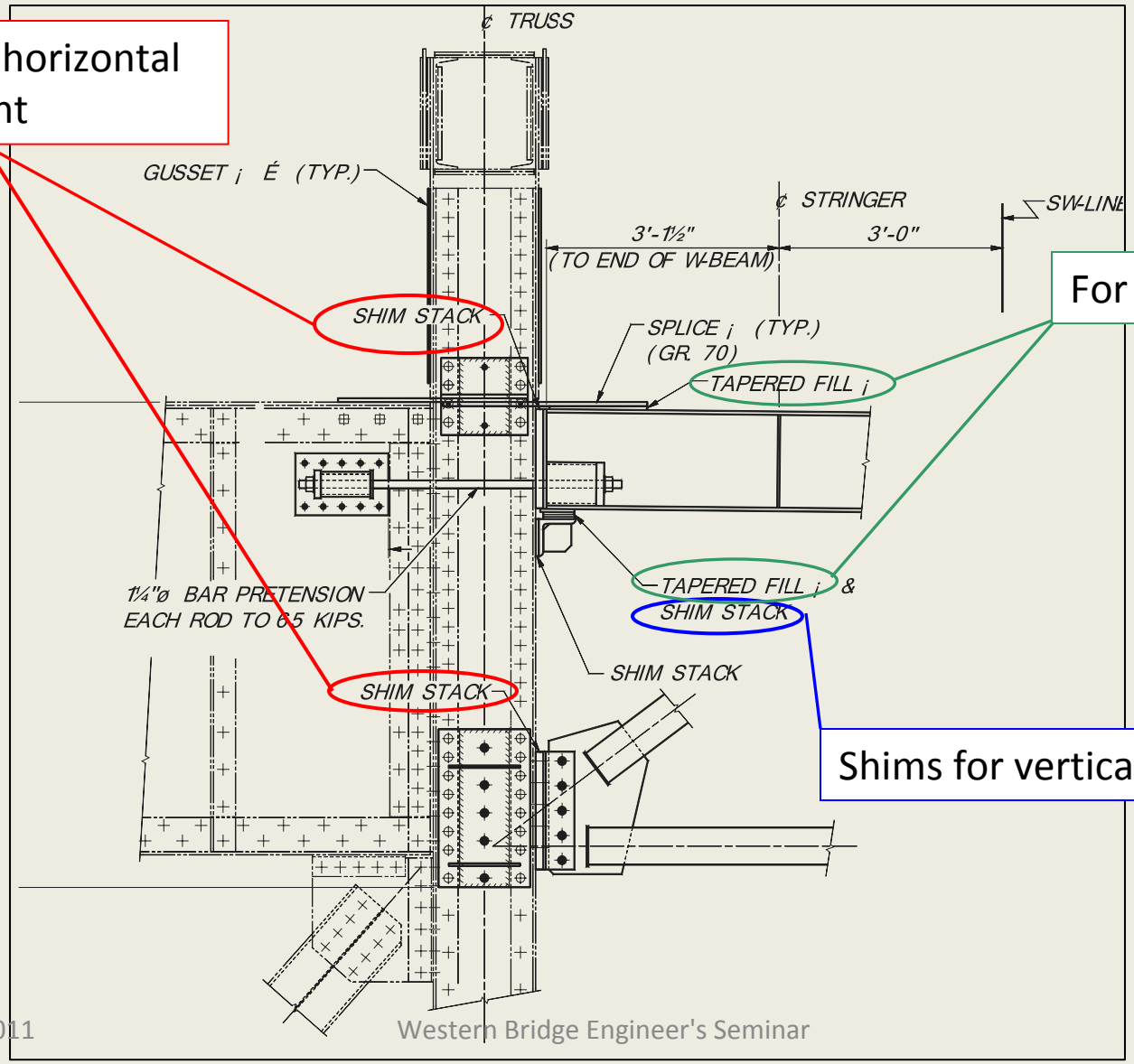
Shims for horizontal adjustment

For x-slope

For profile grade

Shims for vertical adjustment

Sidewalk Floorbeam Frames U5 to U14

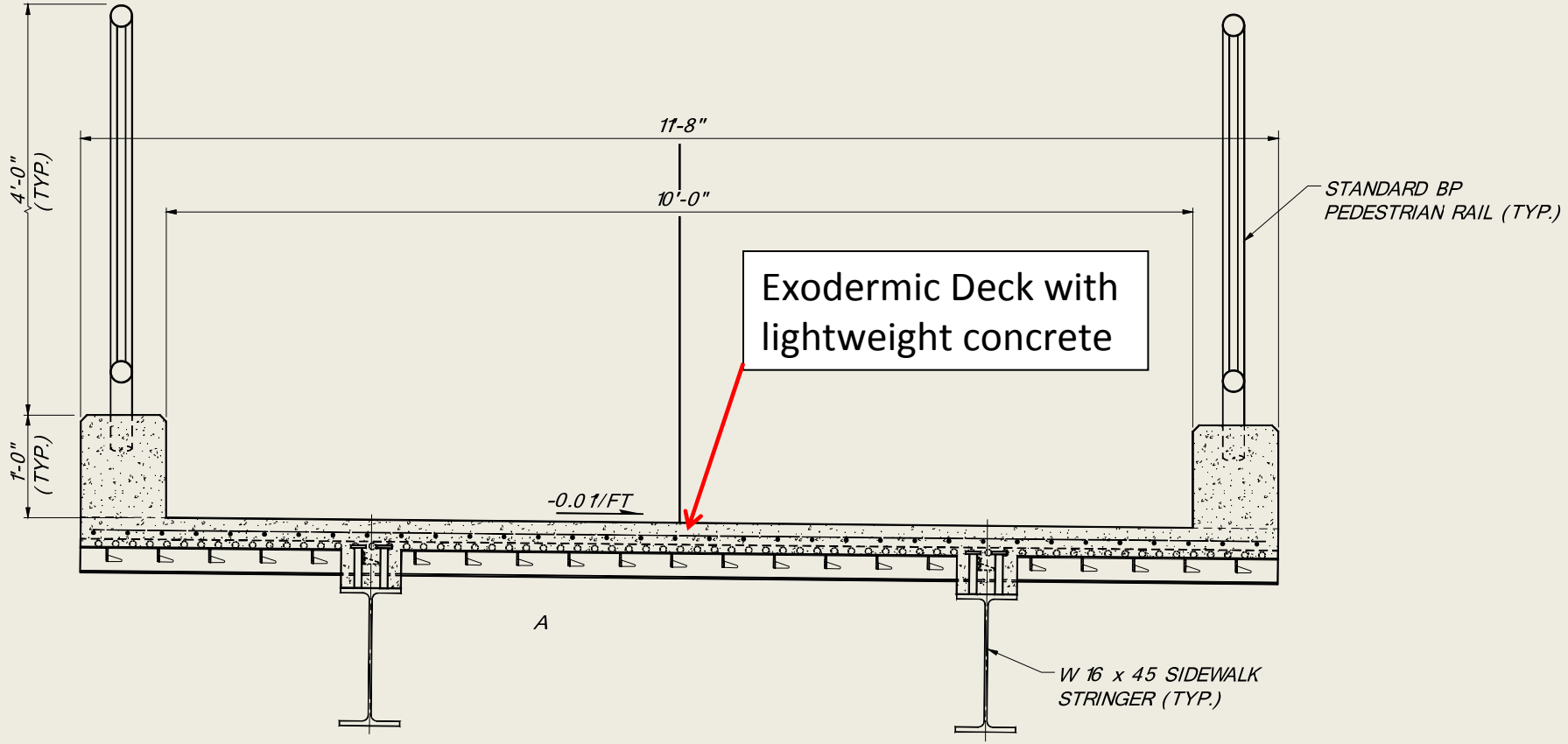


Shims for horizontal adjustment

For x-slope

Shims for vertical adjustment

Sidewalk Typical Section



Sidewalk Floorbeams & Stringers

Finished Sidewalk

Project Statistics

- 94 members strengthened or replaced
- 10 gusset plates strengthened, dozens of joints strengthened
- 13,000 existing rivets removed and replaced with H.S. bolts
    - 2300 of those rivets replaced with countersunk H.S. bolts
- 25,000 new holes drilled into existing members
- 12 magnetic drills operating at various times (lots of bits)
- 600,000 lbs of structural steel added to the truss
- Construction cost = $12.7 million
- Working days – 387 over 2 seasons.

Questions?