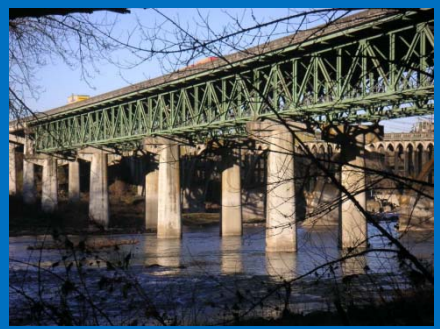
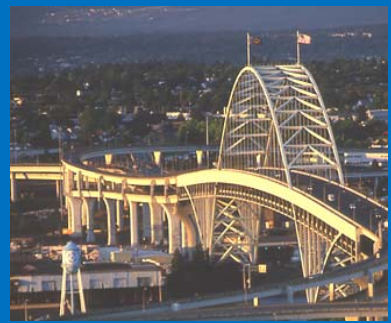
Western Bridge Engineers' Seminar

Presentation

Lessons Learned from Gusset Plate Rating Analysis



Presented By

Joe Krajewski, PE, Associate

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September 25-28, 2011
Phoenix, Arizona

Presentation Outline

- Introduction
- Data Collection
- Rating and Analysis
- Repair and Replacement
- Summary

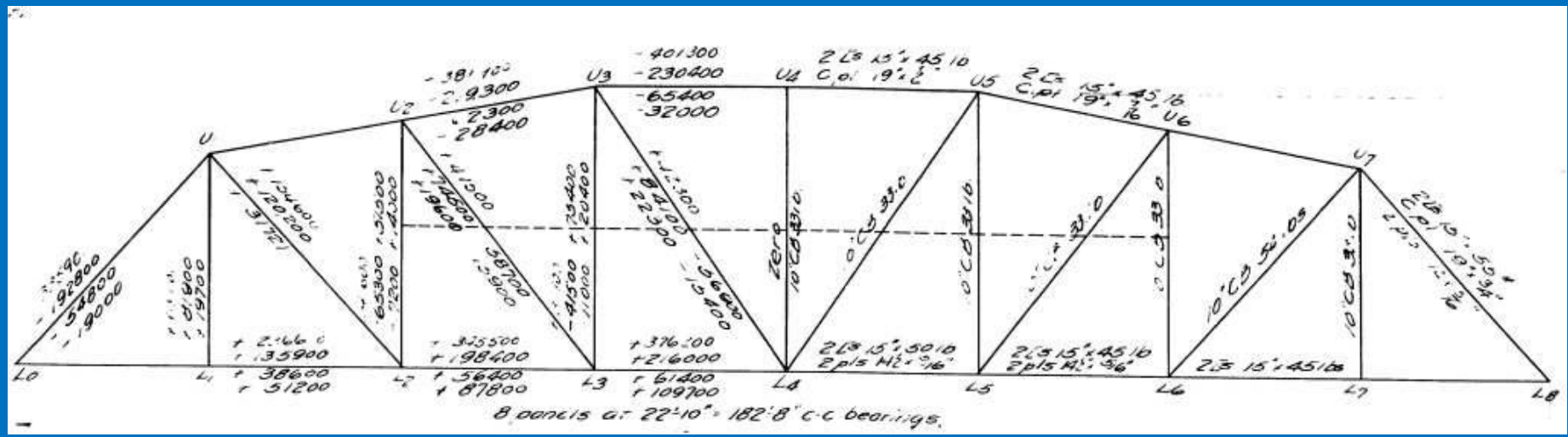
Data Collection

- "As Built" Plans
- Shop Drawings
- Design Calculations
- Inspection Reports
- Photographs
- Specifications & Engineering Manuals
- Visual Inspection

Data Collection – “As Built” Plans

- Theoretically should contain
  - Actual Constructed Dimensions,
  - Materials,
  - Standards &
  - Loading
- Most likely do not contain
  - Temporary Construction
  - Last minute changes. Especially plans produced by hand.
- Truss Plan Sets have sheets or details called “Force” or “Stress” diagrams.

Data Collection – “As Built” Plans

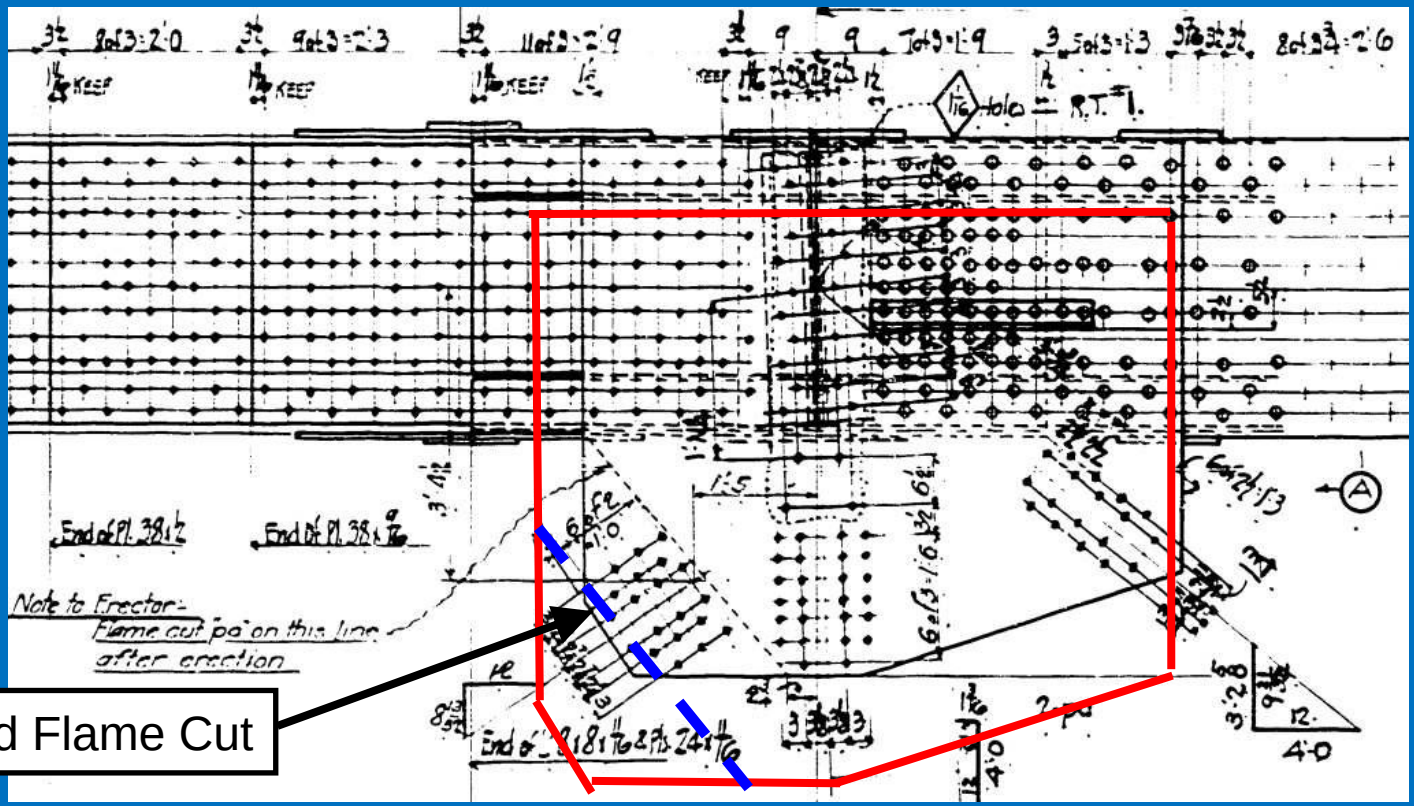


Stress Diagram

Data Collection – Shop Drawings

- Precise Dimensions of Fabrications
- Material Information
- Mill of Origin
- Temporary Construction

Data Collection – Shop Drawings



Gusset Plate with Temporary Member & Flame Cutting

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Data Collection – Design Calculations

- Thinking behind the Plans.
- Assumptions
- References
- Commentary on design choices
- Illustrations

Unfortunately, Design calculations may have been missing or have been thrown away. The older the bridge the greater the probability there are no calculations.

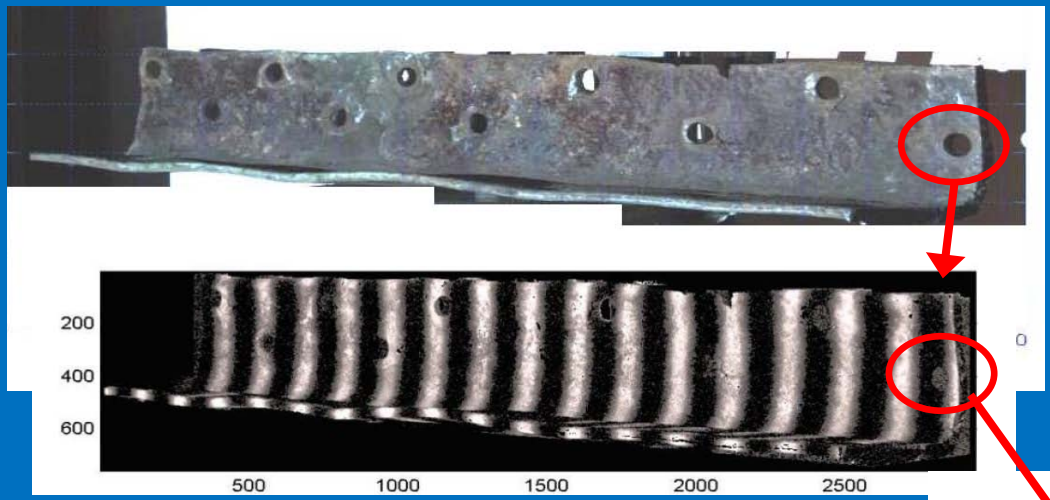
Data Collection – Inspection Reports

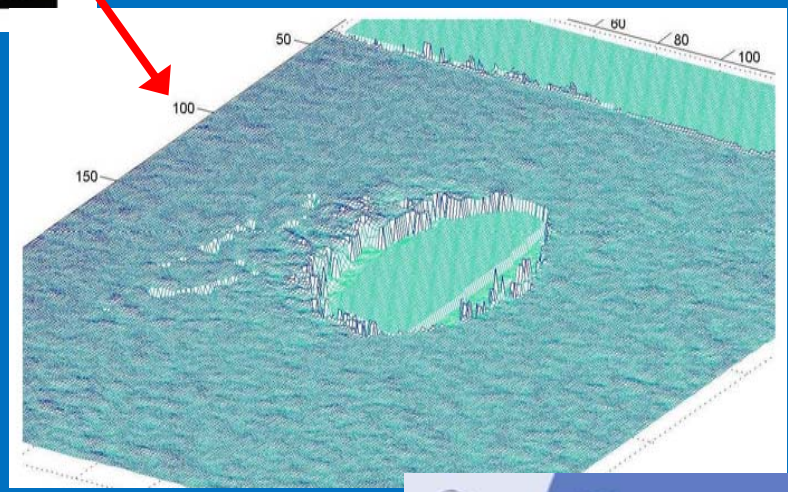
- NBIS Reports
  - 1970 to Present
  - Types
    - Routine every 2 years
    - In depth every 10 years
    - Fracture Critical every 3 years
    - Special and Damage
- Non-NBIS Reports
  - Various levels of inspection depth
  - Don't necessarily follow a standard
- Inspection Report Problems
  - Lack of Consistency, Reliability and Content
  - 2001 FHWA Study concluded NBIS Reports unreliable and inconsistent

Data Collection – Photographs

- Visual Time History
- Digital Photos can provide a faster way to capture gusset geometry
  - Photos can be scaled.
  - Adjusted to eliminate distortion
  - Software reasonably priced
- 3D coordinate modeling techniques
  - Oregon State University – Image Rectification Tool for Evaluation of Gusset Plates
  - Fringe Interferometry – Master's Thesis, Worcester Polytechnic Institute

Data Collection – Photographs





Fringe Interferometry

Master's Thesis Work

Worcester Polytechnic Institute

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Data Collection – Specifications and Engineering Manuals

- Methods, Assumptions and Material Information.
- For Instance, Yield Strengths of Older Steels

Example:	A242-1952T	3/16” – ¾”	50 ksi
		>3/4” – 1 ½”	45 ksi
		>1 ½” – 2”	40 ksi

Gusset Plate Rating and Analysis

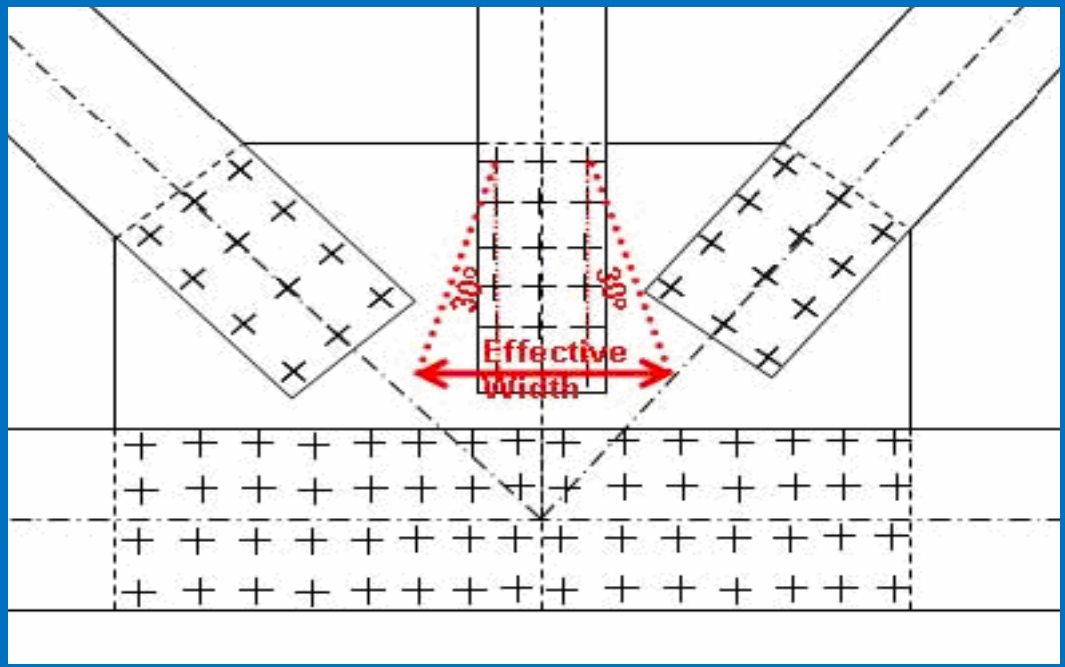
- FHWA Guidelines
  - First introduced in January 2008
  - Has been updated several times
  - Attempts to capture the complex behavior of a gusset plate
  - Rating Checks consist of
    - Fastener,
    - Tension,
    - Shear and
    - Compression of individual portions of a gusset plate.

Gusset Plate Rating and Analysis – FHWA Guidelines

- Fastener Check
  - Shear Capacity of Rivets and Bolts
  - Bearing Capacity of gusset plate
  - AASHTO LFD 10.58
  - AASHTO LRFD 6.13
  - AASHTO Specs assume fasteners equally loaded and concentrically loaded connections.
  - Asymmetrical connections do occur either by design or deterioration.
  - Distribution of load in fasteners is not equal.

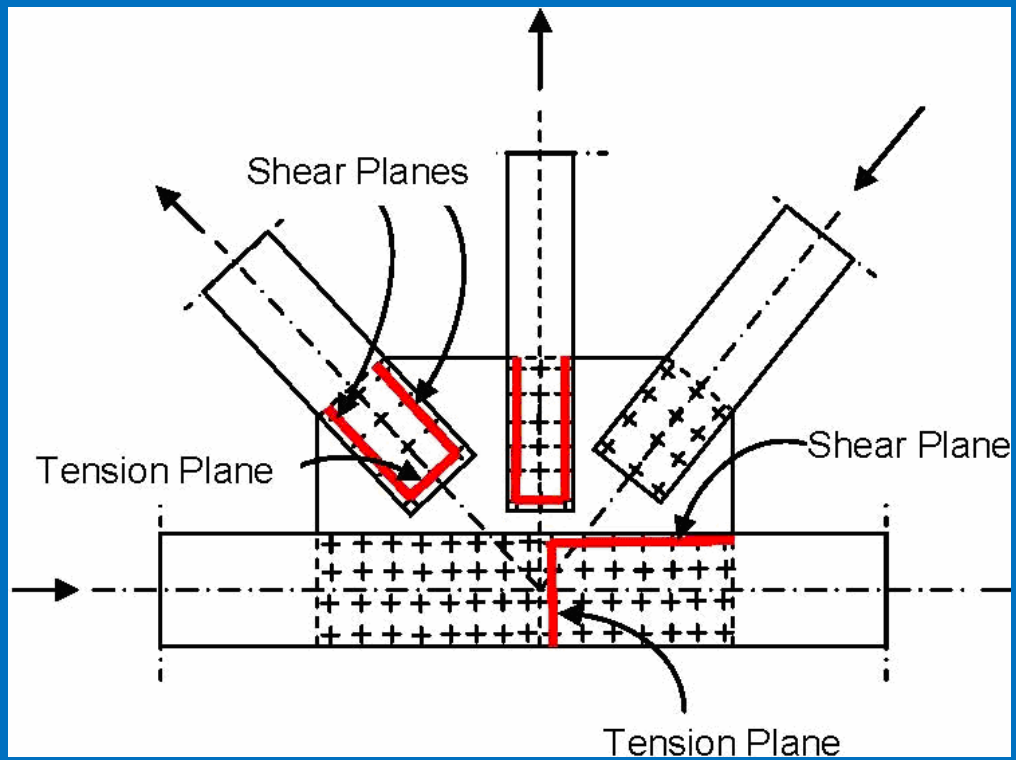
Gusset Plate Rating and Analysis – FHWA Guidelines

- Tension Check
  - Gross Section & Net Section
  - Whitmore Effective Width



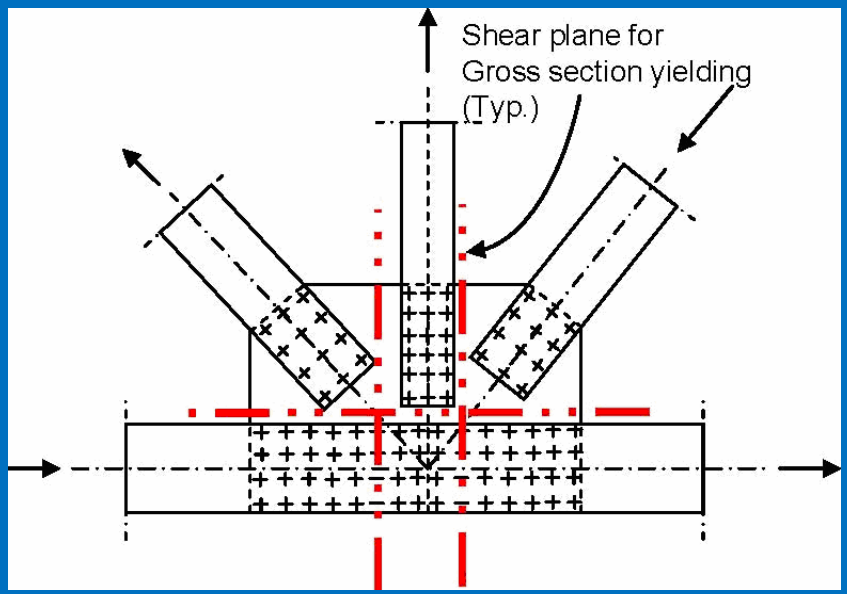
Gusset Plate Rating and Analysis – FHWA Guidelines

- Tension Check
  - Block Shear



Gusset Plate Rating and Analysis – FHWA Guidelines

- Shear
  - Shear Yield on the Gross Section.
  - Shear Fracture on the Net Section.
  - Maximum Force with Concurrent Forces or All Maximum Forces.
  - Which Shear Planes?



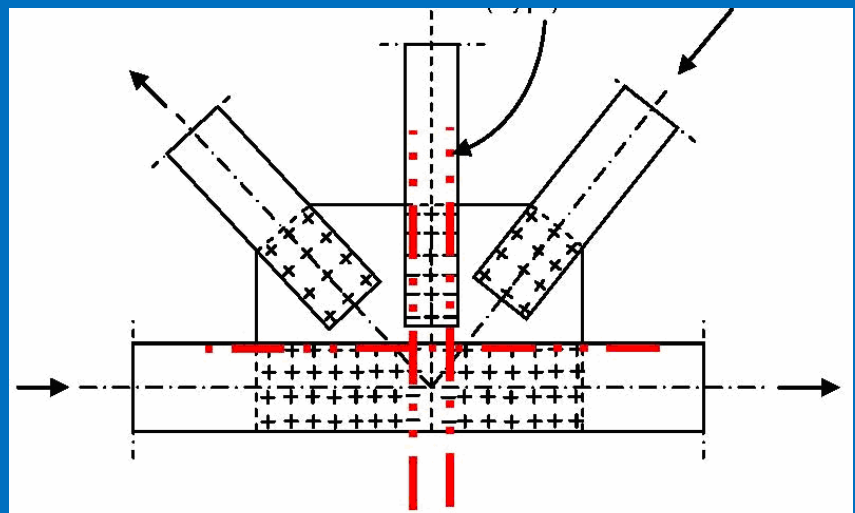
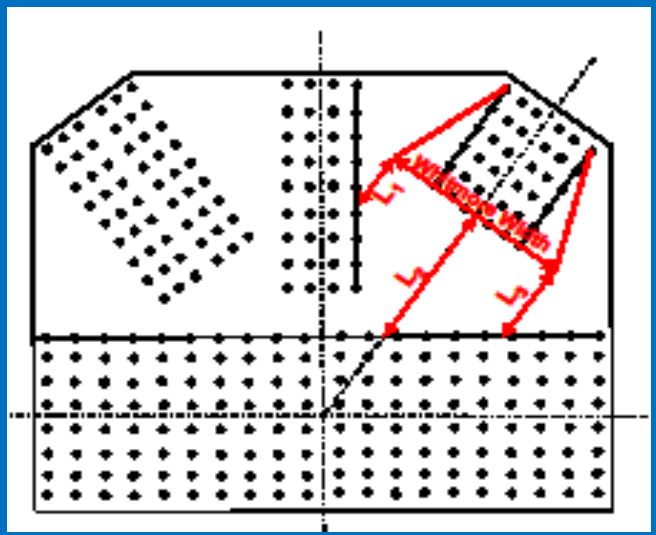


Figure 5 – Examples of net section shear fracture planes

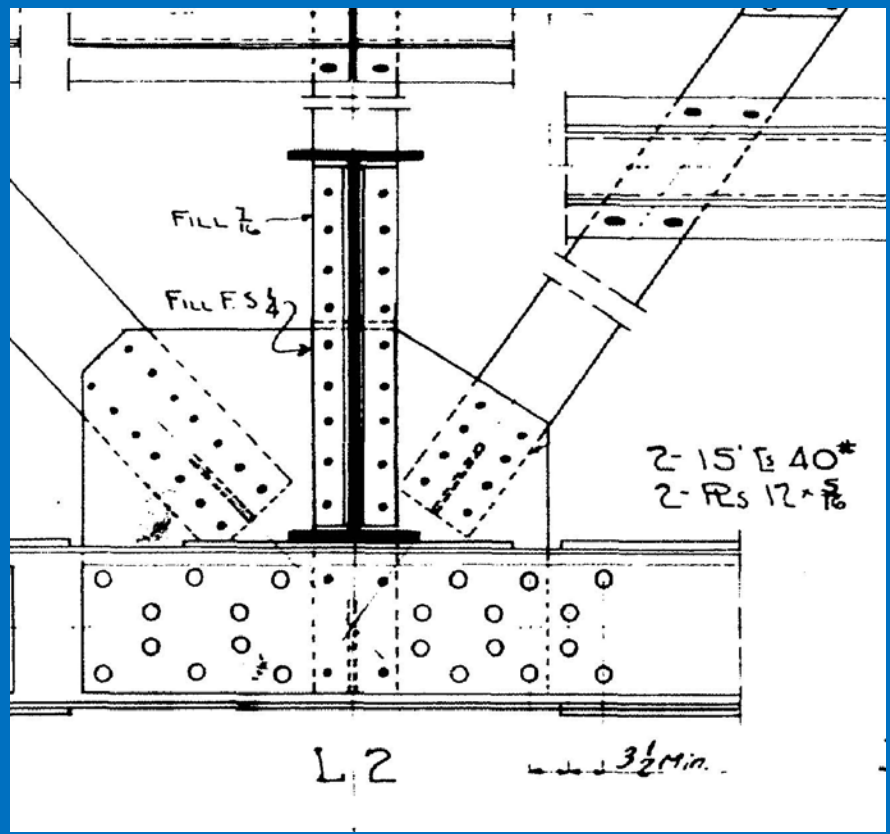
Gusset Plate Rating and Analysis – FHWA Guidelines

- Compression
  - Can be assumed to be an idealized member in compression.
  - Whitmore method for calculating the effective width.
  - Remember that compression force in axially loaded plates is not distributed evenly and it depends on support of edges.
  - A more rigorous analysis reference is
    - *Guide to Stability Design Criteria for Metal Structures*
      - *Edited by T. V. Galambos*



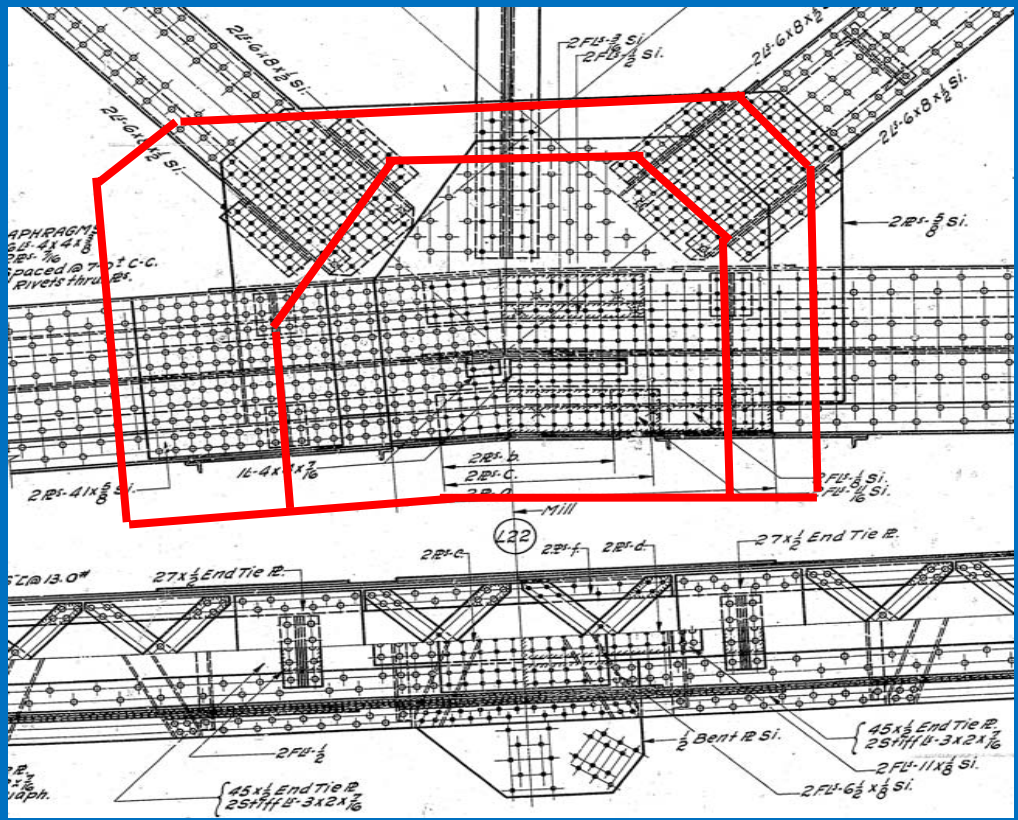
Gusset Plate Rating and Analysis – Configurations Not Covered by FHWA

- Continuous Members
  - Top or Bottom Chords that are continuous at a gusset plate.



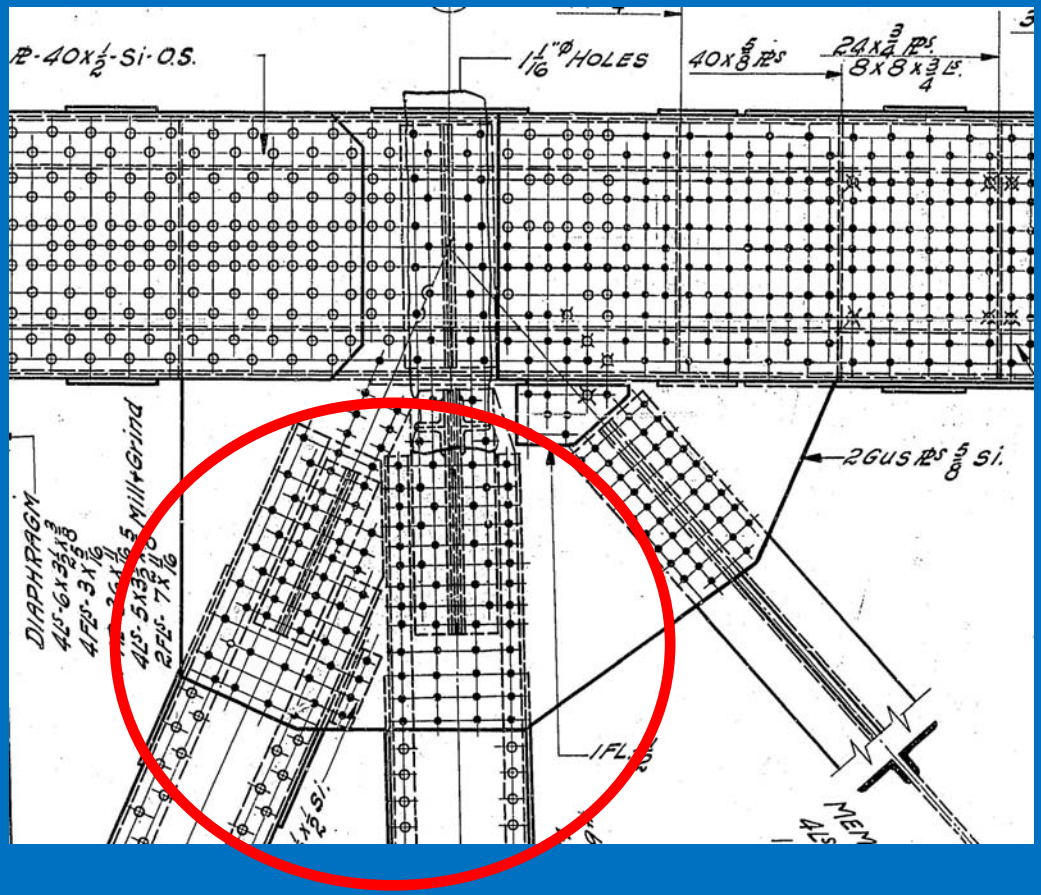
Gusset Plate Rating and Analysis – Configurations Not Covered by FHWA

- Packed Plates



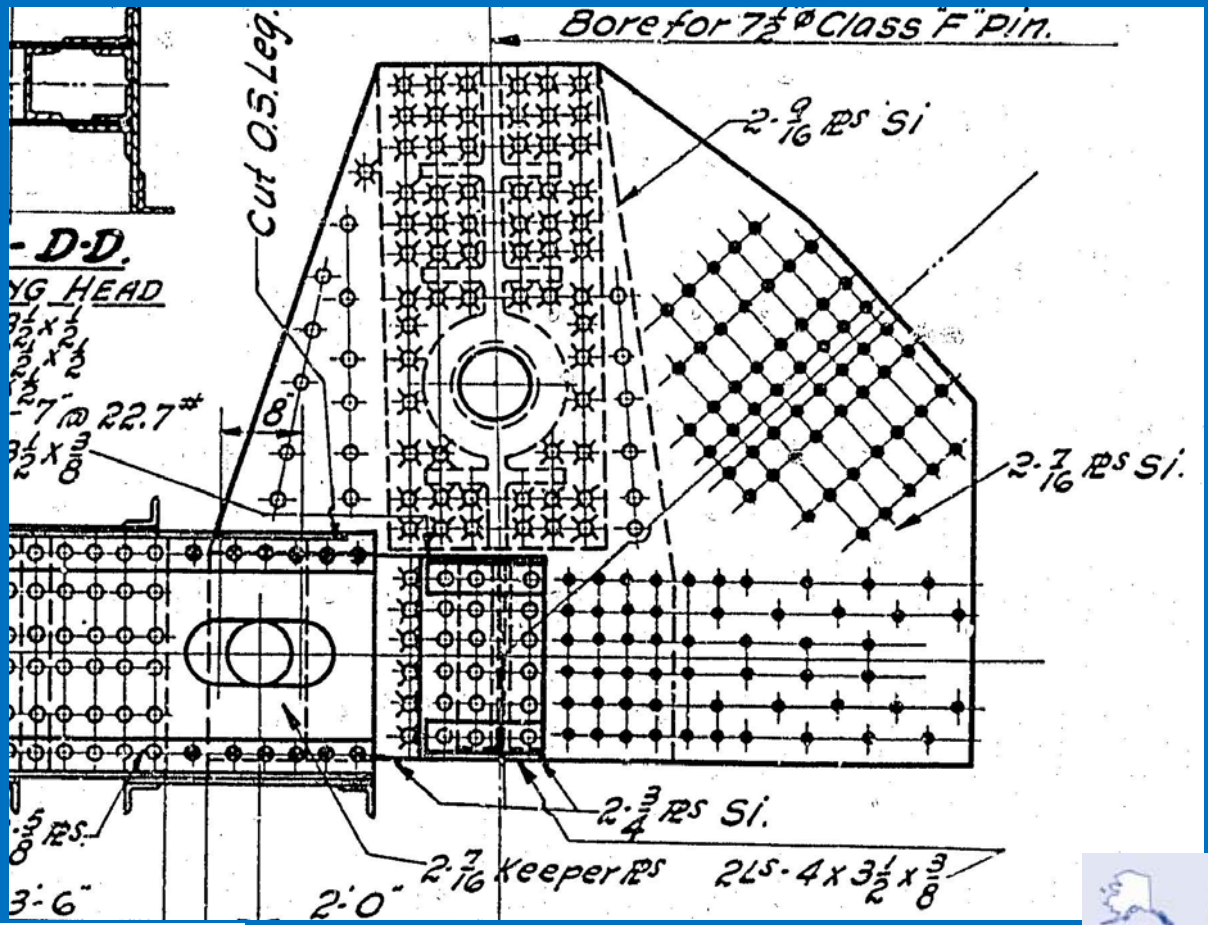
Gusset Plate Rating and Analysis – Configurations Not Covered by FHWA

- Member Combinations



Gusset Plate Rating and Analysis – Configurations Not Covered by FHWA

- Pins

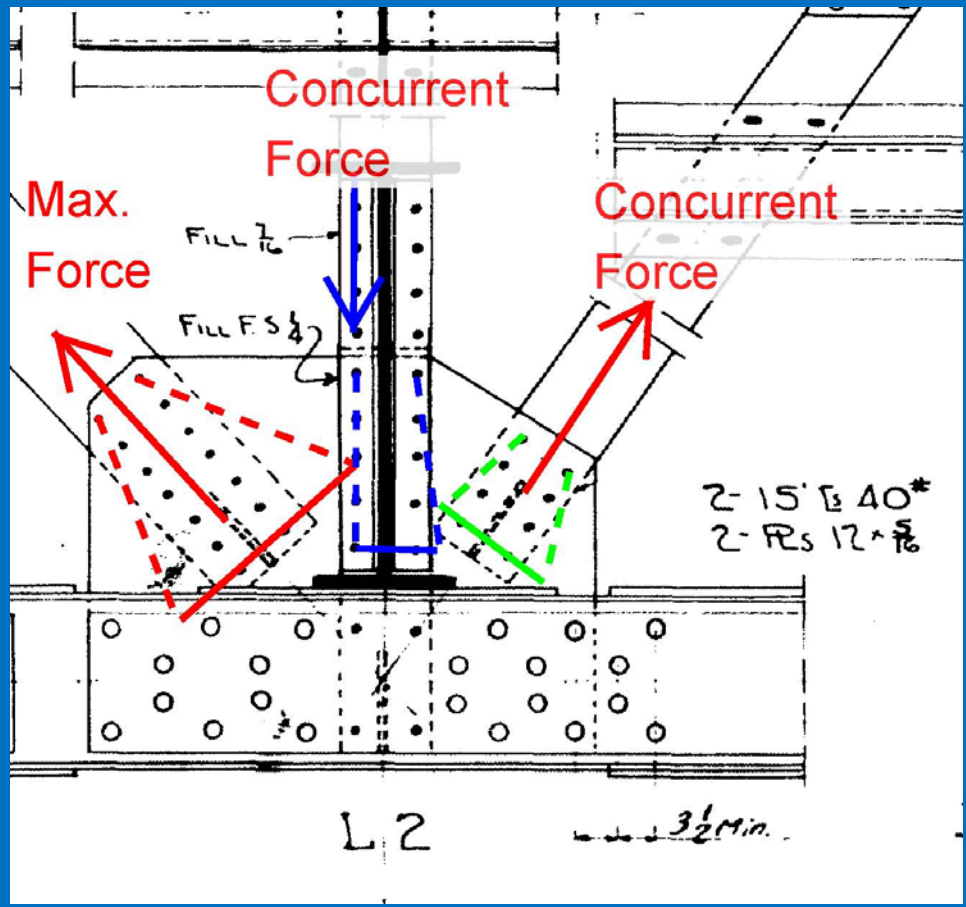


Gusset Plate Rating and Analysis – Rethinking the Procedure

- The FHWA Guidelines are a series of checks on the connection of individual truss members in isolation of the other members.
- Shear Ratings are the exception
- Whitmore Method effective width is used regardless of whether it extends into another member connection.
- Once we get a rating for one member connection how do we know that rating factor can be achieved for the other member connections with concurrent forces?

Gusset Plate Rating and Analysis – Rethinking the Procedure

1. Max. Force to 1 member.
2. Whitmore width to line of fasteners in adjacent connection.
3. Check member with max. force.
4. Check adjacent members with concurrent forces.
5. If adjacent members can't meet rating factor of max. loaded member then adjust Whitmore widths until all members meet same Rating.



Gusset Plate Rating and Analysis – Deterioration

- How to incorporate deterioation into gusset plate rating analysis is little understood.
- For the longest time, deterioration was based on the percentage of surface area with measurable thickness loss.
- A better way: Account for losses based on location on the gusset. Example: Section loss in the unbraced length area of a compression member.
- Other Losses
  - Impacted Rust between plates.
  - Deteriorated connectors.
- Don't forget that gussets with a lot of section loss will plastically deform & have redistribution of forces.

Gusset Plate Rating and Analysis – Repairs

Adding Plate and Edge Stiffeners

Gusset Plate Rating and Analysis – Repairs

Complete Replacement

Gusset Plate Rating and Analysis – Summary

- Gusset plates are geometrically challenging
- Analyzing them is more challenging than other bridge components.
- Keys to a thorough and credible rating
  - Collecting as much information as possible
  - Using the right amount of analysis rigor for each gusset plate.
  - Costs can steer a rating towards repair or replacement
  - Gusset plate rating is very time consuming and tedious, and most important, engineering judgment plays a huge role.

Gusset Plate Rating and Analysis – Summary

- The analysis and rating of gusset plates is being actively researched across the country.

- The major areas of research are;
  - Developing more accurate methods for describing the complex behavior of gusset plate.
  - Developing software to automate gusset plate load rating.
  - Expanding the current guidelines to incorporate more gusset plate configurations.

THANKYOU

QUESTIONS?