TRUSS GUSSET PLATES

NEW YORK STATE
STRUCTURES
DEPT. OF TRANSPORTATION

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NYSDOT
Office of Structures
October 2008

BACKGROUND

- Truss Gusset Plates and Connections of Truss Members to the Gusset Plates are Ordinarily Stronger than the Truss Members to which they are Connected. For this Reason, Load Ratings of Trusses Have not Usually Included a Check of the Gusset Plate Capacity

BACKGROUND

- I-35W Bridge over the Mississippi River in Minneapolis, Minnesota Collapsed on August 1, 2007

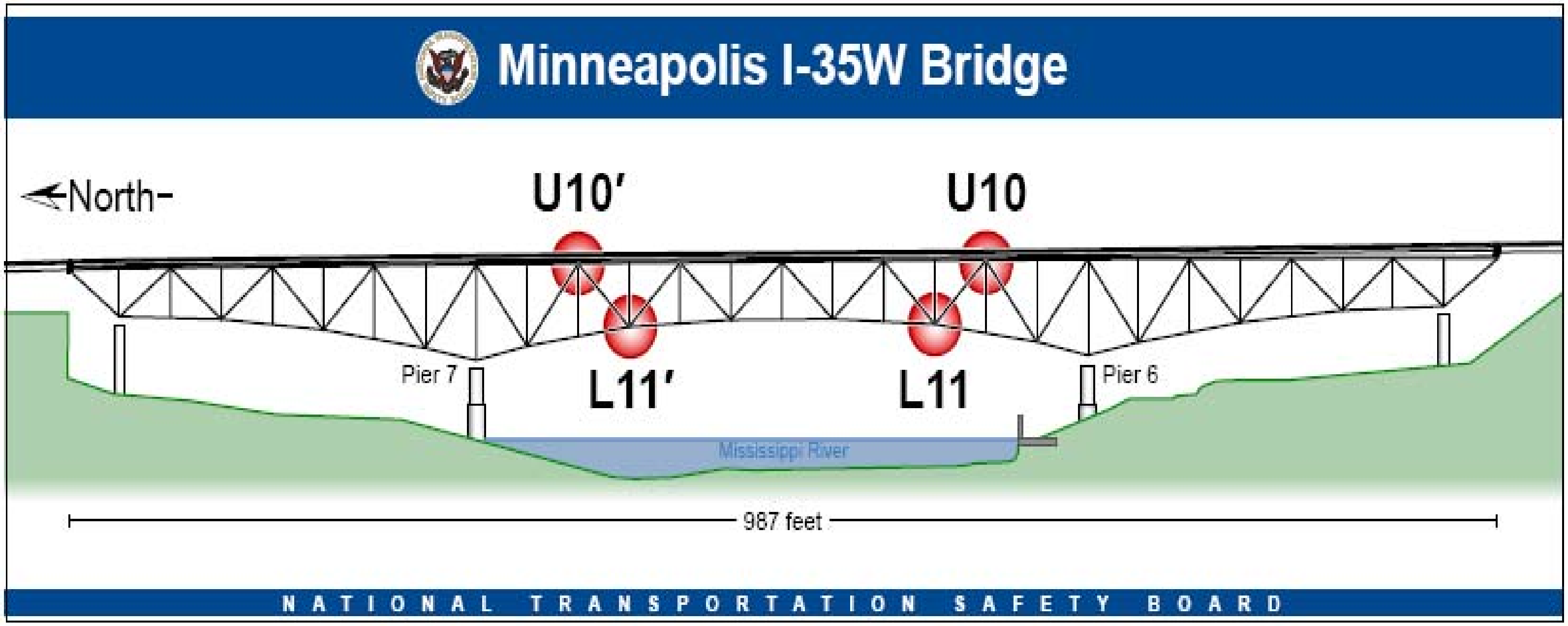
  13 Fatalities, 100 Injuries

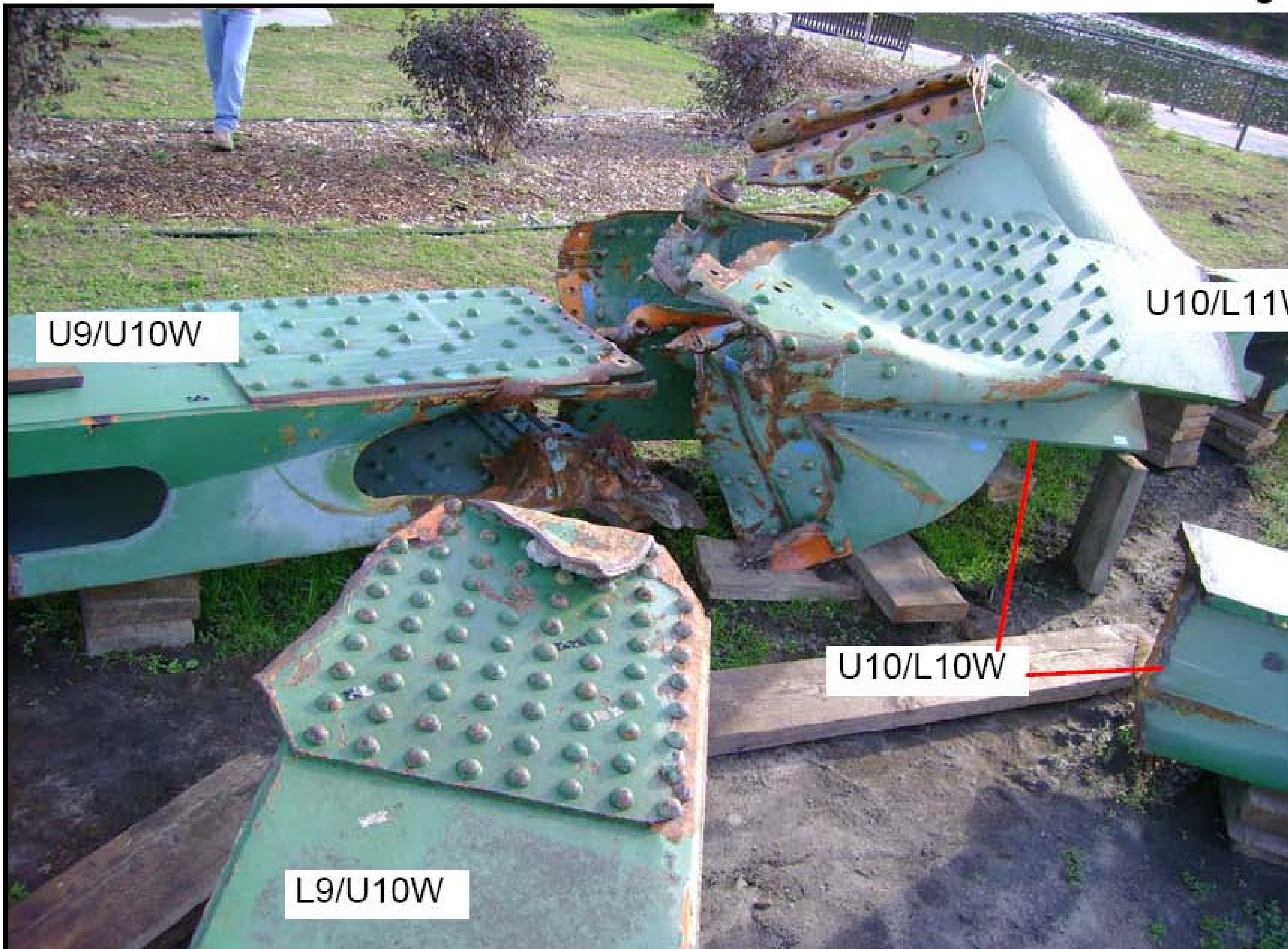
- NTSB Preliminary Finding on Jan 15, 2008: Under-designed Gusset Plate

http://www.ntsb.gov/Recs/letters/2008/H08_1.pdf

A view of the west side of the deck truss portion of the bridge, looking northeast.

Post collapse, viewed looking west.


Minneapolis I-35W Bridge
North
U10′
U10
L11′
L11
Pier 7
Pier 6
Mississippi River
987 feet
NATIONAL TRANSPORTATION SAFETY BOARD



Node U10 West, showing U9/U10W, L9/U10W, U10/U11W, U10/L11W and a portion of U10/L10W.

FHWA TECHNICAL ADVISORY (T 5140.29) RECOMMENDATIONS JANUARY 18, 2008

- **Check the Capacity of Gusset Plates as Part of the Initial Load Ratings**
- **Check the Capacity to Account for Modifications that Result in Significant Changes in Stress Levels**

NYSDOT'S IMPLEMENTATION PLAN

- Identify Truss Type Structures Carrying Highways in New York State
- Identify Bridges with Stress Increase in their Gusset Plates
- Check Capacity of Gusset Plates for the Identified Bridges

TRUSS GUSSET PLATE SCREENING

- **Screening to Include:**
  - **Bridges Whose Gusset Plates Have Been Subjected to Increased Stresses Due to Increased Applied Loads (Dead or Live)**
  - **Bridges Whose Gusset Plates Have Lost Capacity Due to Deterioration or Damage**

CAUSES of DEAD LOAD INCREASE

- Increased Deck Thickness
- Deck Overlay Increase
- Bridge Deck Widening
- Widening Roadway Width (Curb to Curb, Rail to Rail)
- Addition of Sidewalk Overhang
- Addition of Major Utilities
- Addition of Concrete Barrier to Replace Rail

CAUSES of LIVE LOAD INCREASE

- **Current Live Loading > Design Live Loading**
- **Increase in Number of Lanes Since Original Construction**
- **Increase in Deck Roadway Width (Increased LL Distribution to Trusses)**
- **Known to be in an Area of Increased Overweight Loads**

TRUSS GUSSET PLATE SCREENING

- **605 Truss Structures Carrying Highways in NYS**
  (NYCDOT and Authorities not Included)
- **350 out of 605 (58 %) are Locally Owned**
- **145 Bridges with Stress Increase in Gusset Plates that Required Analysis**
- **42 out of 145 Requiring Analysis (29 %) are Locally Owned**

STATE and LOCAL SUMMARY

Region	Truss Population	Requiring Analysis	% Requiring Analysis
1	108	21	**19.4%**
2	50	8	**16.0%**
3	41	7	**17.1%**
4	87	47	**54.0%**
5	44	8	**18.2%**
6	28	3	**10.7%**
7	70	26	**37.1%**
8	75	11	**14.7%**
9	94	12	**12.8%**
10	6	1	**16.7%**
11	2	1	**50.0%**
Sub Total	**605**	**145**	
Percentages		**24%**	**24%**

LOCAL SUMMARY

Region	Local Trusses	Requiring Analysis	% Requiring Analysis
1	53	3	**5.7%**
2	24	1	**4.2%**
3	25	2	**8.0%**
4	24	0	**0.0%**
5	28	3	**10.7%**
6	22	2	**9.1%**
7	55	18	**32.7%**
8	38	5	**13.2%**
9	81	8	**9.9%**
10	0	0	**0.0%**
11	0	0	**0.0%**
Sub Total	**350**	**42**	
Percentages		**12%**	**12%**

NYSDOT ISSUANCE

- **Technical Advisory (TA 08-001)**
  Load Factor Design (LFD) Analysis for Existing Trusses

- **Structures Design Advisory (SDA 08-001)**
  Load and Resistance Factor Design (LRFD) for New and Replacement Trusses

WHAT TO CHECK?

- Combined Flexural and Axial Loads
- Shear on Both the Gross and Net Sections
- Unsupported Edge Distance
- Edge Slenderness Ratio
- The Resistance of Fasteners
- Block Shear Rupture Resistance
- Analysis of Whitmore Section
- Gusset Plates in Compression

LRFD LIVE LOAD CASES FOR NEW AND REPLACEMENT BRIDGES

- **HL-93 & NYSDOT Design Permit Vehicle Live Loads :**

- **The Higher Loaded Chord is Maximized with Concurrent Forces in the Other Members.**

- **The Higher Loaded Diagonal is Maximized with Concurrent Forces in the Other Members.**

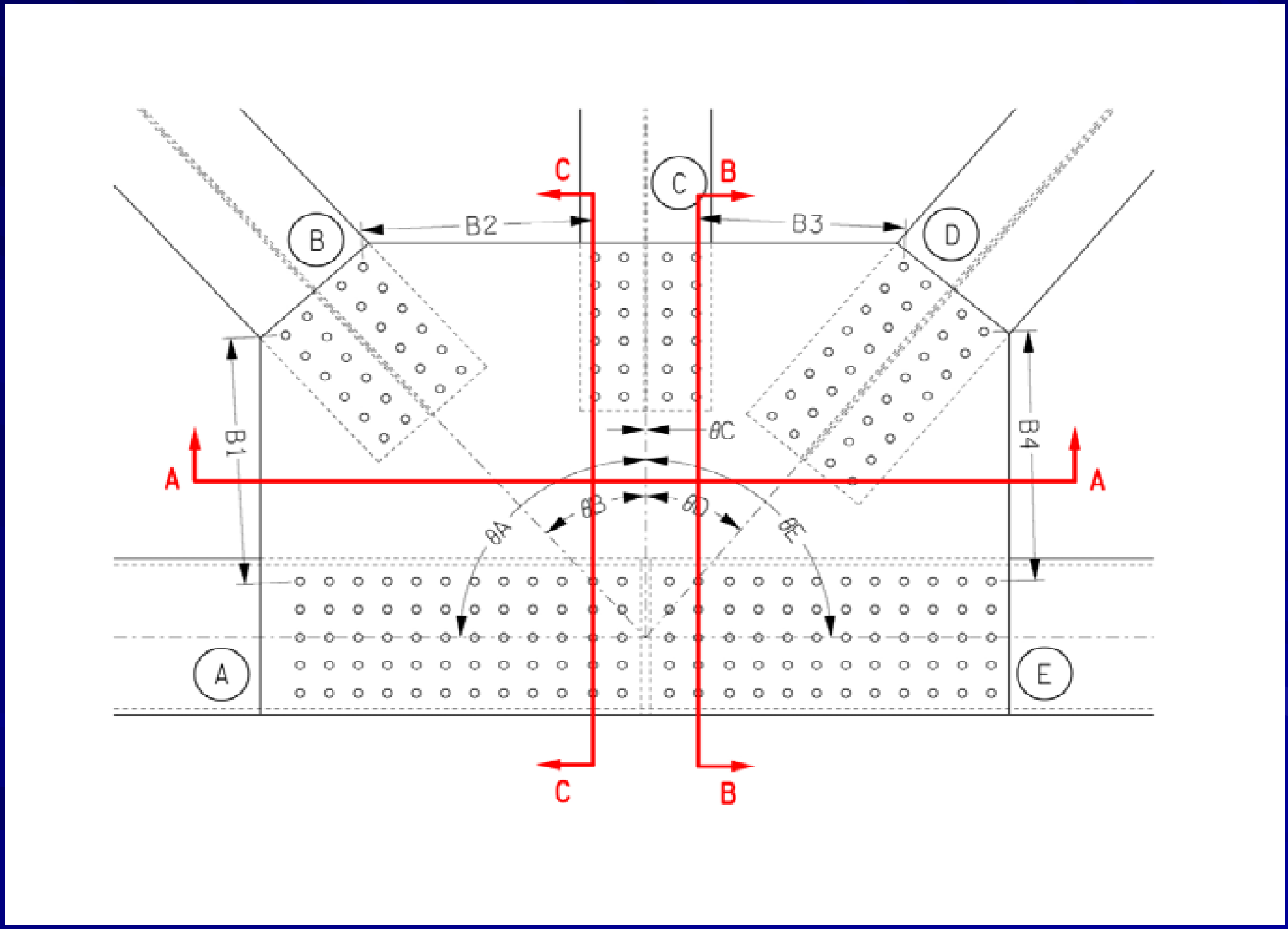
LFD LIVE LOAD CASES FOR EXISTING BRIDGES

- HS-20 Truck or Lane Load:

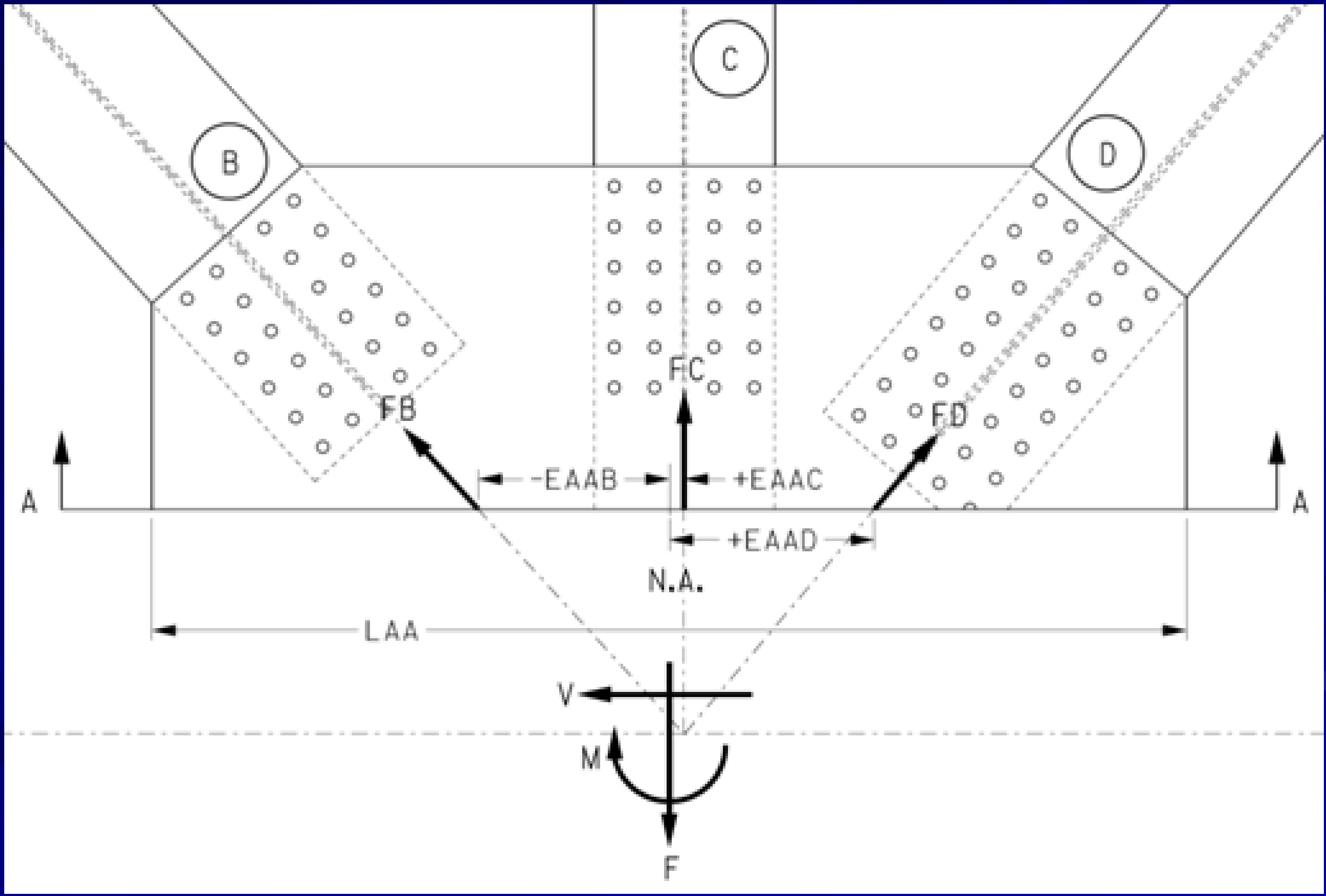
- Case I: The Maximum Truss Member Tensile Forces.

- Case II: The Maximum Truss Member Compressive Forces.

SECTIONS OF INTEREST



FREEBODY DIAGRAM



MEMBER FORCES

For Each LL+I Case:

- **Factored Member Forces**
- **Horizontal Components**
- **Vertical Components**

FORCES & STRESS

Forces Acting on Section:

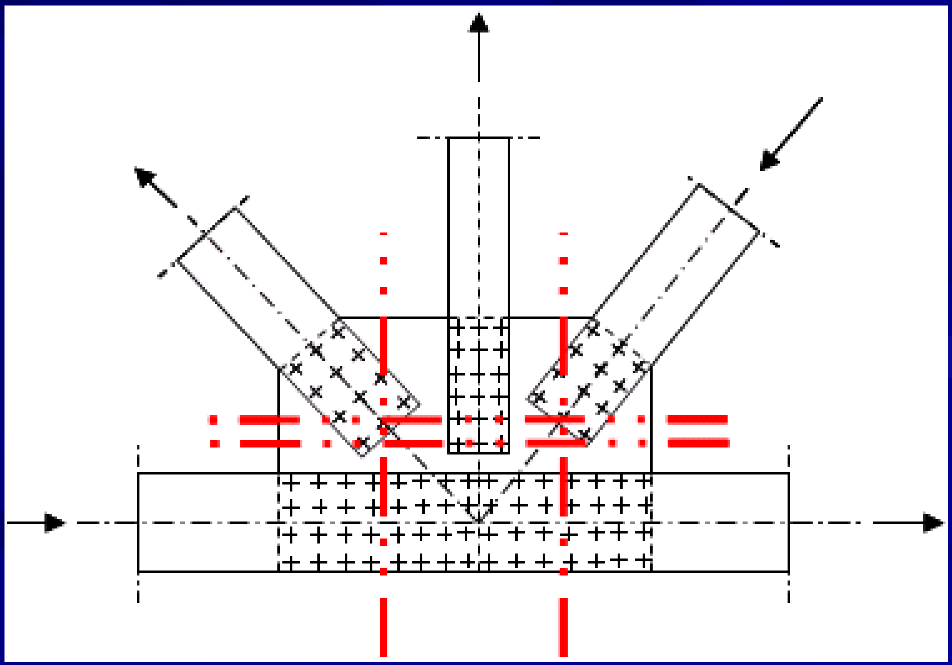
- Axial Force
- Shear Force
- Bending Moment

Stress Along Section:

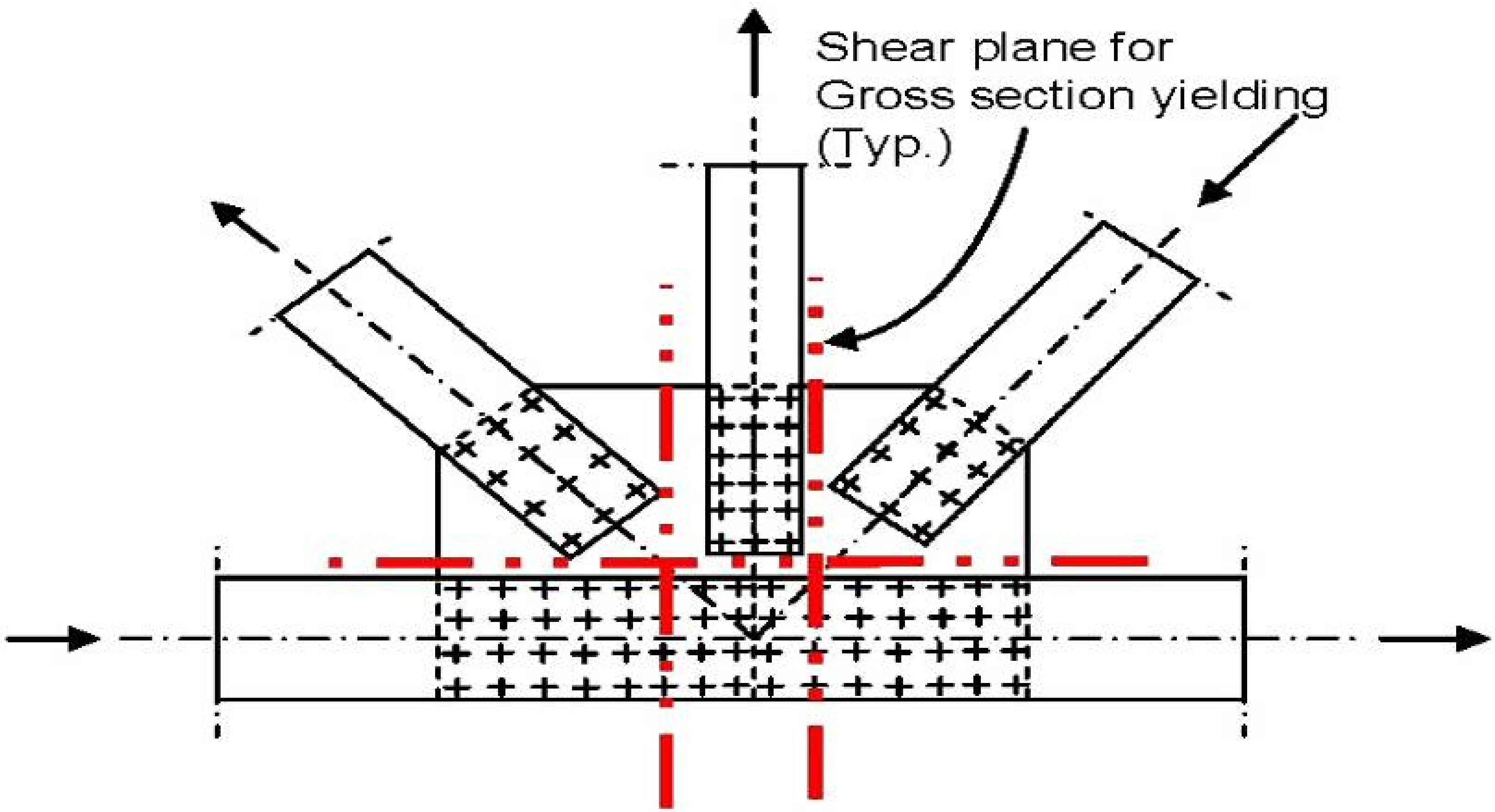
- Axial Stress
- Maximum Shear Stress
- Flexural Stress

GUSSET PLATES UNDER COMBINED FLEXURAL AND AXIAL LOADS

FHWA Guide: The Maximum Elastic Stress *may be* Taken as ϕf Fy

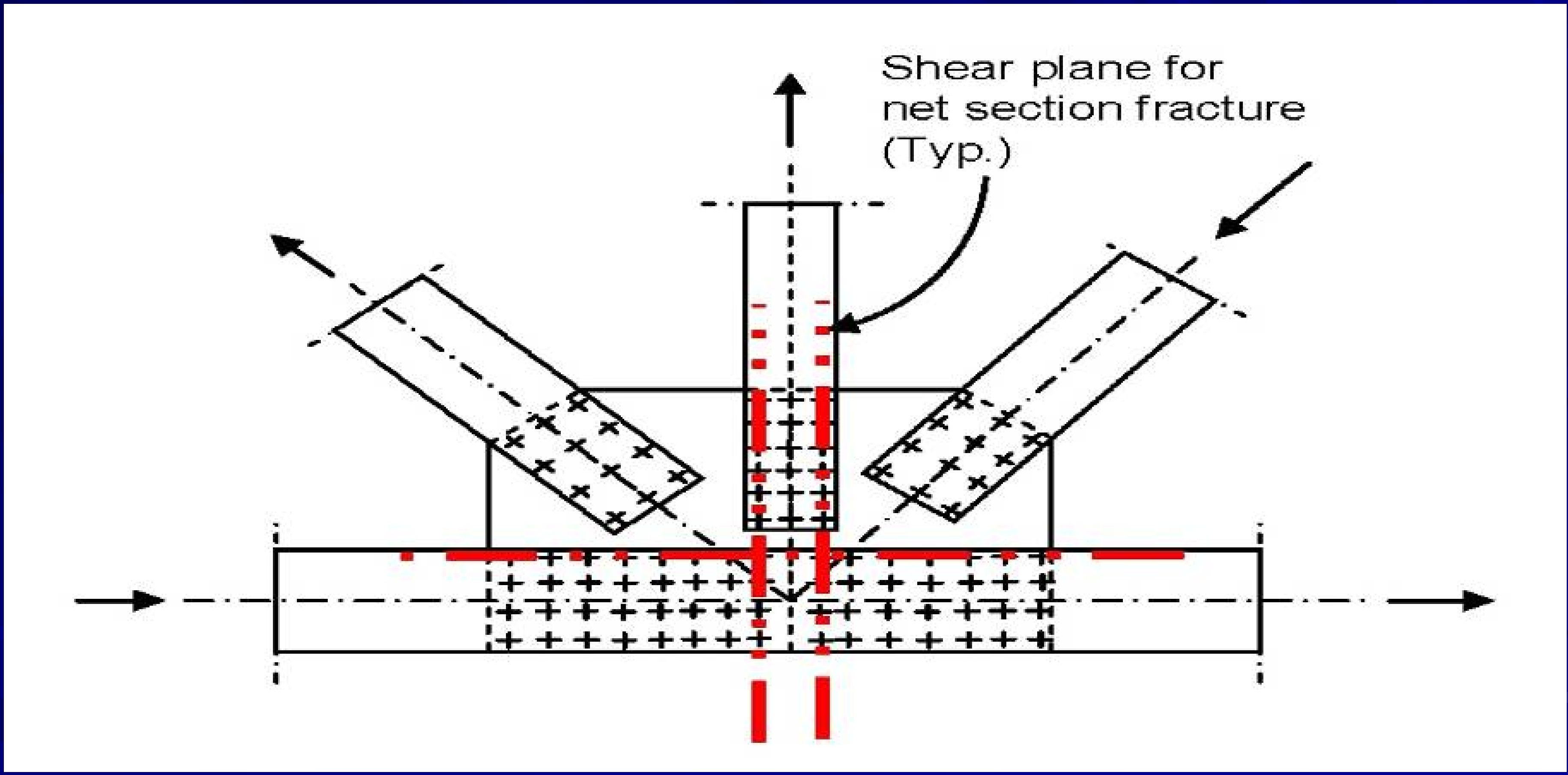


GUSSET PLATES IN SHEAR



Gross Shear Yield Sections

GUSSET PLATES IN SHEAR



Net Shear Fracture Sections

UNSUPPORTED EDGE DISTANCE

- **Allowable Length of Unsupported Edges**

$$b_{all} := \frac{11000psi}{\sqrt{F_y \cdot psi}} \cdot t_{gp}$$

EDGE SLENDERNESS RATIO REQUIREMENT

- Allowable Slenderness Ratio

$$SR_{all} := 120$$

MEMBER CONNECTION DESIGN

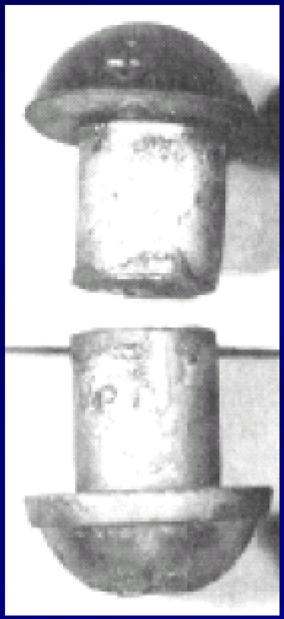
- **Strength Limit State for Not Less than The Larger of:**

The Average of The Factored Axial Force and The Factored Axial Resistance of the Member

OR

75 % of the Factored Axial Resistance of the Member

THE RESISTANCE OF FASTENERS



Fasteners Shear

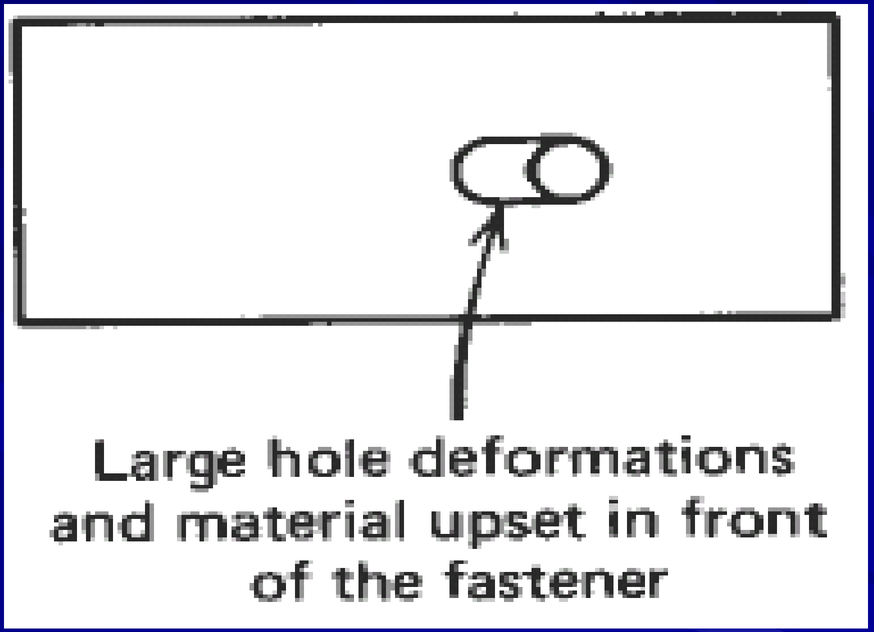
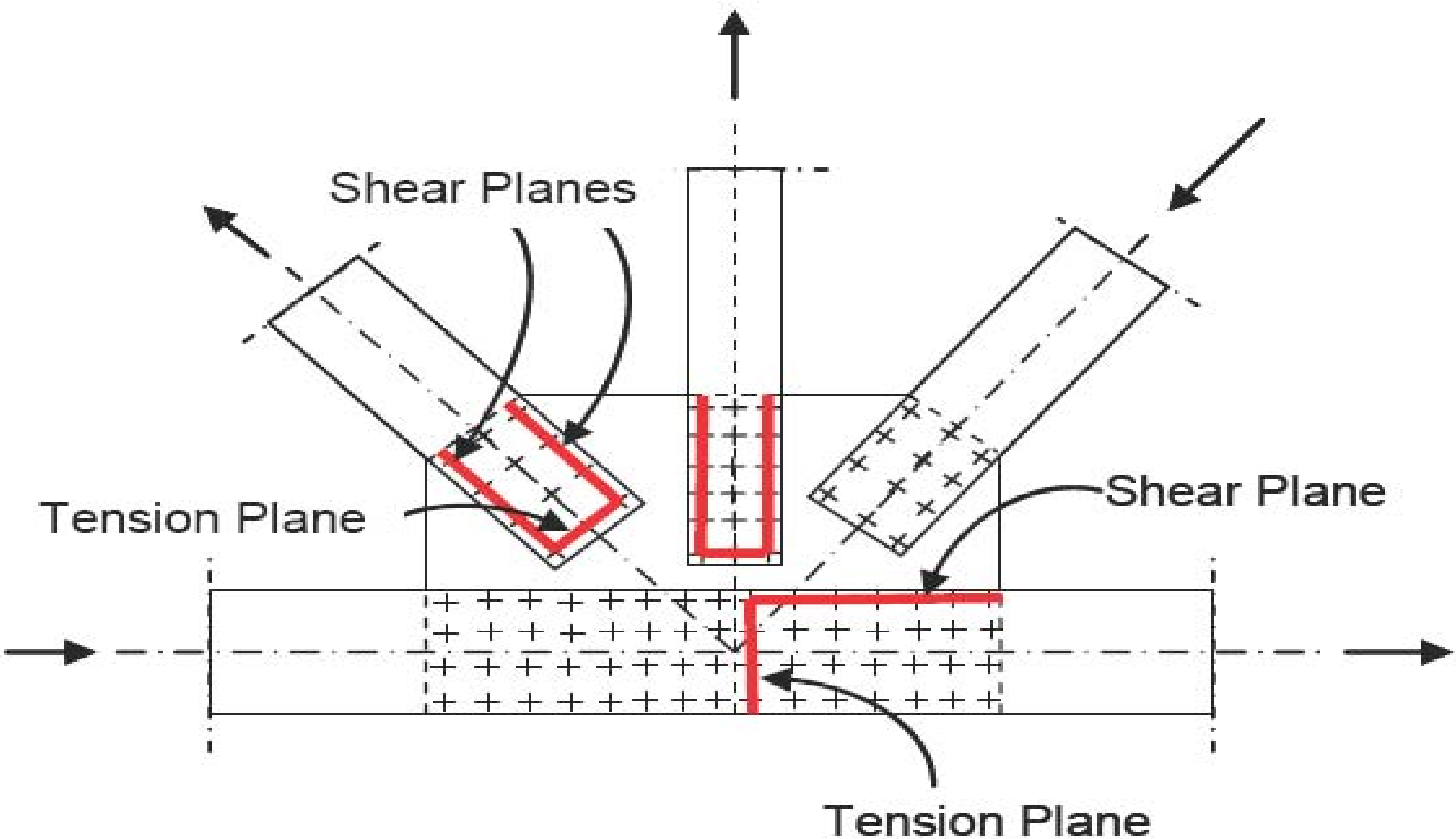


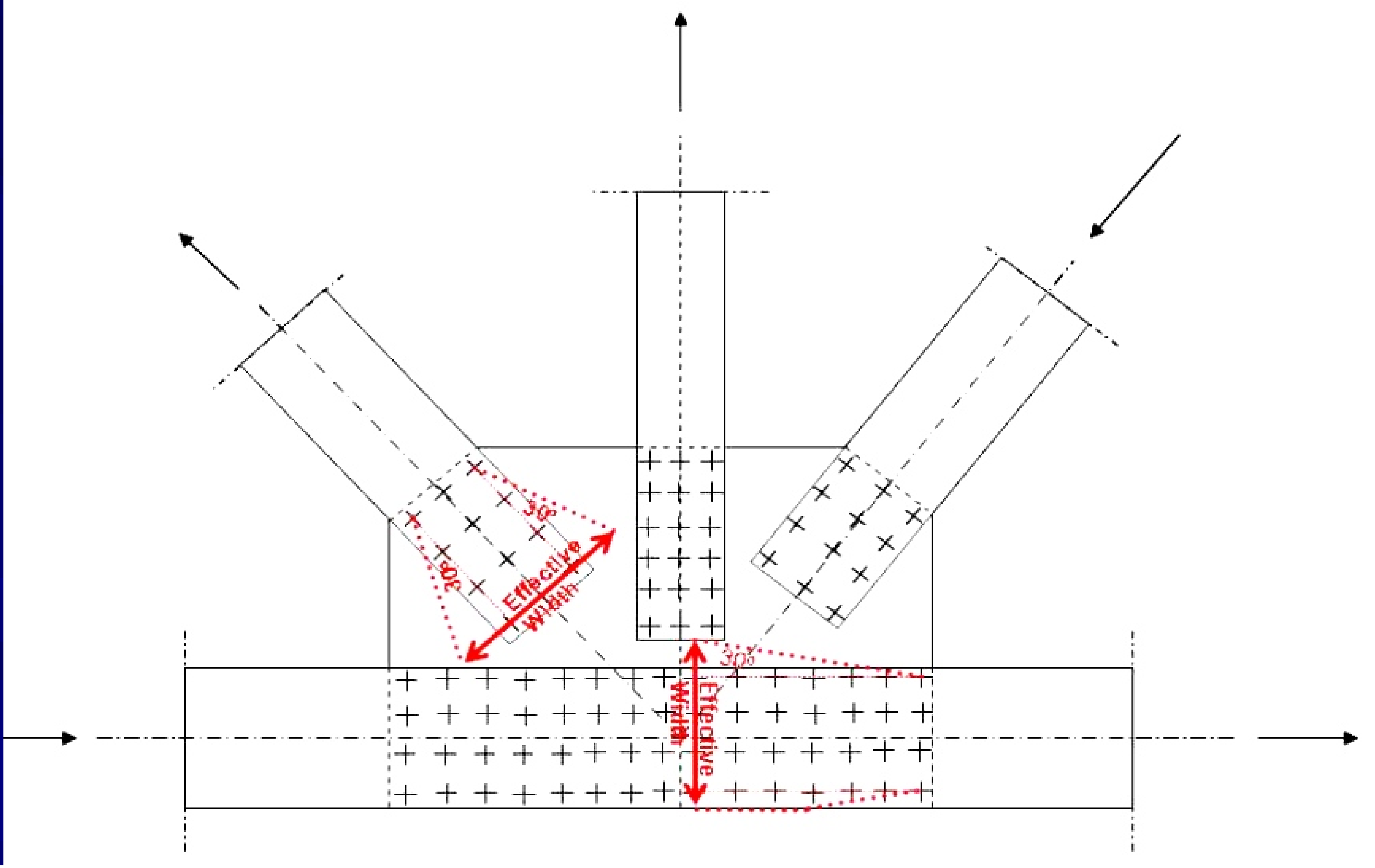
Plate Bearing Failures

BLOCK SHEAR RUPTURE RESISTANCE

- If $A_{tn} \ge 0.58A_{vn}$, then: $R_r = \phi_{bs}\left(0.58F_yA_{vg} + F_uA_{tn}\right)$
- Otherwise: $R_r = \phi_{bs}\left(0.58F_uA_{vn} + F_yA_{tg}\right)$



WHITMORE SECTION

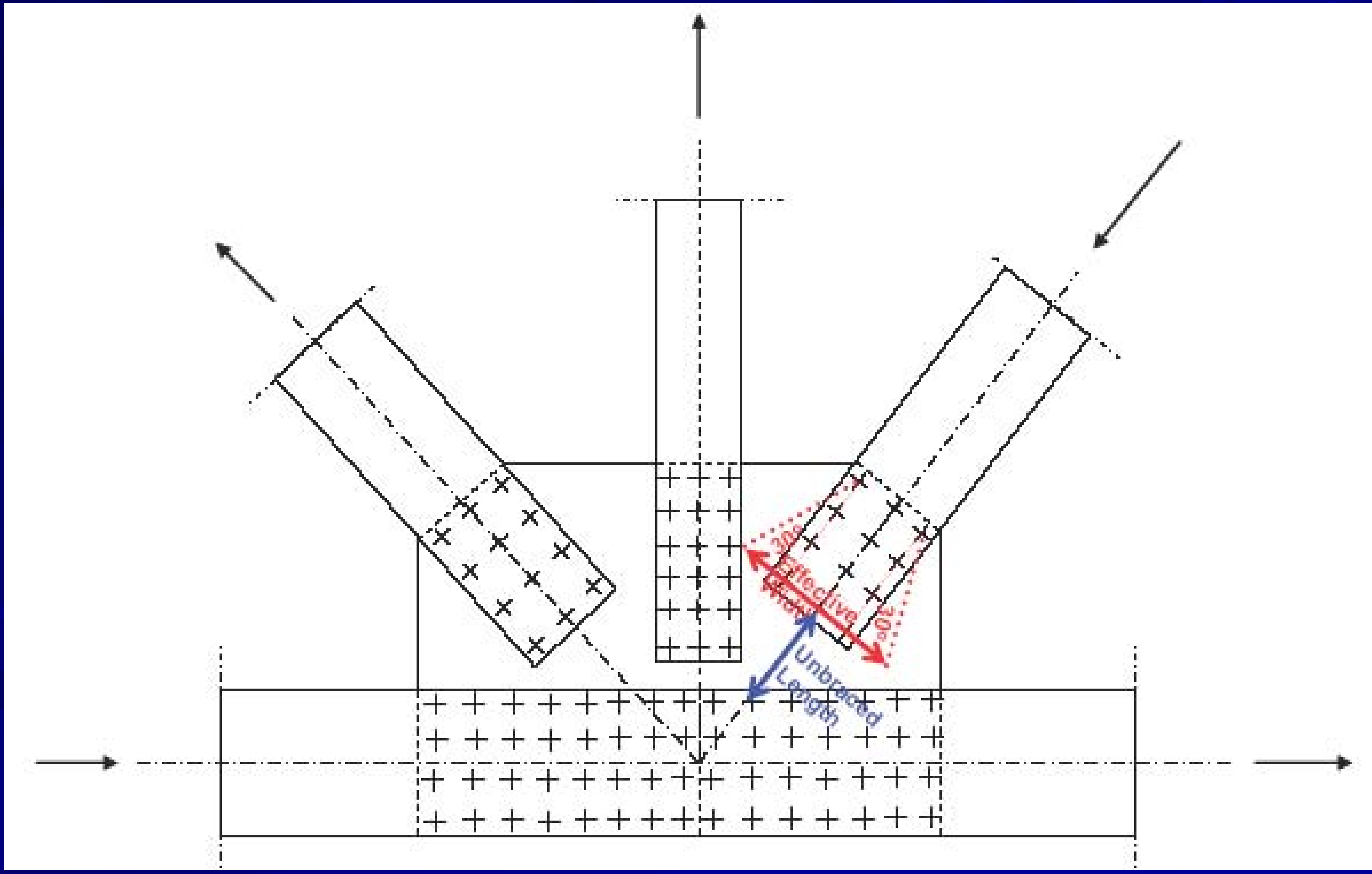


ANALYSIS OF WHITMORE SECTION

Allowable Tensile Force on Gross Section (Yielding Resistance)

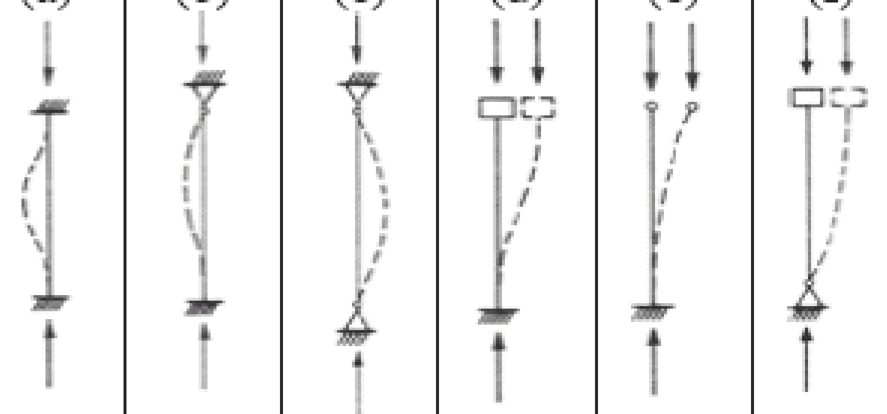
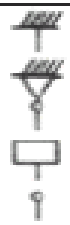
Allowable Tensile Force on Net Section (Fracture Resistance)

GUSSET PLATES IN COMPRESSION



EFFECTIVE LENGTH FACTOR, K

Value of K will Depend on the Anticipated Buckled Shape

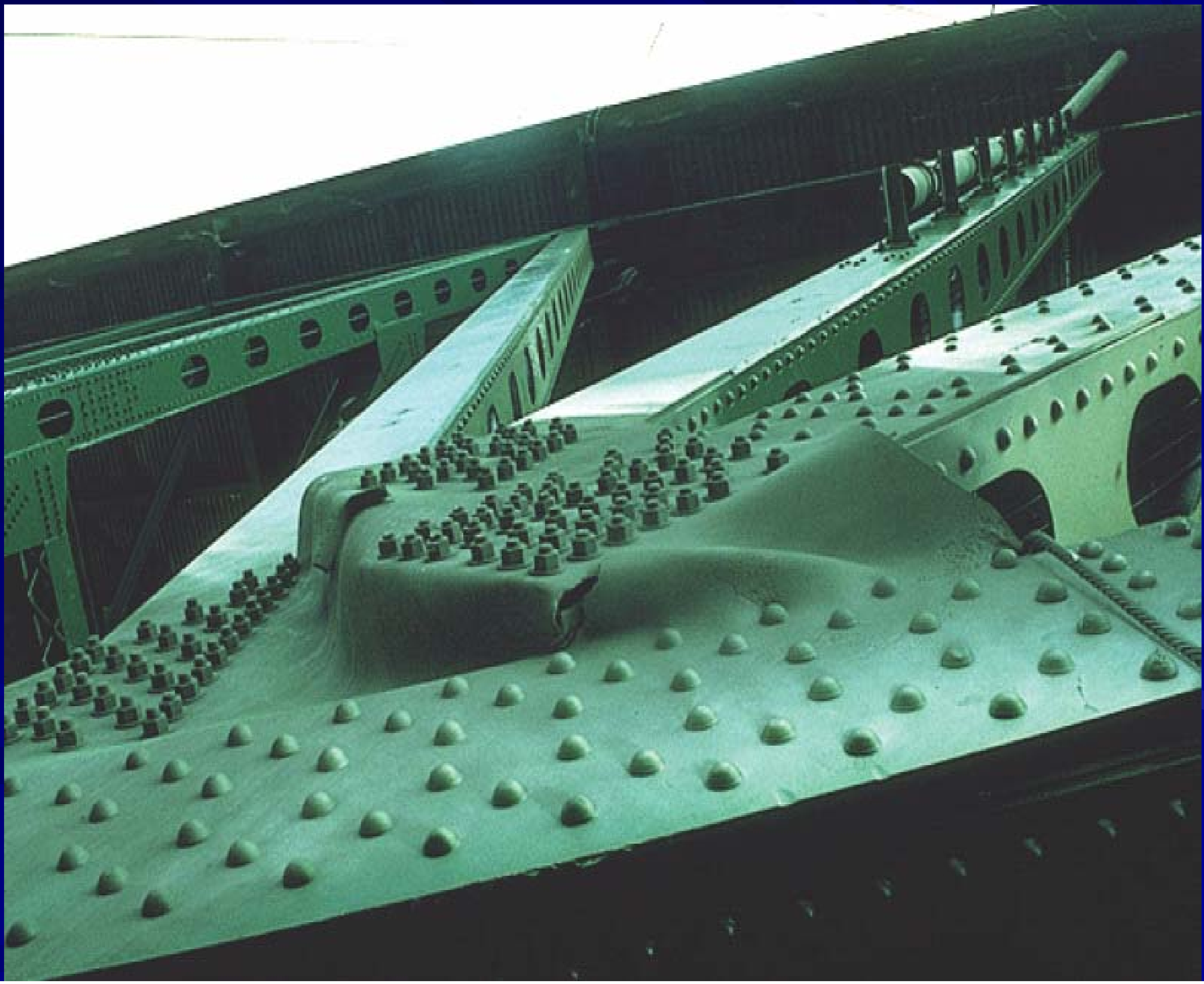
Buckled shape of column is shown by dashed line	(a)	(b)	(c)	(d)	(e)	(f)
						
Theoretical K value	0.5	0.7	1.0	1.0	2.0	2.0
Design value of K when ideal conditions are approximated	0.65	0.80	1.2	1.0	2.1	2.0
End condition code		Rotation fixed Rotation free Rotation fixed Rotation free			Translation fixed Translation fixed Translation free Translation free	

"k"

- "k" Value Vary from 0.65 to 2.1
  in Most Cases, k = 1.0 (Pinned-Pinned)

SAMPLE PHOTOS

GUSSET PLATES IN COMPRESSION




08.01.2007


2008/ 8/18


SP3
RT
L22


SP3
LT
L22

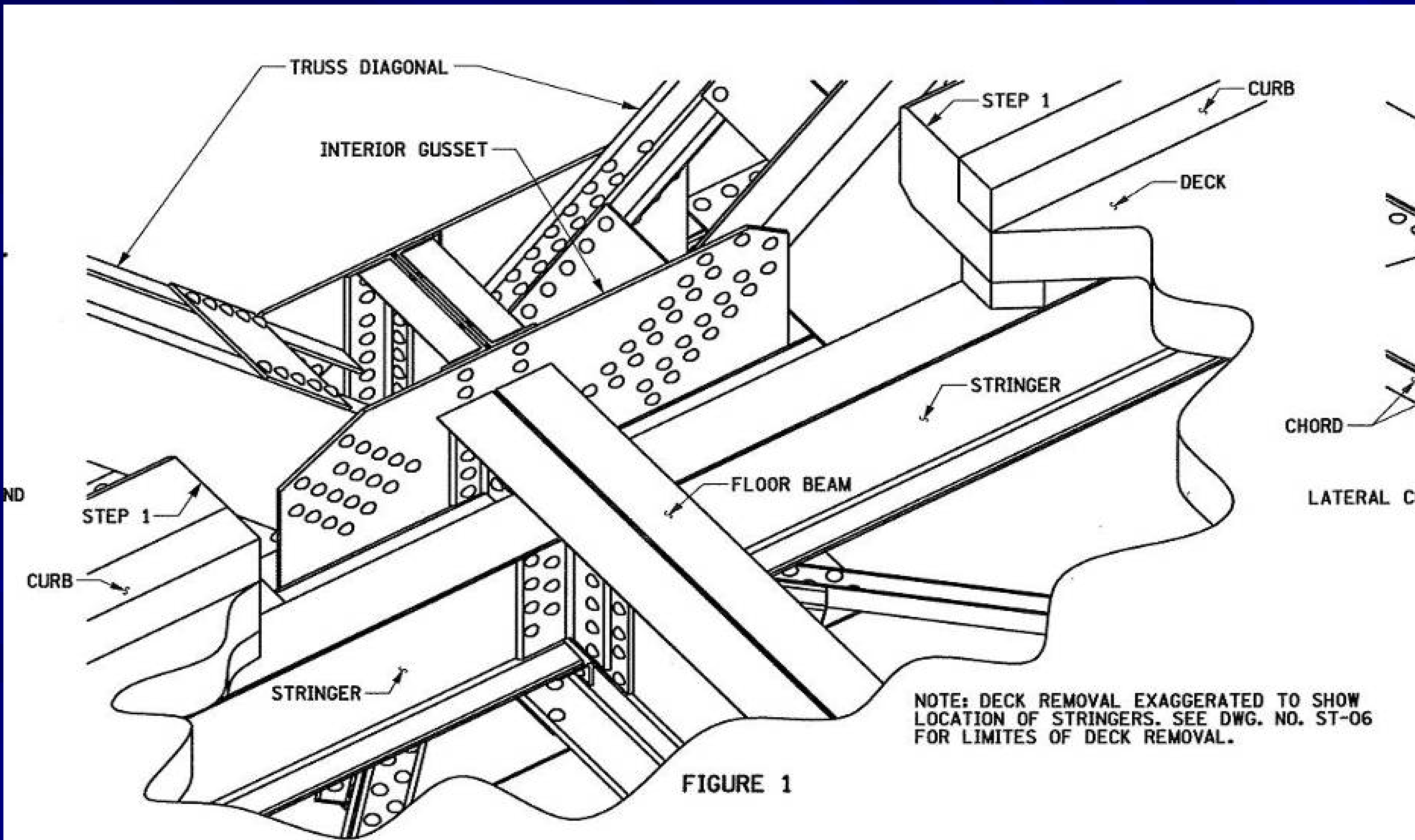

2008/ 8/14


L10
RT.
EXT.
06.20.2008 08:

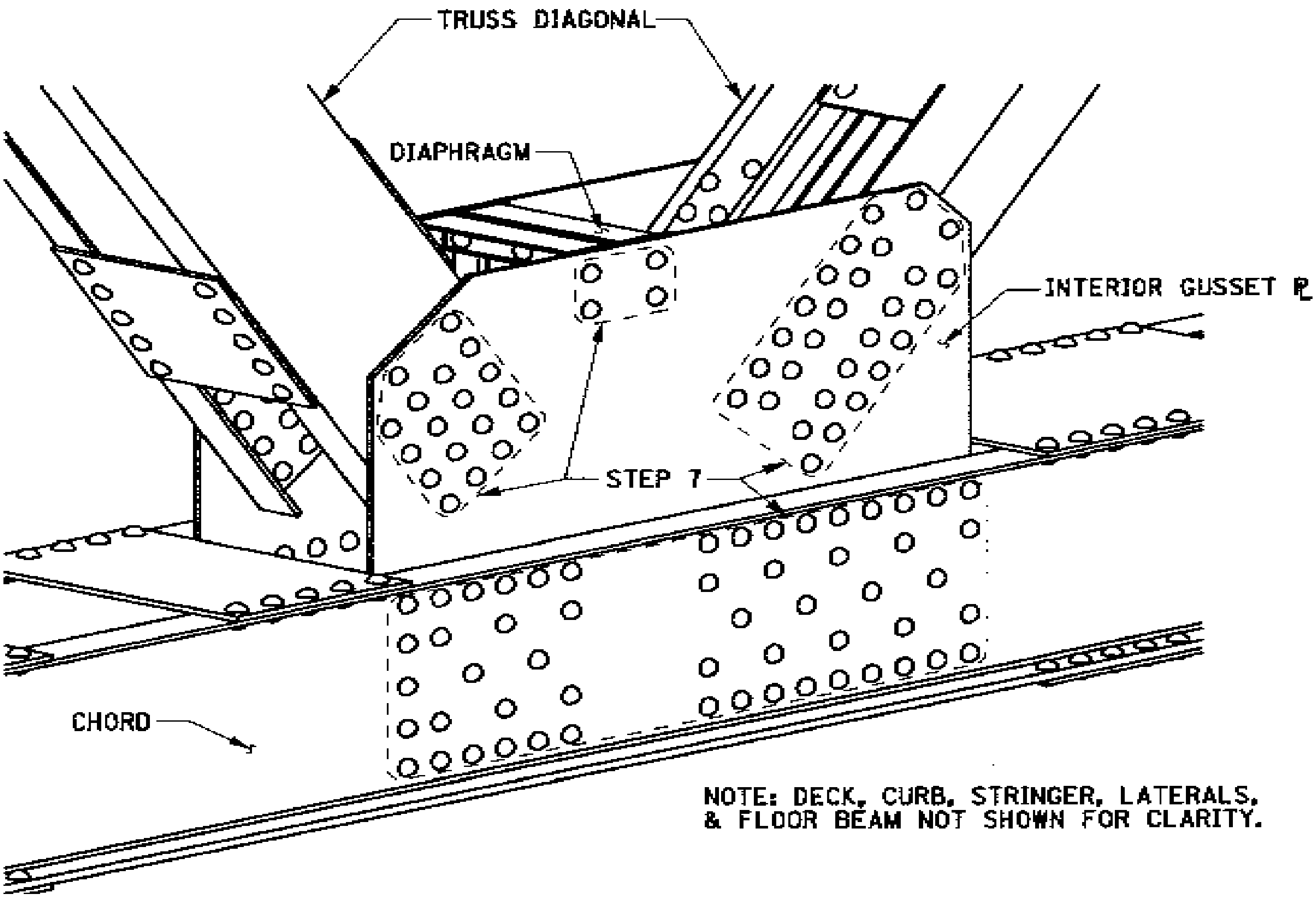
REPAIR EXAMPLE

- ROUTE 23 OVER SCHOHARIE CREEK

CONNECTION IN 3D



CONNECTION IN 3D



DAMAGED PLATE

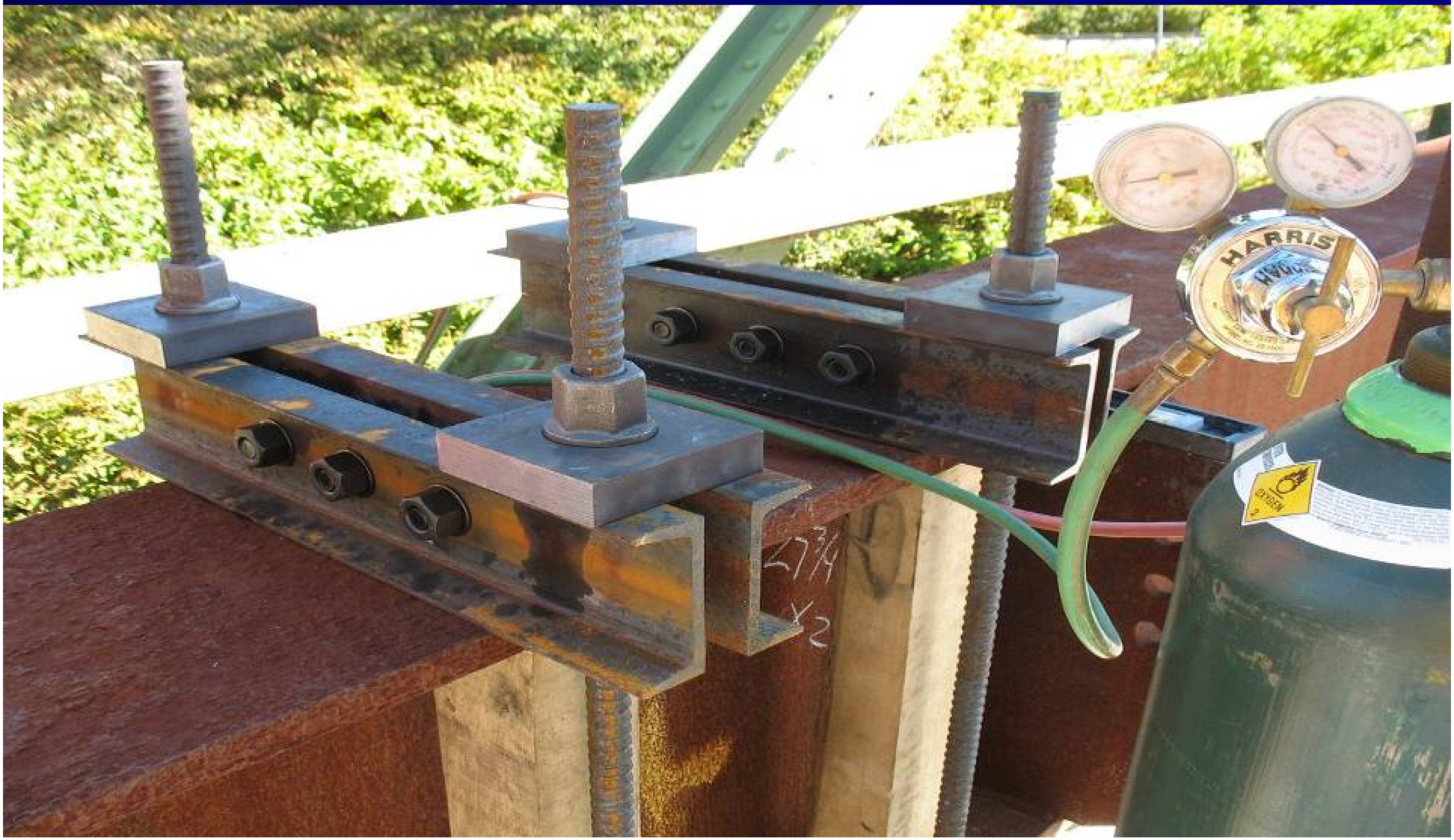
ANGLES REPAIR

WOOD BLOCK

STRONGBACK BEAM

STRONGBACK

DETAILS



STAGING AREA

RIVETS REMOVAL

RIVETS REMOVAL

NEW PLATE INSTALLED

CHORD CONNECTION

DIAGONAL & DIAPHGRAM CONNECTION

UNDER TRUSS VIEW

BOTTOM LATERAL PLATE

UPDATE

- NYSDOT Continues to Analyze the Identified State and Local Trusses
- Emergency Repairs Were Done to 4 Trusses out of 23 that Were Analyzed
- 16 % of Trusses Analyzed;13 % Needed Repairs

WEB REFERENCES

1. Technical Advisory (TA 08-001) Load Factor Design (LFD) Analysis for Existing Trusses
   https://www.nysdot.gov/divisions/engineering/structures/manuals/technical-advisory/repository/TA_08-001-Truss_Gusset_Plate_Analysis.pdf

2. Structures Design Advisory (SDA 08-001) Load and Resistance Factor Design (LRFD) for New and Replacement Trusses:
   https://www.nysdot.gov/divisions/engineering/structures/repository/manuals/SDA-08-001_Gusset_Plate_Design.pdf

3. FHWA TECHNICAL ADVISORY (T 5140.29)
   http://www.fhwa.dot.gov/legsregs/directives/techadvs/t514029.htm

4. National Transportation Safety Board Safety Recommendation
   http://www.ntsb.gov/Recs/letters/2008/H08_1.pdf