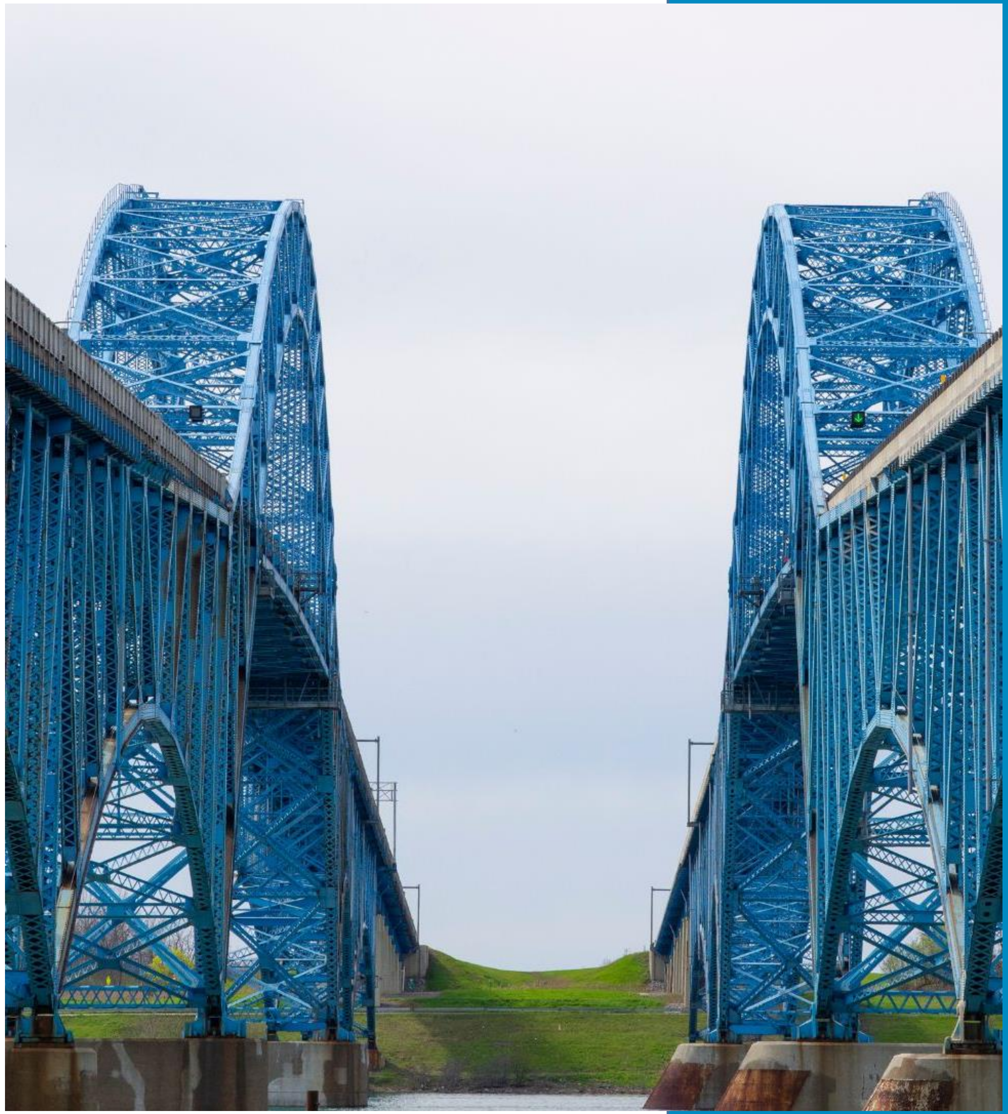
AASHTOWare™ BRIDGE DESIGN AND RATING

Use of Bridge Rating Data in the New York State DOT Load Rating Bridge Safety Assurance Programs

Ratan Huda, MS, PE (NYSDOT)

Ekin Senturk, AVP, PhD, PE (HNTB)



RADBUG 2024 | August 6-7 | Buffalo, NY

Agenda:

- Overview of AASHTOWare BrR Use in Bridge Safety Assurance Program
  - Load Rating and Posting of Bridges
  - Permitting Overweight Vehicles on State Bridges
- Corroded Beam End Shear Rating with BrR
- Gusset Plate Load Rating in BrR
- Questions and Answers

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Load Rating and Posting of Bridges

- Load Rating Levels
  - Level 1: requires detail calculation, documentation, and PE certification
  - Level 2: solely BrR rating; requires update of model after every Inspection
  - Level 3: unratable with BrR
- Total Bridges in NY: 17,800
- Inspection: 10,000/Year (approximate excluding Authority bridges)
- Level 2 with BrR: 8000/Year (approximate)

Load Rating and Posting of Bridges

- Load Posting (EI 20-026)
  - Use Level 2 (BrR) if Level 1 Rating is not available or outdated.
  - Safe Load Capacity (SLC) = SLC Factor x H20 Operating
  - Compare SLC against “H” Load Equivalent Force Effects of Legal Loads (Profile)

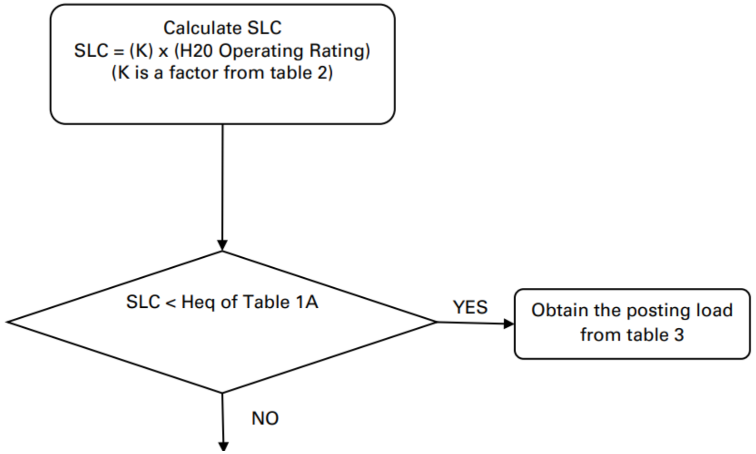

Table 1A
"H"-LOADING EQUIVALENT TO LEGAL LOADS
(EXCLUDING SU6 & SU7)

Effective pan Length (ft.)	H Equivalent Legal Load
Up to 12*	H16
13-19	H21
20-34	H25
35-45	H26
46-53	H27
54-64	H28
65-75	H26
76-90	H25
91-105	H23
106-120	H22
121-140	H21
Over 140	H20

Table 1B
"H"-LOADING EQUIVALENT TO LEGAL LOADS
(INCLUDING SU6 & SU7)

Effective Span Length (ft.)	H Equivalent Legal Load
Up to 12	H16
13-19	H22
20-34	H29
35-45	H31
46-53	H33
54-64	H33
65-75	H32
76-90	H30
91-105	H28
106-120	H26
121-140	H25
Over 140	H23

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Permitting Overweight Vehicles on State Bridges

- Use Level 2 (BrR) if Level 1 Rating is not available or outdated.
- Compare HS20 Operating Rating (Tonnage) against Permit Vehicle Load Effect (PVLE in Tonnage).
- PVLE is approximated using BIGTRUK
- When PVLE (w/Scrawl speed) > HS20 OPR, Permit requester has option for refined analysis with BrR.

Permitting Overweight Vehicles on State Bridges

OVERLOAD EVALUATION CRITERIA EXAMPLE		
Permit Type	**Max PVLE w/o Multiple Presence Factor**	**Review Action**
All Permits (except Annual Crane Permits).	Less than or equal to 100 % HS20	All permits recommended approved for bridges that are not load posted.
Trip Permits	Greater than 100 % and less than or equal to 150 % HS20	Trip Permit recommended approved for bridges that are not “R” or load posted.
Trip Permits	Greater than 150 % HS20	Speed Restrictions on individual bridges or routes may be required.

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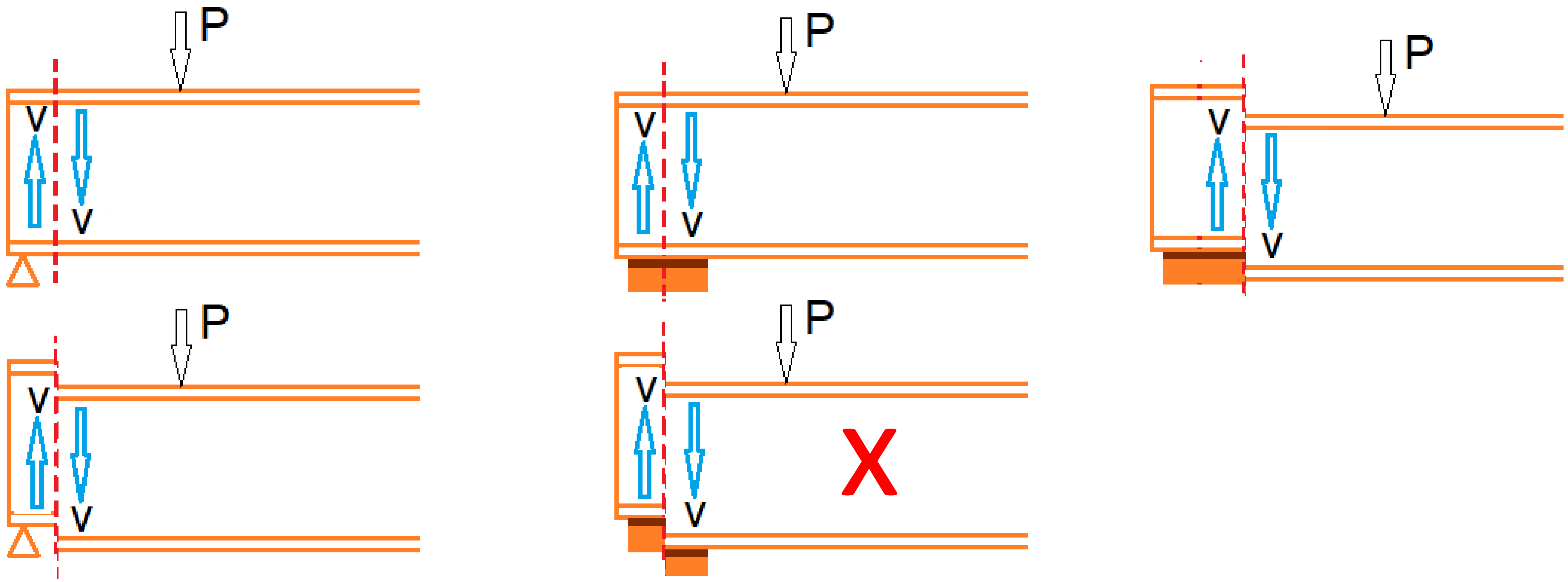
Corroded Beam End Shear Rating with BrR



Corroded Beam End Shear Rating with BrR

3.4—Web Shear: yielding/buckling may take place along a vertical line of worst section loss beyond the face of the support. Shear failure associated with corrosive section loss is unlikely to take place beyond one web depth distance from the face of the support. However, if section loss is present beyond one web depth distance from the face of the support, it shall be recorded and input in the analysis model of the bridge.

NEW YORK STATE OF OPPORTUNITY.	Department of Transportation Office of Structures	TECHNICAL ADVISORY	TA 24-XXX

Title: **Requirements for Inspection, Documentation, and Load Rating of Corroded Steel Beam Ends**

Issued By: Office of Structures - Structure Management Bureau	**Approved By:**
Bridge Inspection, Inventory and Bridge Safety Assurance	**James H. Flynn, P.E.** Deputy Chief Engineer Structures — **Date**

3.4—Web Shear: yielding/buckling may take place along a vertical line of worst section loss beyond the face of the support. Shear failure associated with corrosive section loss is unlikely to take place beyond one web depth distance from the face of the support. However, if section loss is present beyond one web depth distance from the face of the support, it shall be recorded and input in the analysis model of the bridge.

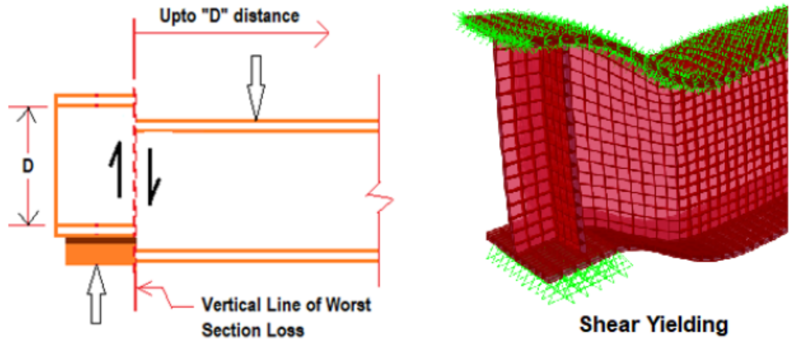


Figure 3.4-1: Web Shear

Corroded Beam End Shear Rating with BrR

5.3.1—Deterioration Profile for Shear:

LOS in the web shall be from the vertical line of worst section loss at or beyond the face of the bearing. In the case where the bearing length is very small and/or the vertical line of worst section loss is within the bearing length but closer to the face of the bearing, it is practical to assume this LOS is at the face of the bearing.

AASHTOWare BrR: LOS from above the bearing length are suitable to check Web Crippling and Yielding over the length of the bearing. However, BrR does not perform Web Crippling and Yielding checks. LOS inputs from above the bearing length in BrR would result in an ambiguous Shear check at the center line of the support. Shear checks shall start from the face of the bearing. Hence, the starting point for the deterioration profile in BrR shall be at or beyond the face of the bearing. To get the critical shear rating at the beam end, a point of interest (POI) shall be added at the face of the bearing.

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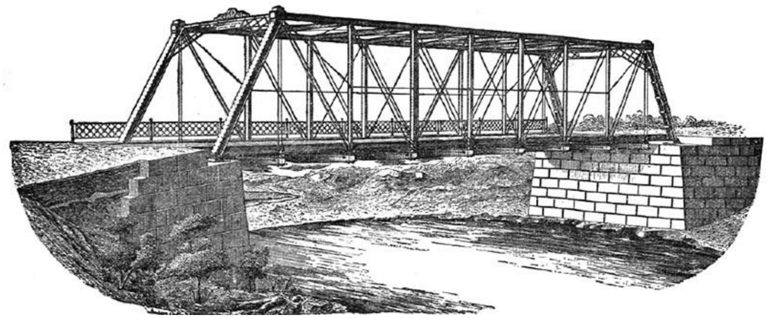
OUTLINE

- **PART 1 – NYSDOT CONTRACT D037658**
- Summary of the work
- Established Workflow
- NYSDOT Gusset Evaluation Tool
- Issues identified in versions earlier than 7.5 involving Interaction Checks

- **PART 2 – USING NEW FEATURES IN BrR v7.5.1**
- Gusset Plate Failure Mechanisms
- Single Member Checks
- Interaction Checks
- Global Shear – Override Angle
- Partial Shear – Override Angle



Griggs, Frank. "The Pratt Truss." STRUCTURE Magazine, https://www.structuremag.org/?p=8600.

NYSDOT CONTRACT D037658

- Truss BrR XML files were updated with gusset plate input for 80 highway bridges.
- A workflow was developed to streamline input extraction from plans.
- Rating results were cross-checked against NYSDOT's LFD & LRFR MathCAD Gusset Plate Analysis tool.
- Issues found were shared with ProMiles Technical Support.

INPUT DATA EXTRACTION WORKFLOW

FIND AND REVIEW APPROPRIATE AS-BUILT DRAWING(S) →
- AS-BUILT DRAWING

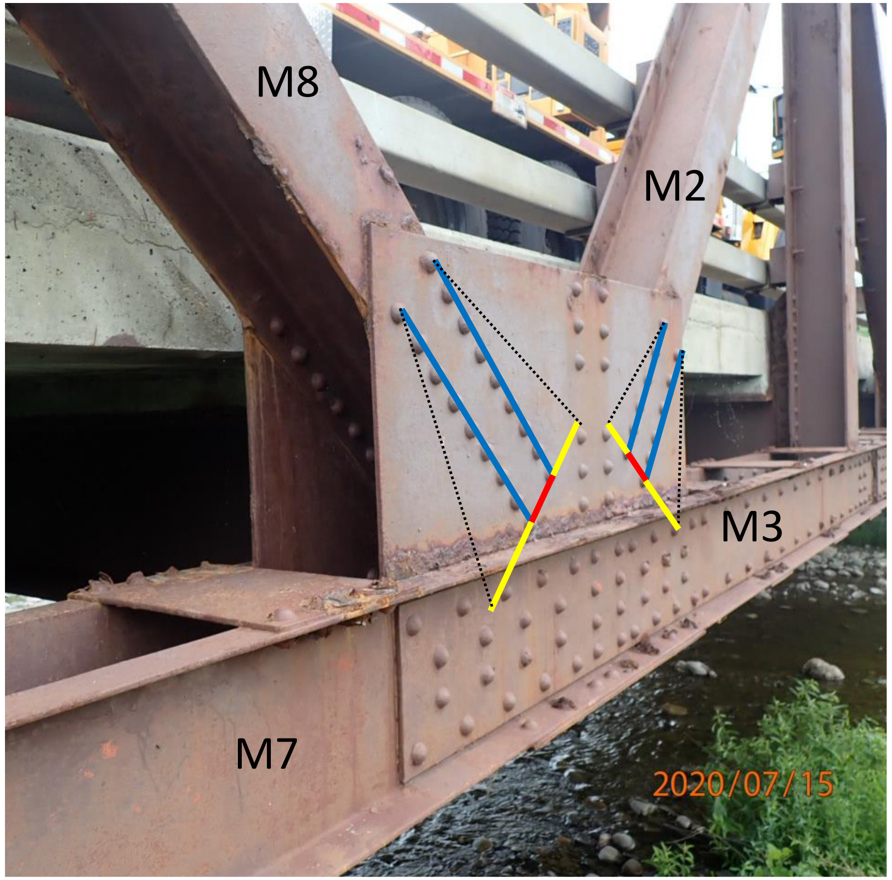
SCALE THE DRAWING IN CAD TO EXTRACT INPUT INFORMATION FOR BrR

QC THE AS-BUILT DEFINITIONS →
- SKETCHES
- GENERAL NOTES FOR AS-BUILT

REVIEW INSPECTION REPORT →
- INSPECTION REPORT

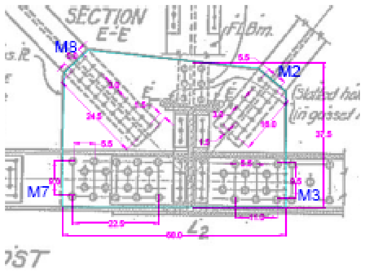
CREATE AS-INSPECTED GUSSET PLATES DEFINITIONS

QC THE AS-INSPECTED DEFINITIONS →
- UPDATED BrR MODEL
- GENERAL NOTES



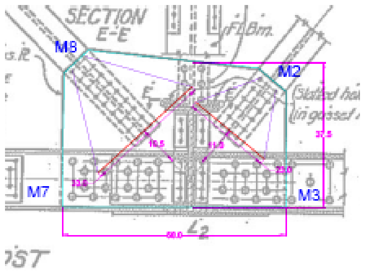
SCALING IN CAD – USE OF LAYERS FOR EACH INPUT GROUP

❶



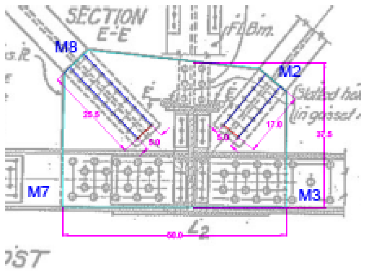
L2 GP: fastener dimensions

❷



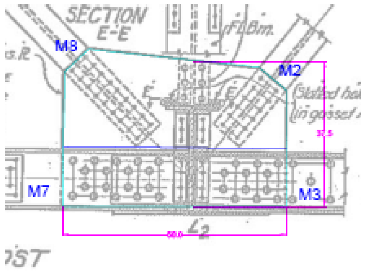
L2 GP: Whitmore dimensions

❸



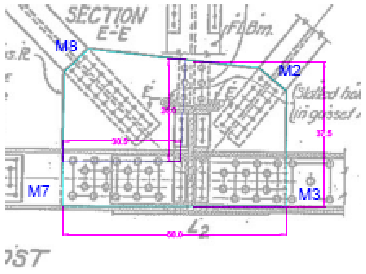
L2 GP: block shear dimensions

❹



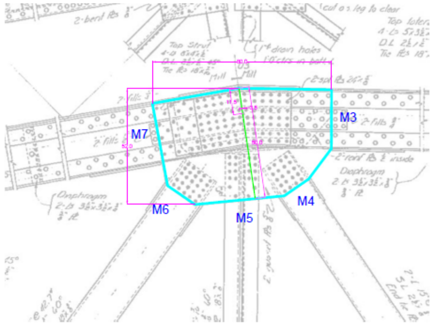
L2 GP: global shear dimensions

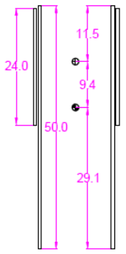
❺



L2 GP: partial shear dimensions

CHORD SPLICES





$A = 92.5\ in^2$
$I = 17628\ in^4$
$y' = 29.1\ in$
$S_x = I/y' = 607\ in^3$

U3 GP: chord splice section properties

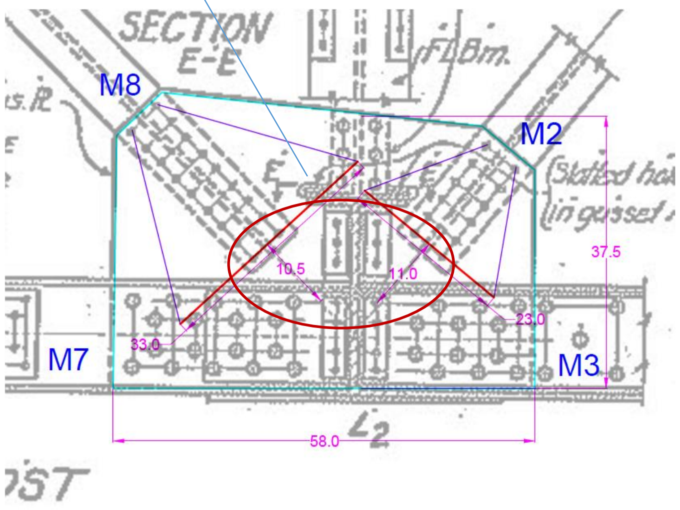
USE OF SKETCHES FOR INPUT AND QC

Name: L2 GP (AS-BUILT)

Description | Panel point | Fasteners | Plate tension | Plate compression | Plate shear | Chord splice | Load transfer

Left plate

	Whitmore width (in)	T (in)	Lmid (in)	K (LFR)
Member 2	23.000		11.000	0.500
Member 3	1000.000		0.001	0.500
Member 7	1000.000		0.001	0.500
Member 8	33.000		10.500	0.500



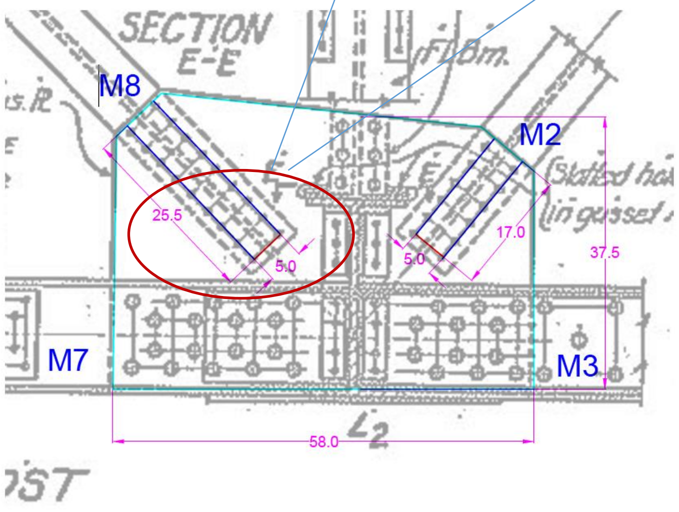
L2 GP: Whitmore dimensions

Name: L2 GP (AS-BUILT)

Description | Panel point | Fasteners | Plate tension | Plate compression | Plate shear | Chord splice | Load transfer

Left plate

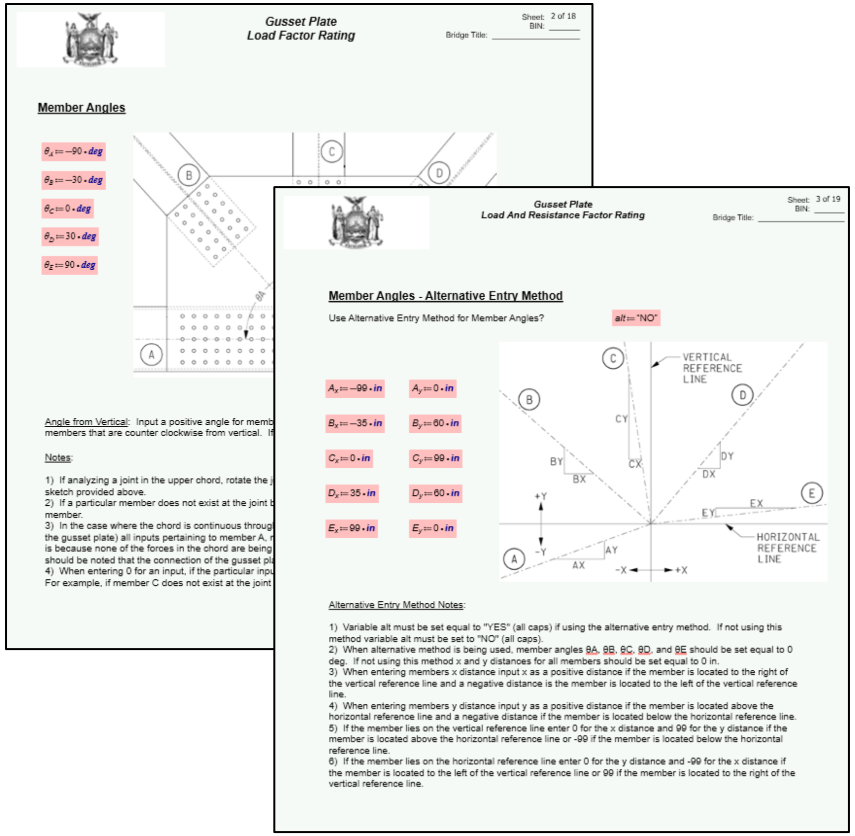
	Yielding and net fracture						Block shear						
	Whitmore width (in)	T (in)	Nfasteners	U	Rp	Beta (LFR)	Ltension (in)	Ttension (in)	NTfasteners	Lshear (in)	Tshear (in)	NVfasteners	NShear
Member 2	23.000		2.000	1.000	1.000	0.150	5.000		2.000	17.000		5.500	2.000
Member 3	1000.000		1.000	1.000	1.000	0.150	1000.000		0.000	1000....		1.000	1.000
Member 7	1000.000		1.000	1.000	1.000	0.150	1000.000		0.000	1000....		1.000	1.000
Member 8	33.000		5.000	1.000	1.000	0.150	5.000		2.000	25.500		8.500	2.000



L2 GP: block shear dimensions

NYSDOT GUSSET PLATE EVALUATION TOOL

- MathCAD based evaluation tool based on AASHTO MBE 3rd Edition
- Developed and maintained by HNTB
- Supports both LFD and LRFR
- More flexible than BrR, can be used for rating more complex gusset plates
- Used for validating results from BrR



ISSUES THAT WERE RESOLVED IN BrR 7.5.1

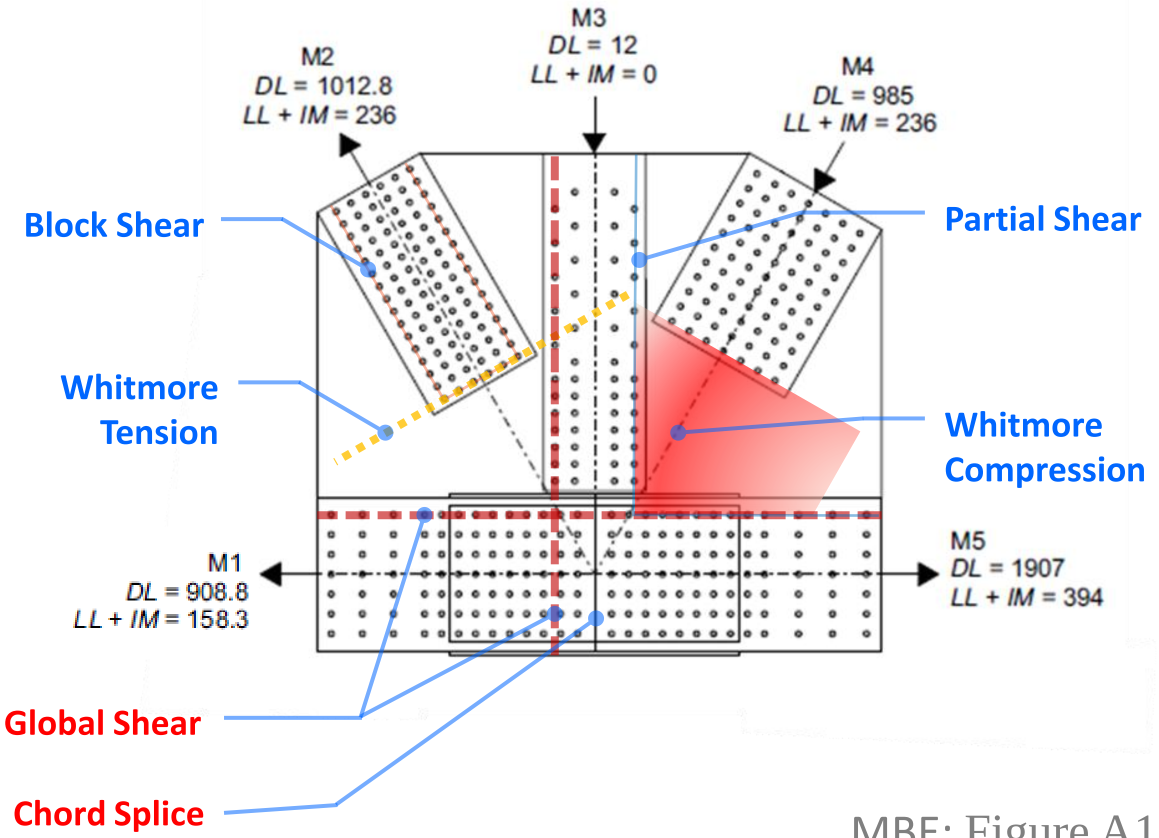
Ticket #	Issues	Status
BSSD-2370	Shear plane orientation issues: The BrR algorithm considers global vertical and horizontal shear planes instead of true planes, except for continuous chord cases.	Resolved in version 7.5.1
BSSD-2704 BSSD-2708	Global shear force resolving issues for non-collinear chord members. Due to this issue, often, some of the truss members' forces are not counted while calculating shear forces.	Resolved in version 7.5.1
BSSD-2738	Partial shear plane check issues: BrR sometimes issues incorrect angles to horizontal and vertical shear plans.	Resolved in version 7.5.1

From BrR 7.5.1 Release Notes:

13. BSSD-2370 - Define custom shear plane orientation for gusset plate analysis
14. BSSD-2424 - LRFD/LRFR longitudinal rebar rating should consider effective Aps if within transfer or development length region
15. BSSD-2708 - Allow the user to select which members are considered above/below and left/right w.r.t. gusset plate shear plane
16. BSSD-2738 - Improvements to gusset plate partial shear input and reporting

GUSSET PLATE FAILURE MECHANISMS

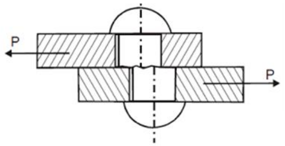
- FASTENER RESISTANCE
- TENSION RESISTANCE
  - BLOCK SHEAR
  - WHITMORE SECTION
- COMPRESSION RESISTANCE
  - WHITMORE SECTION
- PARTIAL SHEAR RESISTANCE
- GLOBAL SHEAR RESISTANCE
  - HORIZONTAL SHEAR
  - VERTICAL SHEAR
- CHORD SPLICE RESISTANCE



MBE: Figure A11.1-2

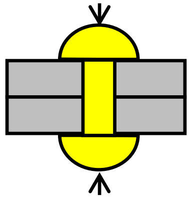
CHECKS FOR SINGLE MEMBER DEMANDS

- **FASTENER RELATED CHECKS**



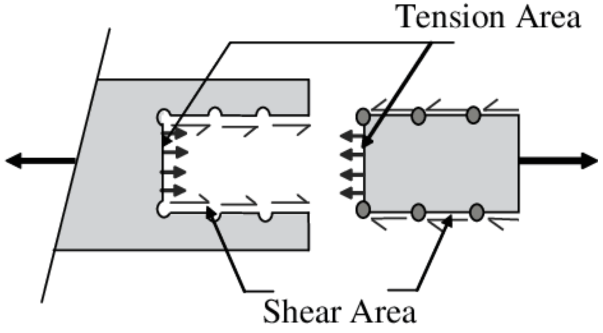
Fastener shear resistance

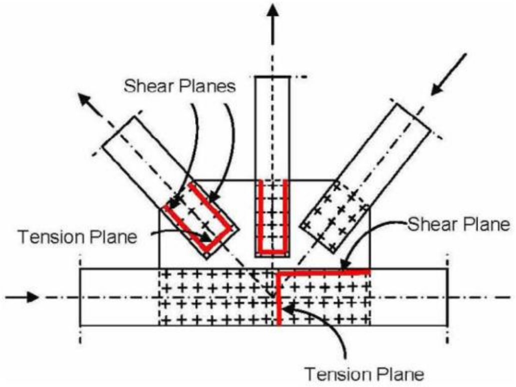
Bearing resistance



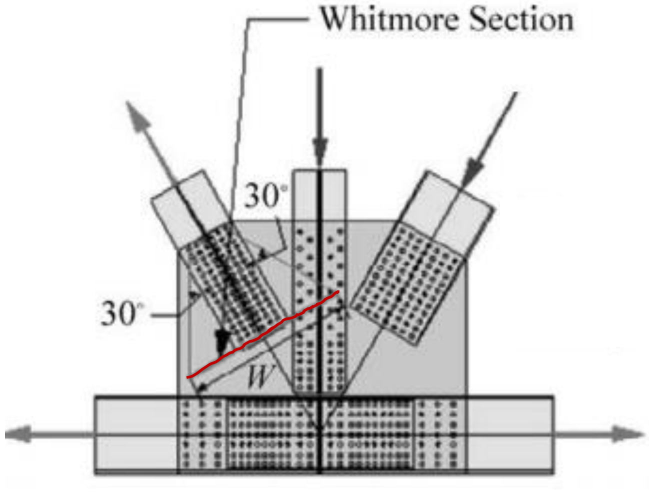
Slip resistance

- **BLOCK SHEAR CHECK**



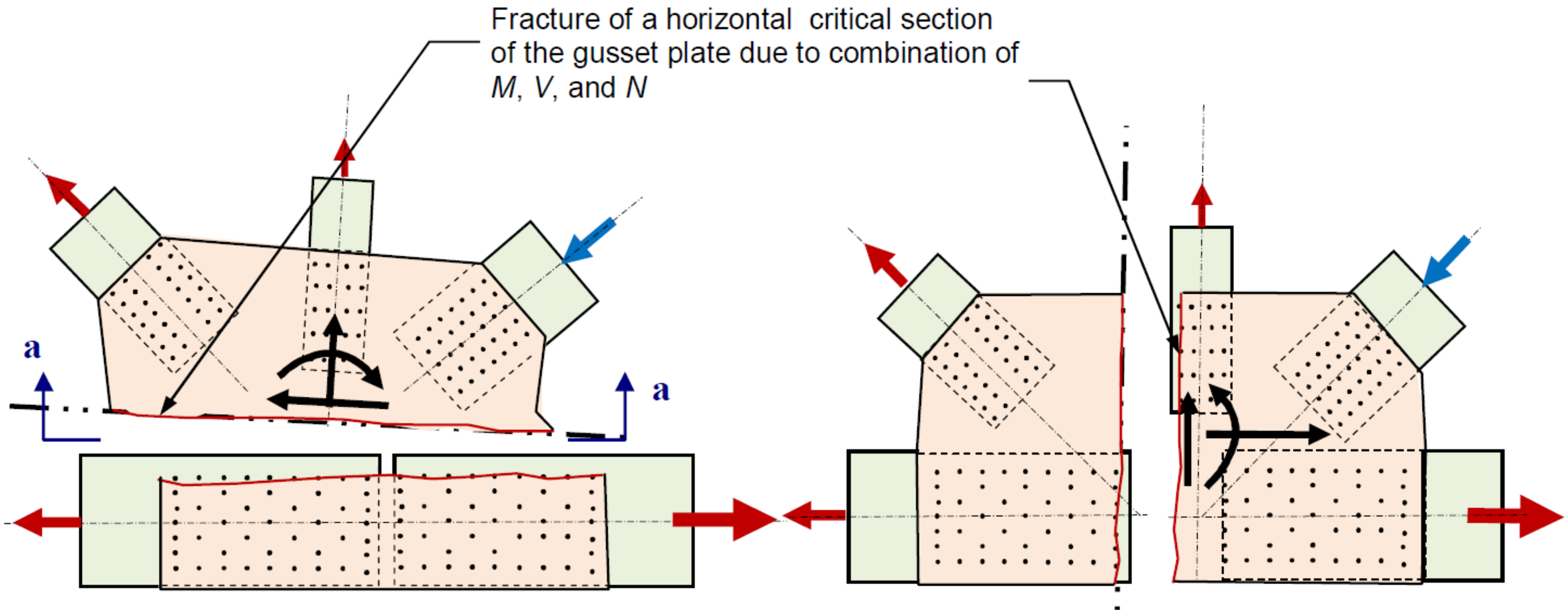


- **WHITMORE SECTION CHECKS (TENSION/COMP)**



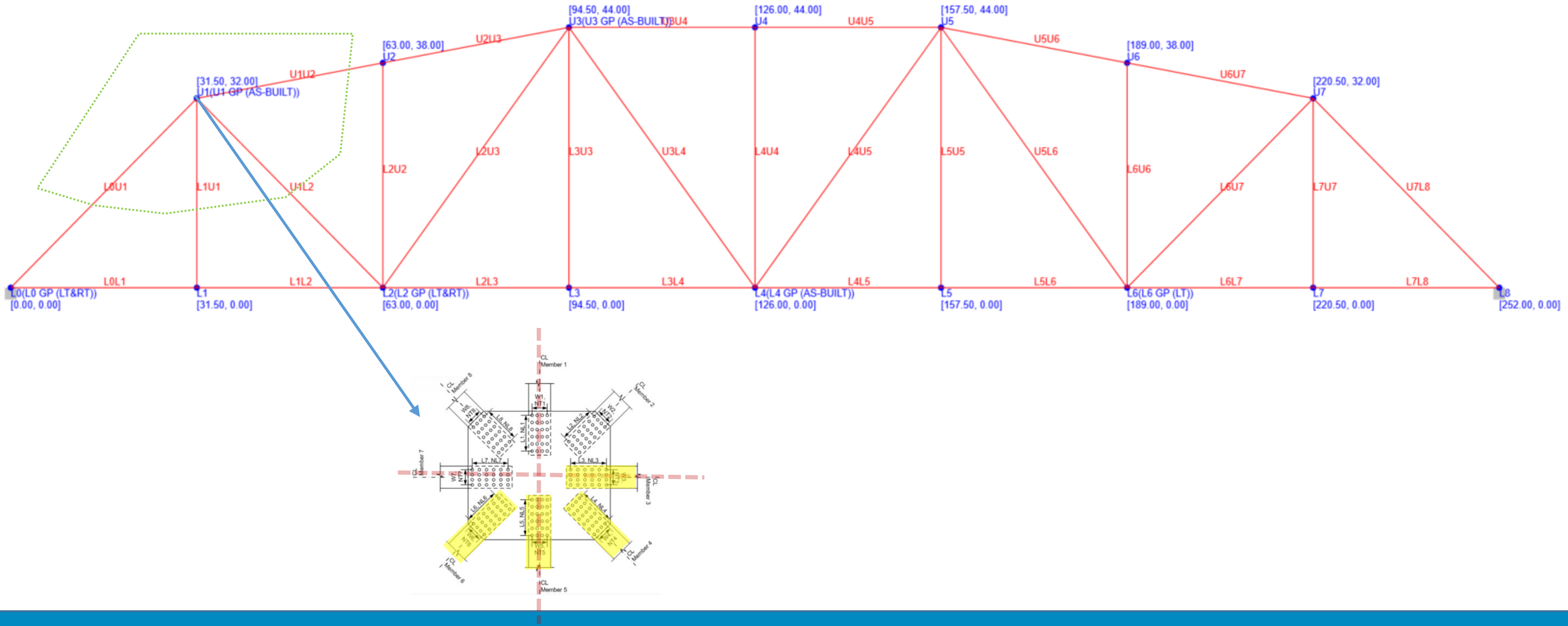
Hu, ISIJ International, Vol. 53 (2013), No. 8, pp. 1443–1452

GLOBAL SHEAR – MEMBER INTERACTION FOR DEMANDS



Astaneh-Asl, Gusset Plates in Steel Bridges- Design and Evaluation, 2010

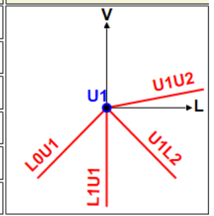
A TYPICAL TRUSS: BrR MEMBER INPUT CONVENTION



GLOBAL SHEAR: ISSUE PRIOR TO v7.5.1

- MEMBER ORIENTATION MATTERS!
- ACTUAL SHEAR PLANE IS NOT DETECTED
- ONLY L0U1 IS CONSIDERED IN DEMAND CALCULATIONS

Panel Point (ft)	Member	Theta (Degrees)	DL Force (kip)	LL Force (kip)	
				Compression	Tension
U1 [31.50, 32.00]	L0U1	225.45	-807.28	-234.31 (L)	
	U1U2	10.78	-836.05	-223.44 (L)	
	L1U1	270.00	134.26		108.46 (T)
	U1L2	314.55	363.44	-35.55 (T)	122.00 (L)
	Net Longitudinal Force:		0.00	80.05	
	Net Vertical Force:		-25.61	70.22	

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VERTICAL SHEAR RATING FACTOR CALCULATIONS

      C - A1 * VDL(%Load)
RF = ----------------------
      A2 * VLL(1+I)(%Load)

C =  1052.700 (kip)

VDL Left   =   287.656 (kip)
VDL Right =   -337.223 (kip)

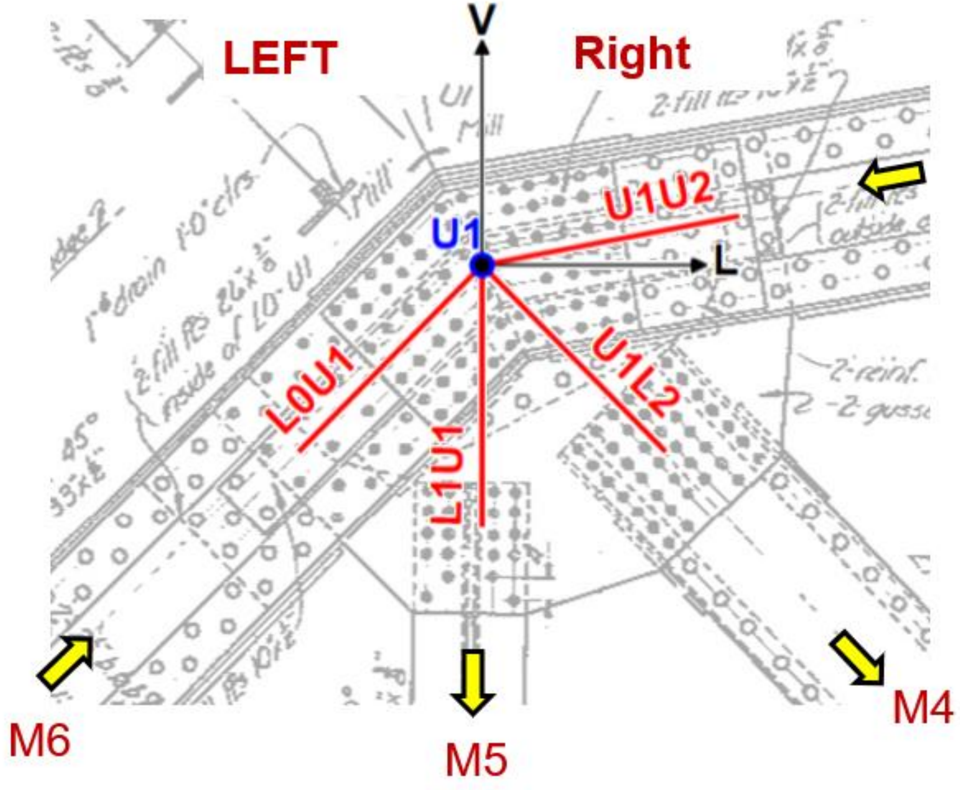
A1 = Dead Load Factor
A2 = Live Load Factor
```

$$Theta := 225.45 \cdot deg$$

$$PDL_{L0U1} := -807.28 \cdot kip$$

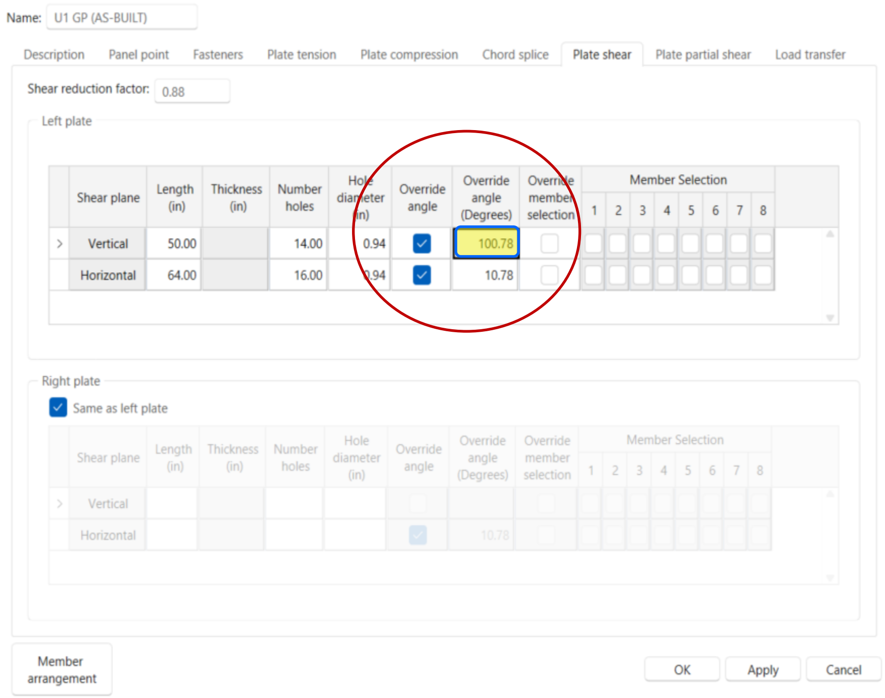
$$Perc\_Transfer := 50\%$$

$$VDL := Perc\_Transfer \cdot PDL_{L0U1} \cdot \sin(Theta) = 287.65\ kip$$



GLOBAL SHEAR – NEW OPTION: OVERRIDE ANGLE

- MBE C6A.6.12.6.6 – FAILURE OF A FULL-WIDTH SHEAR PLANE REQUIRES RELATIVE MOBILIZATION BETWEEN TWO ZONES OF THE PLATE


Name: U1 GP (AS-BUILT)

Description | Panel point | Fasteners | Plate tension | Plate compression | Chord splice | Plate shear | Plate partial shear | Load transfer

Shear reduction factor: 0.88

Left plate

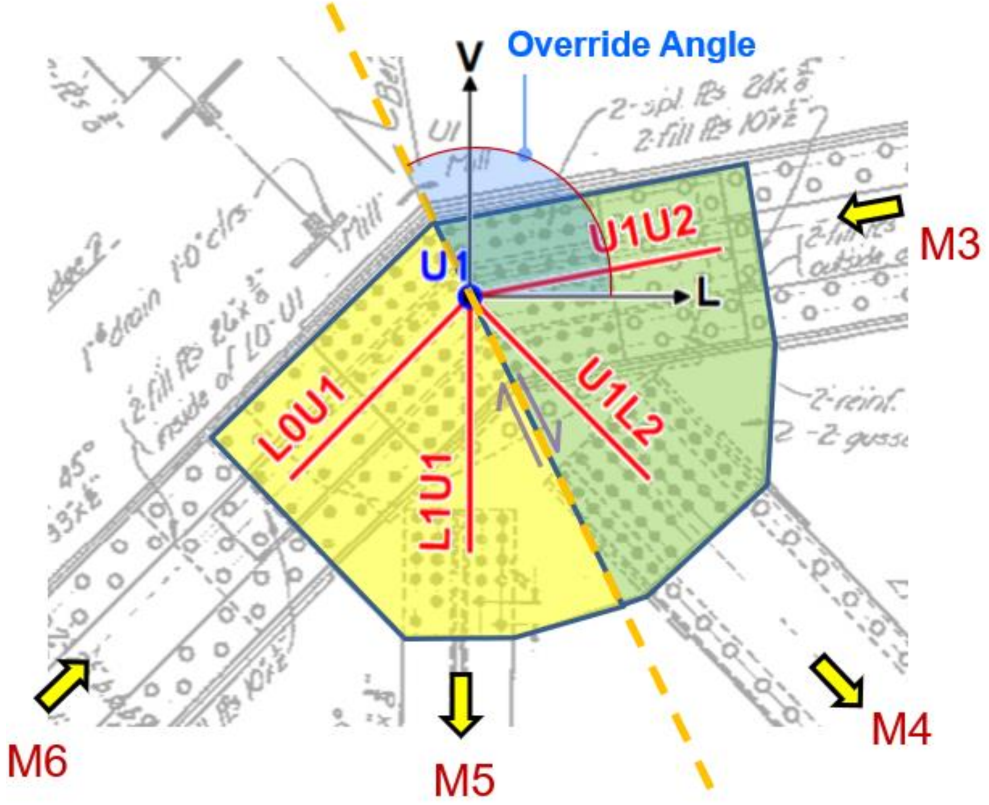
Shear plane	Length (in)	Thickness (in)	Number holes	Hole diameter (in)	Override angle	Override angle (Degrees)	Override member selection	Member Selection 1	2	3	4	5	6	7	8
Vertical	50.00		14.00	0.94	☑	100.78	☐	☐	☐	☐	☐	☐	☐	☐	☐
Horizontal	64.00		16.00	0.94	☑	10.78	☐	☐	☐	☐	☐	☐	☐	☐	☐

Right plate

☑ Same as left plate

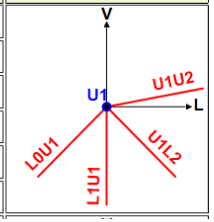
Shear plane	Length (in)	Thickness (in)	Number holes	Hole diameter (in)	Override angle	Override angle (Degrees)	Override member selection	Member Selection 1	2	3	4	5	6	7	8
Vertical															
Horizontal					☑	10.78									

Member arrangement | OK | Apply | Cancel



GLOBAL SHEAR – NEW OPTION: OVERRIDE ANGLE

- MBE C6A.6.12.6.6 – FAILURE OF A FULL-WIDTH SHEAR PLANE REQUIRES RELATIVE MOBILIZATION BETWEEN TWO ZONES OF THE PLATE

Panel Point (ft)	Member	Theta (Degrees)	DL Force (kip)	LL Force (kip) Compression	LL Force (kip) Tension	
U1 [31.50, 32.00]	L0U1	225.45	-807.28	-234.31 (L)		
	U1U2	10.78	-836.05	-223.44 (L)		
	L1U1	270.00	134.26		108.46 (T)	
	U1L2	314.55	363.44	-35.55 (T)	122.00 (L)	
	Net Longitudinal Force:		0.00	80.05		
	Net Vertical Force:		-25.61	70.22		


```
VERTICAL SHEAR RATING FACTOR CALCULATIONS

       C - A1 * VDL(%Load)
RF = ----------------------
       A2 * VLL(1+I)(%Load)

C =  1052.700 (kip)

VDL Left   =    97.727 (kip)
VDL Right  =  -302.154 (kip)
```

$$Vertical\_angle := 90 \cdot deg$$

$$Override\_angle := 100.78 \cdot deg$$

$$Theta\_adj := Vertical\_angle - Override\_angle = -10.78\ deg$$

$$Theta_{L0U1} := 225.45 \cdot deg$$

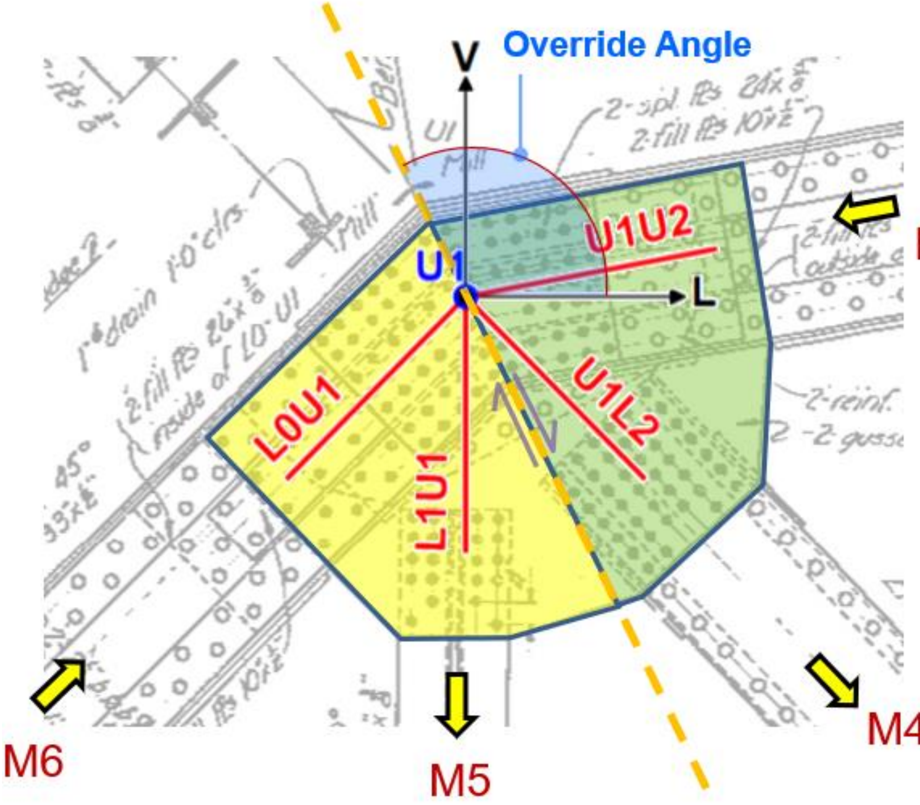
$$Theta_{L1U1} := 270 \cdot deg$$

$$PDL_{L0U1} := -807.28 \cdot kip$$

$$PDL_{L1U1} := 134.26 \cdot kip$$

$$Perc\_Transfer := 50\%$$

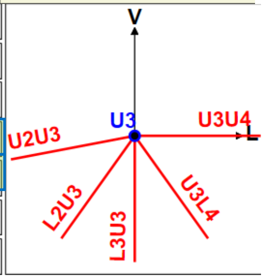
$$VDL := Perc\_Transfer \cdot PDL_{L0U1} \cdot \sin(Theta_{L0U1} + Theta\_adj) + PDL_{L1U1} \cdot \sin(Theta_{L1U1} + Theta\_adj) = 97.72\ kip$$

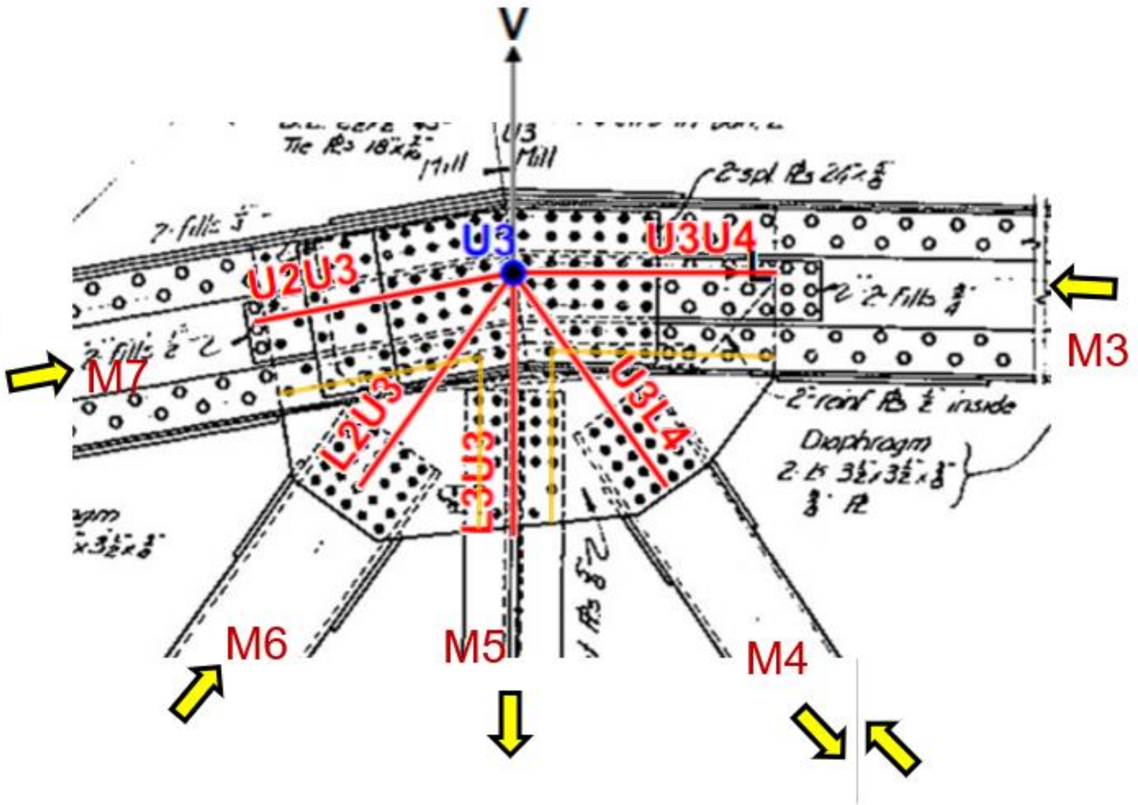


PARTIAL SHEAR PLANE INPUTS

- MEMBER SELECTION IS USER DEFINED
- CONSIDER ALL LOAD COMBINATIONS FOR MEMBER SELECTIONS!

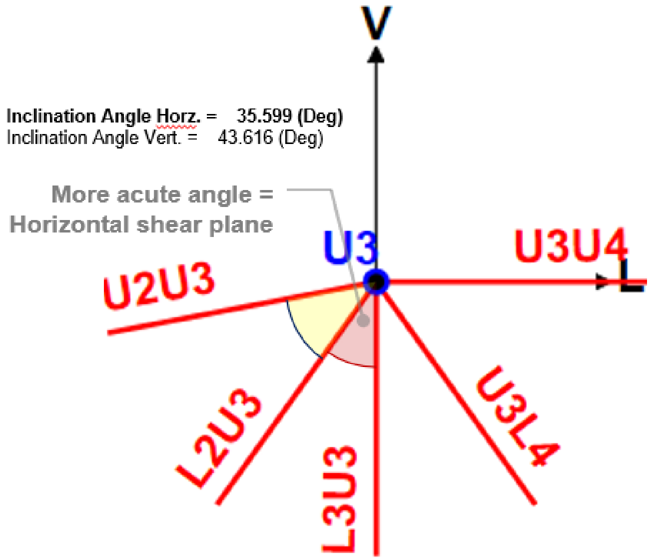
Panel Point (ft)	Member	Theta (Degrees)	DL Force (kip)	LL Force (kip)	
				Compression	Tension
U3 [94.50, 44.00]	U2U3	190.78	-836.05	-223.44 (L)	
	U3U4	0.00	-948.66	-252.75 (L)	
	L3U3	270.00	140.71		108.46 (T)
	L2U3	234.40	-115.96	-78.74 (L)	72.19 (T)
	U3L4	305.60	102.85	-57.43 (T)	83.05 (L)
	Net Longitudinal Force:		0.00	108.71	
	Net Vertical Force:		-26.38	192.87	

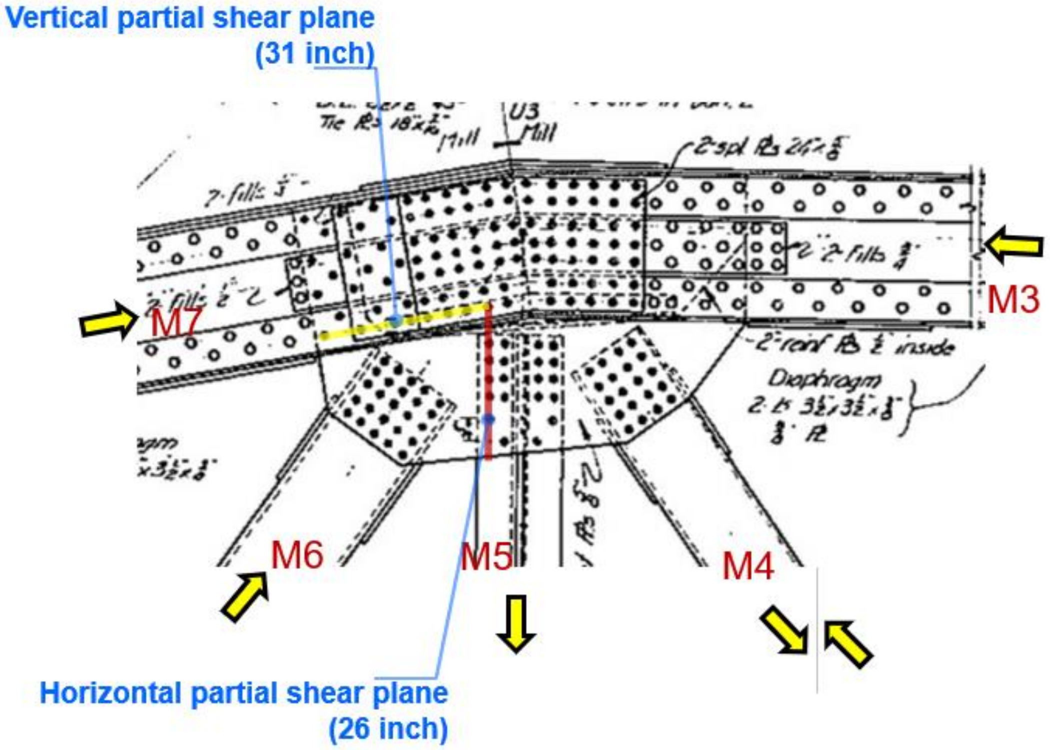




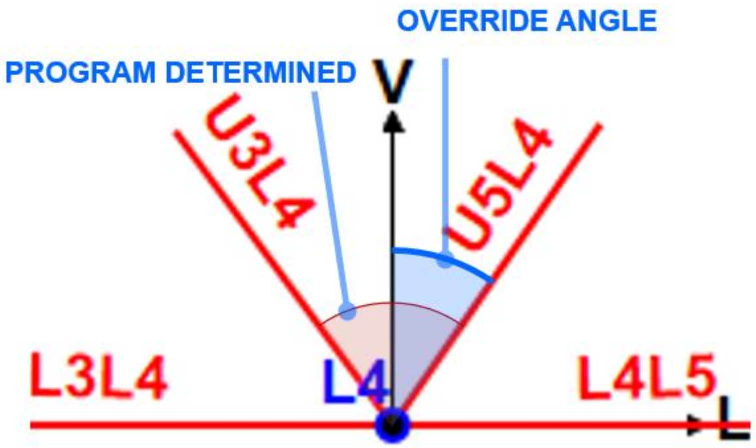
PARTIAL SHEAR PLANE INPUTS

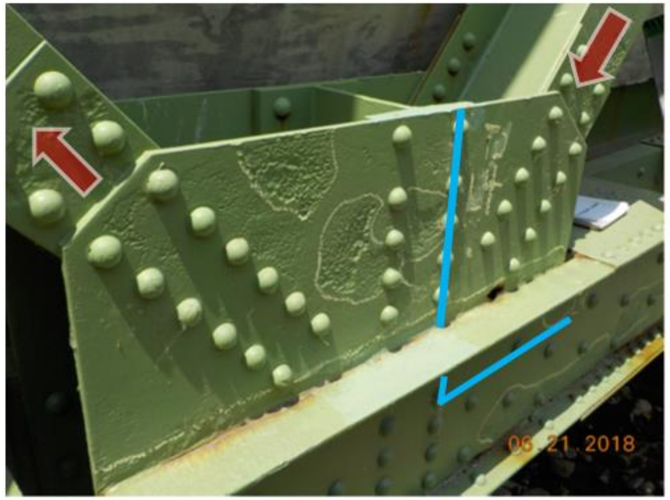
- DEFINITION OF HORIZONTAL& VERTICAL ANGLES IS PROGRAM SPECIFIC: ACUTE ANGLE = HORIZONTAL
- MAKE SURE LENGTH INPUTS MATCH ANGLE INPUTS!





PARTIAL SHEAR – NEW OPTION: OVERRIDE ANGLE





Description | Panel point | Fasteners | Plate tension | Plate compression | Chord splice | Plate shear | Plate partial shear | Load transfer

Left plate partial shear planes

Member	Shear plane direction	Length (in)	Thickness (in)	Advanced options	Override Angle (Degrees)
Member 2	Horiz...	29.000	0.625		
Member 2	Vertical	30.500	0.625		

Right plate partial shear planes

Same as left plate

Member	Shear plane direction	Length (in)	Thickness (in)	Advanced options	Override Angle (Degrees)
M...	Horiz...	29.000	0.531		
M...	Vertical	30.500	0.531		

PARTIAL SHEAR – NEW OPTION: OVERRIDE ANGLE

Description | Panel point | Fasteners | Plate tension | Plate compression | Chord splice | Plate shear | Plate partial shear

Left plate partial shear planes

	Member	Shear plane direction	Length (in)	Thickness (in)	Advanced options	Override Angle (Degrees)
>	Member 2	Horiz...	26.500	0.625	☐	
	Member 2	Vertical	30.500	0.625	☐	
	Member 8	Horiz...	29.000	0.625	☐	
	Member 8	Vertical	30.500	0.625	☐	

Right plate partial shear pl

☐ Same as left plate

	Member	Shear pl directic
>	M...	Horiz...
	M...	Vertical
	M...	Horiz...
	M...	Vertical

```
Gusset Plate - Truss Member U5L4: Panel Point L4     Stage 3

PARTIAL SHEAR PLANE RATING FACTOR CALCULATIONS

        C - A1 * DL(%Load)
RF =    -------------------
        A2 * LL(1+I)(%Load)

where,

   C(Horizontal) =            515.975 (kip)
   C(Vertical) =              593.858 (kip)

   DL (Axial Dead Load) =     -25.251 (kip)

   A1 = Dead Load Factor
   A2 = Live Load Factor

Inclination Angle Horz. =    55.426 (Deg)
Inclination Angle Vert. =    71.043 (Deg)
```

RF	Capacity (Ton)
N/A	-
13.265	265.29
N/A	-
23.951	479.03

Description | Panel point | Fasteners | Plate tension | Plate compression | Chord splice | Plate shear | Plate partial shear | Lc

Left plate partial shear planes

	Member	Shear plane direction	Length (in)	Thickness (in)	Advanced options	Override Angle (Degrees)
>	Member 2	Horiz...	26.500	0.625	☑	55.43
	Member 2	Vertical	30.500	0.625	☑	34.57
	Member 8	Horiz...	29.000	0.625	☐	
	Member 8	Vertical	30.500	0.625	☐	

Right plate partial shear plane

☐ Same as left plate

	Member	Shear plane direction
>	M...	Horiz...
	M...	Vertical
	M...	Horiz...
	M...	Vertical

```
        C - A1 * DL(%Load)
RF =    -------------------
        A2 * LL(1+I)(%Load)

where,

   C(Horizontal) =            515.975 (kip)
   C(Vertical) =              593.858 (kip)

   DL (Axial Dead Load) =     -25.251 (kip)

   A1 = Dead Load Factor
   A2 = Live Load Factor

Inclination Angle Horz. =    55.426 (Deg)
Inclination Angle Vert. =    71.043 (Deg)

Partial Shear Plane Angle Overrides:
   User Defined Angle Horz. =    55.430 (Deg)
   User Defined Angle Vert. =    34.570 (Deg)
```

RF	Capacity (Ton)
N/A	-
5.086	101.72
N/A	-
9.184	183.68

Agenda:

- Overview of AASHTOWare BrR Use in Bridge Safety Assurance Program
  - Load Rating and Posting of Bridges
  - Permitting Overweight Vehicles on State Bridges
- Corroded Beam End Shear Rating with BrR
- Gusset Plate Load Rating in BrR
- Questions and Answers