Parametrix

Application of the Triage Evaluation Procedure for Gusset Plate Load Rating

Joe Merth, PE
Shane Brown, PE

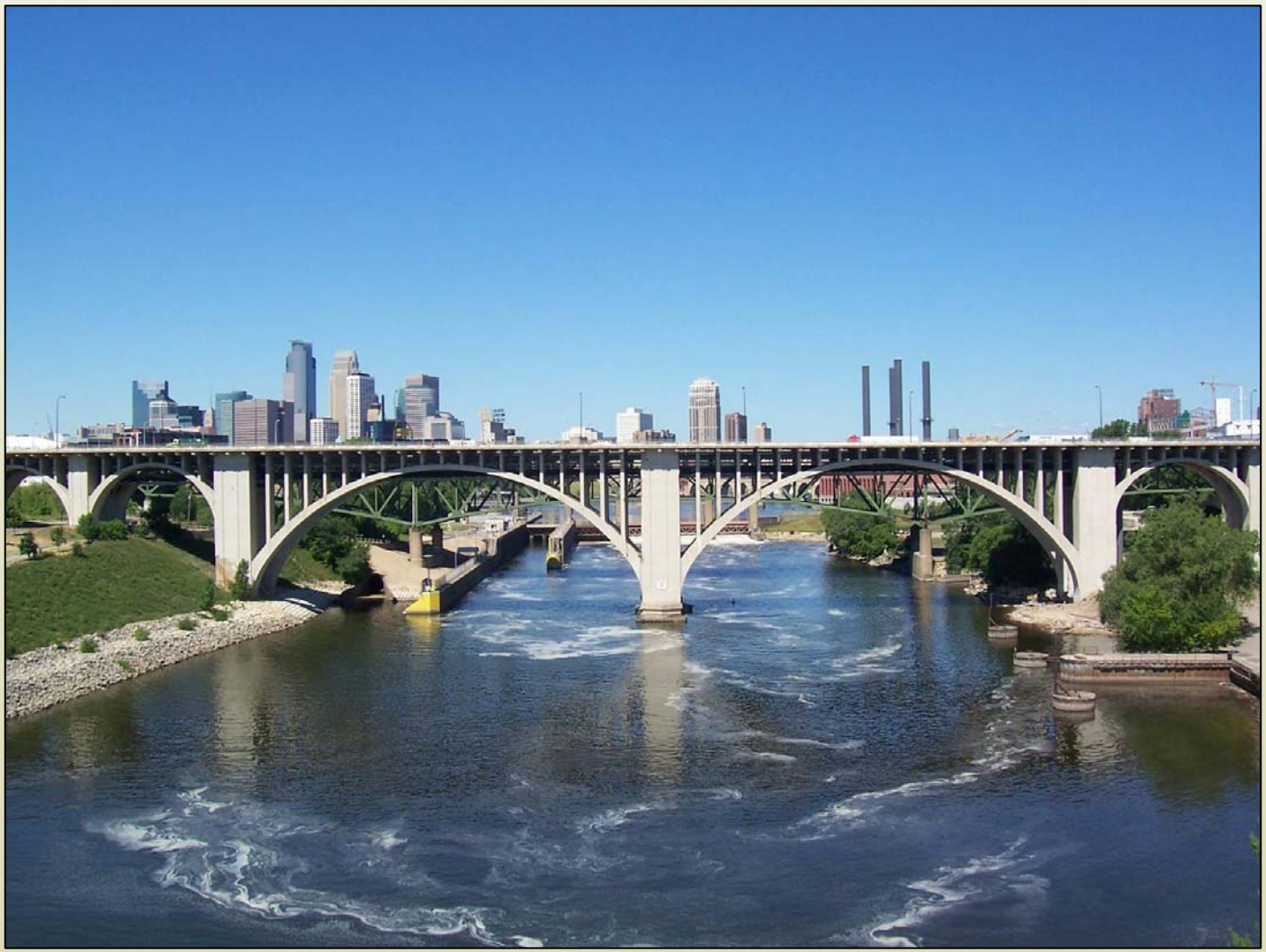
Parametrix

Overview

- Background
- Triage Method
- Triage Spreadsheet
- Procedure
- Results/Challenges

Parametrix

Background



Parametrix

Parametrix

Parametrix

NTSB Findings & Recommendations (NTSB/HAR-08/03)

- Insufficient gusset plate design.
- Lack of guidance for gusset plate inspection.
- No guidance for load rating gusset plates.

Parametrix

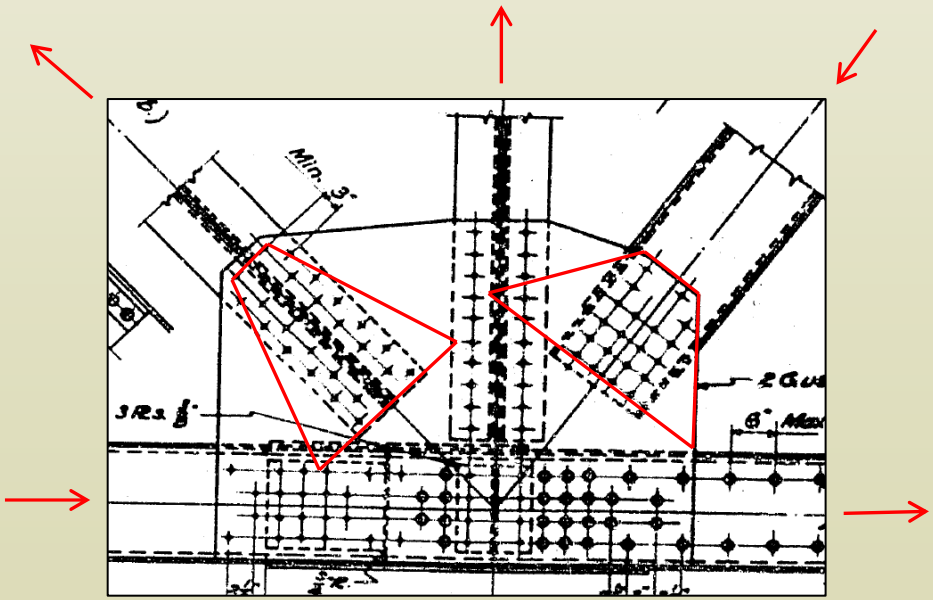
FHWA Technical Advisory - T5140.29

- *Load-carrying Capacity Considerations of Gusset Plates in Non-load-path Redundant Steel Truss Bridges*
  - *New Bridges - Check capacity of gusset PL's as part of initial load rating*
  - *Existing Bridges – Load rate gusset PL's due to change of condition*
- *Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges* (Pub. No. FHWA-IF-09-014)
- Manual for Bridge Evaluation (MBE) changes

Triage Spreadsheet

- Development of the Triage Method
  - Efficient
  - “Triage”- quick method of prioritization
  - Identify gusset PL’s for further study
- Basic Assumptions
  - Whitmore widths
  - Service loads
  - Max member forces only
  - LFR Method used

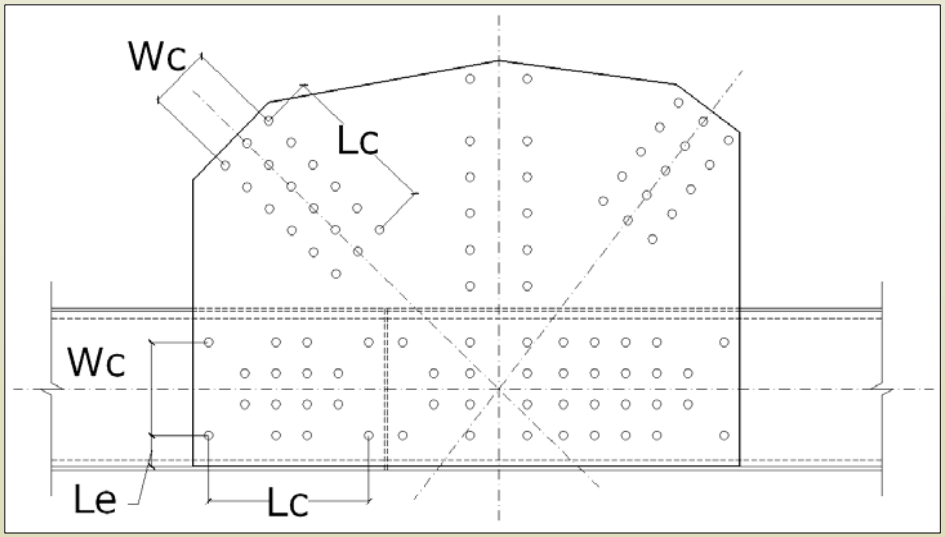
$$RF = \frac{\Phi C - \gamma_{DL} D \pm S}{\gamma_{LL} LL(1+IM)}$$



Parametrix

Required Input

- Calculated DL's and LL's
- Load Factors
- LL+I and DF's
- Condition Factors
- Material Properties
- Rivets/Bolts
- Plate Geometry



Parametrix

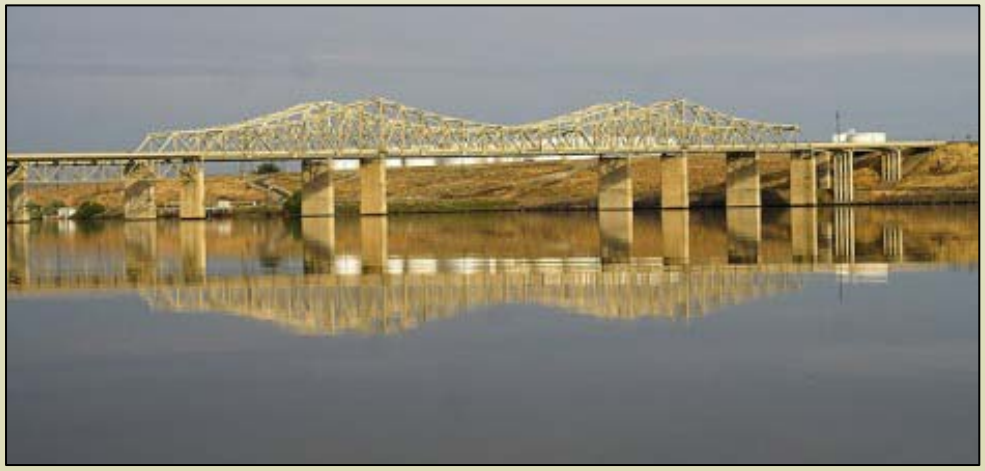
Results

- Rating Factors for
  - HS-20, Legal Loads, Overload Trucks
  - Includes Operating and Inventory
- Rating Factors based on minimum of
  - Buckling
  - Yielding
  - Rivets

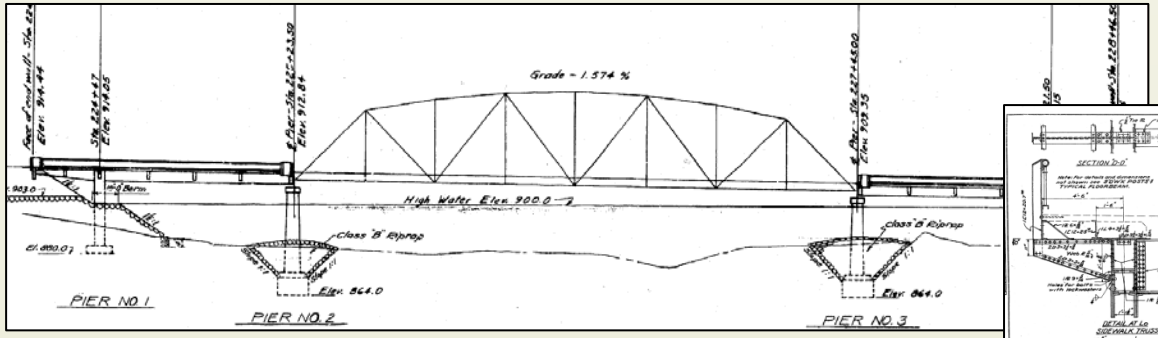
LL Input and RF Summary						Minimum RF	Controlling Connection ID	Controlling Resistance Type	Operating RF for LFR only	
Load Case ID	Live Loads									
	Truck Type	Overload?	γ_{LL}	Impact Factor (I)	Rating Method				γ_{LL}	Minimum RF
1	HS20	N	2.17	0.118	LFR	0.67	L2-U3	Buckling	1.3	1.12
2	A1	N	2.17	0.118	LFR	1.37	L2-U3	Buckling	1.3	2.29
3	A2	N	2.17	0.118	LFR	1.01	L2-U3	Buckling	1.3	1.68
4	A3	N	2.17	0.118	LFR	0.93	L2-U3	Buckling	1.3	1.56
5	NRL	N	2.17	0.118	LFR	0.88	L2-U3	Buckling	1.3	1.48
6	Legal Lane	N	2.17	0.118	LFR	0.87	L2-U3	Buckling	1.3	1.45
7	OL1	Y	1.3	0.1	LFR	1.46	L2-U3	Buckling	1.3	1.46
8	OL2	Y	1.3	0.1	LFR	0.75	L2-U3	Buckling	1.3	0.75

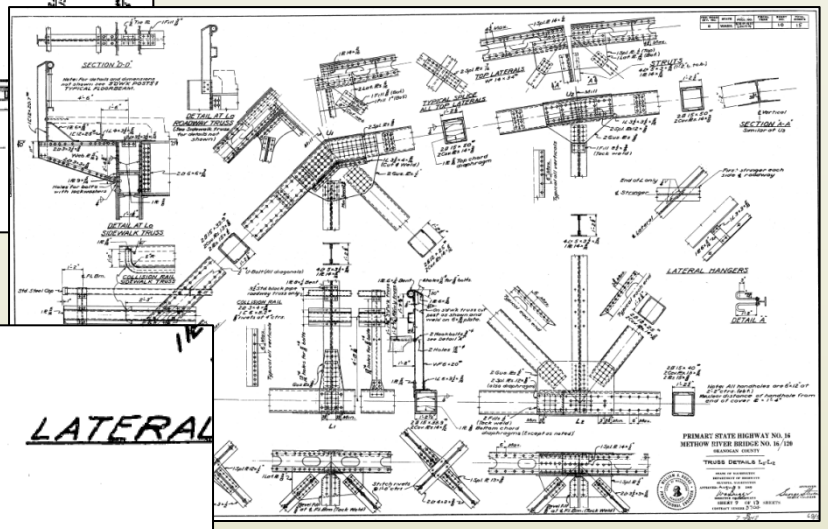
WSDOT Triage Implementation

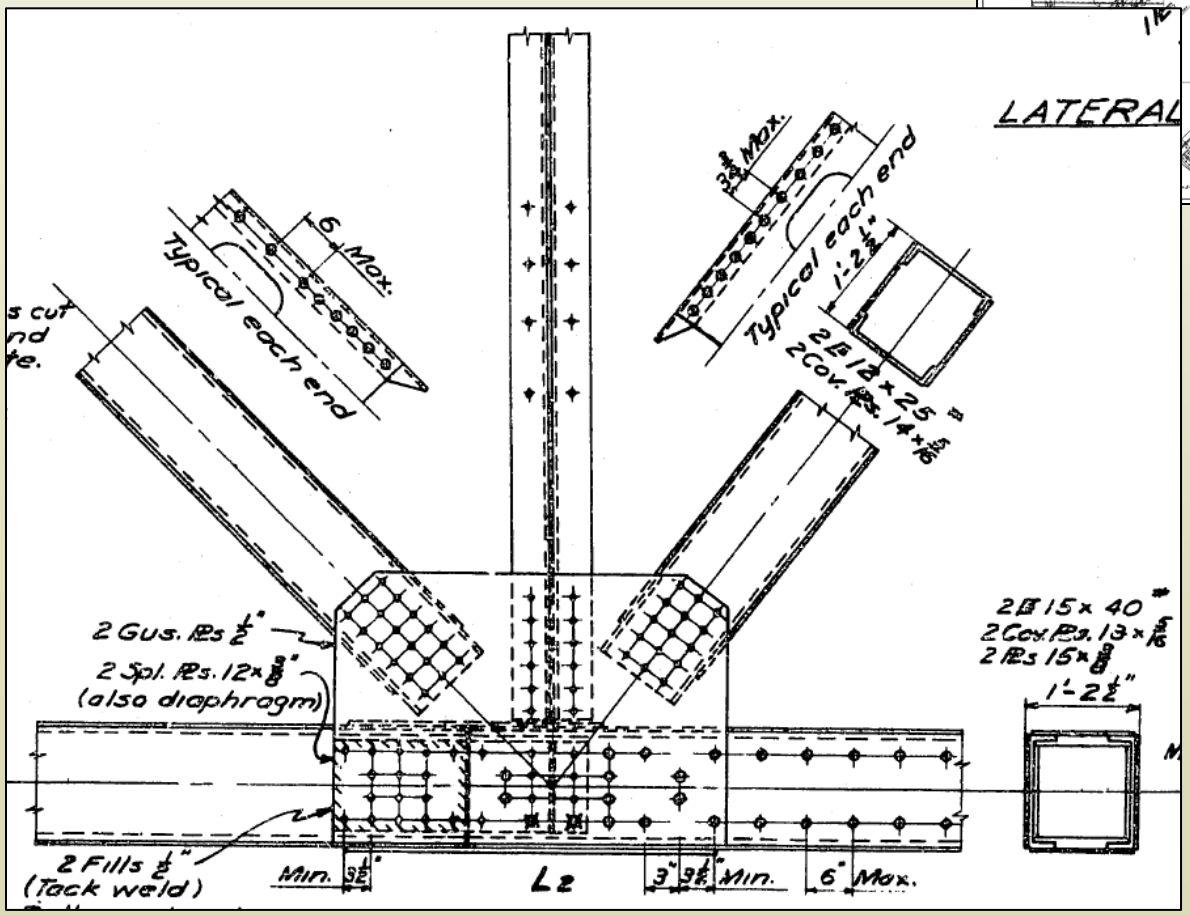
- Rated approximately 50 trusses
- WSDOT Inventory - 120 Truss Bridges
- Priority to bridges with lowest RF's
- Packaged similar trusses



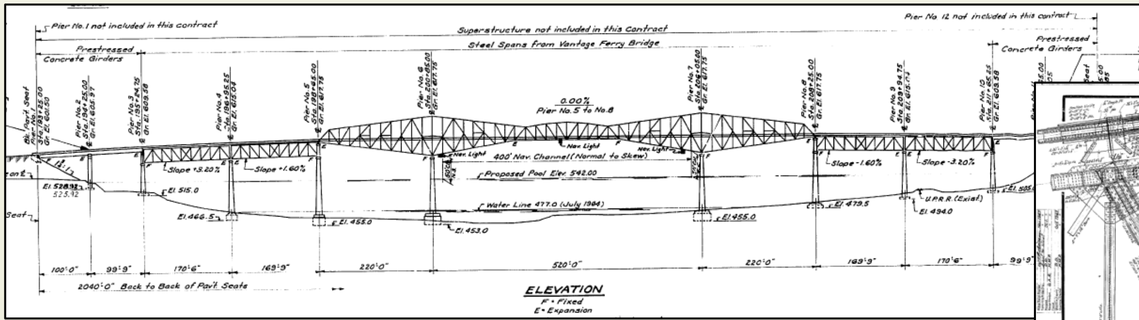
Parametrix

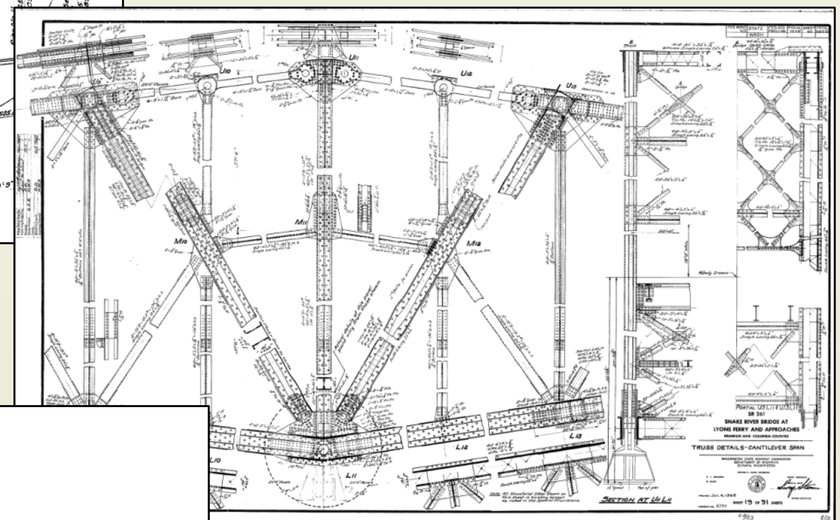

Grade = 1.574 %
High Water Elev. 900.0
Class 'B' Riprap
Elev. 864.0
PIER NO. 1
PIER NO. 2
PIER NO. 3

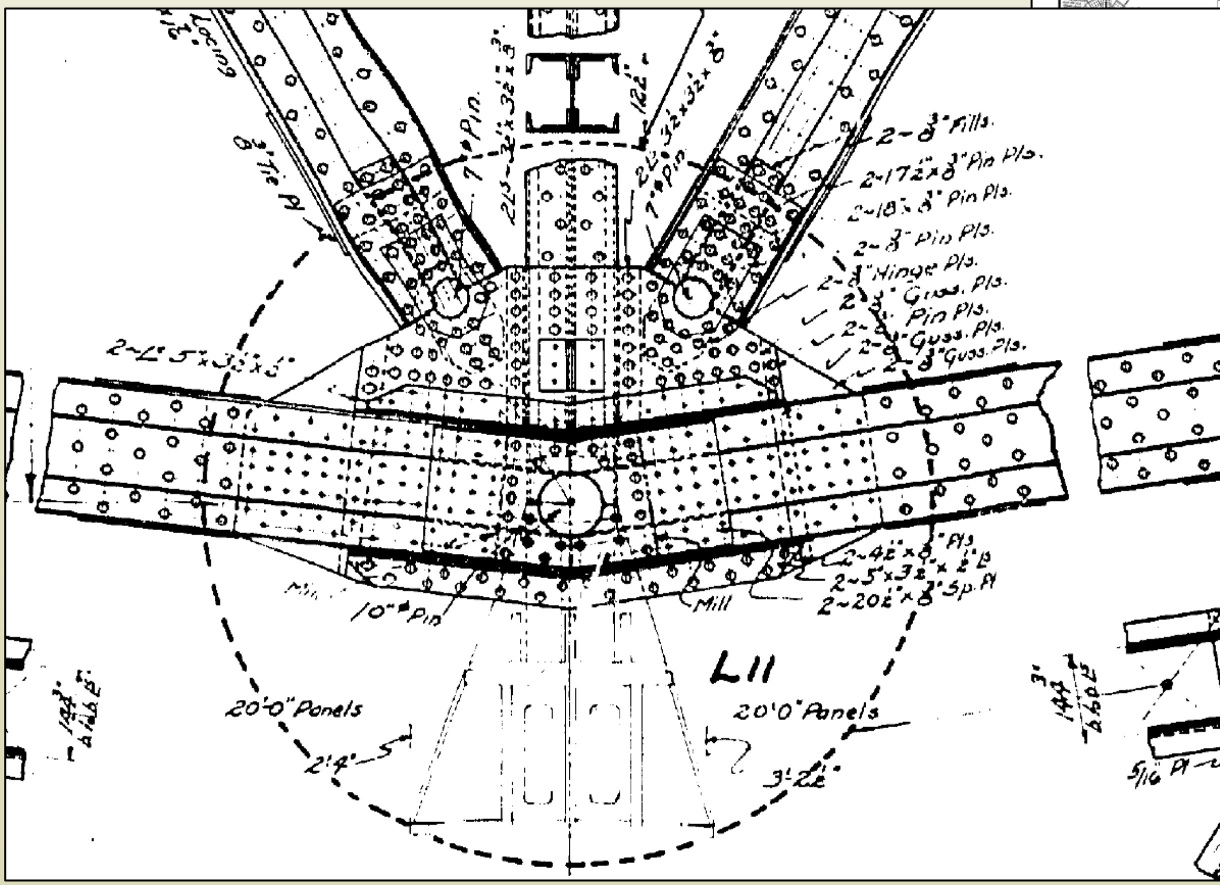

LATERAL DANGERS
PRIMARY STATE HIGHWAY NO. 16
METHOW RIVER BRIDGE NO. 16/129
TRUSS DETAILS


LATERAL
6" Max.
Typical each end
3" Max.
Typical each end
1'-2½"
2 Gus. Pls ½"
2 Spl. Pls. 12×⅜"
(also diaphragm)
2 Fills ½"
(Tack weld)
Min. 9½"
L2
3" 9½" Min.
6" Max.
2 Cov. Pls. 13×⅝
2 Pls 15×⅜
1'-2½"

Parametrix


Pier No. 1 not included in this contract
Superstructure not included in this Contract
Steel Spans From Vantage Ferry Bridge
Pier No. 12 not included in this contract
Prestressed Concrete Girders
0.00%
Pier No. 5 to No. 8
400' Nav. Channel (Normal to Skew)
Proposed Pool Elev. 542.00
Water Line 477.0 (July 1964)
2040'-0" Back to Back of Pav't. Seats
ELEVATION
F = Fixed
E = Expansion

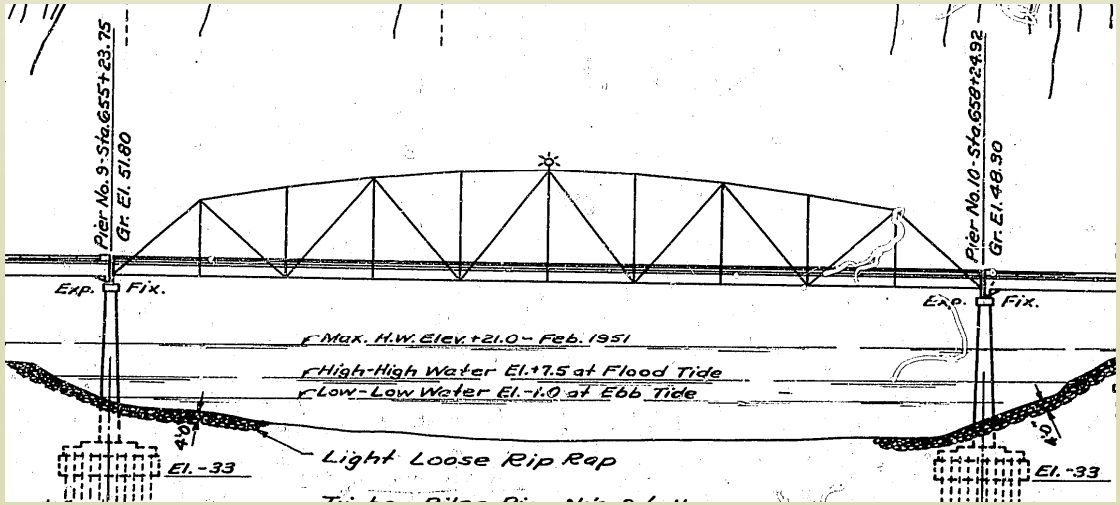

TRUSS DETAILS-CANTILEVER SPAN
SECTION AT U6L6


7" Pin
2-3/8" Fills
2-3/8" Pin Pls.
2-3/8" Hinge Pls.
10" Pin
Mill
L11
20'-0" Panels
20'-0" Panels

Parametrix

Procedures for a Typical Truss

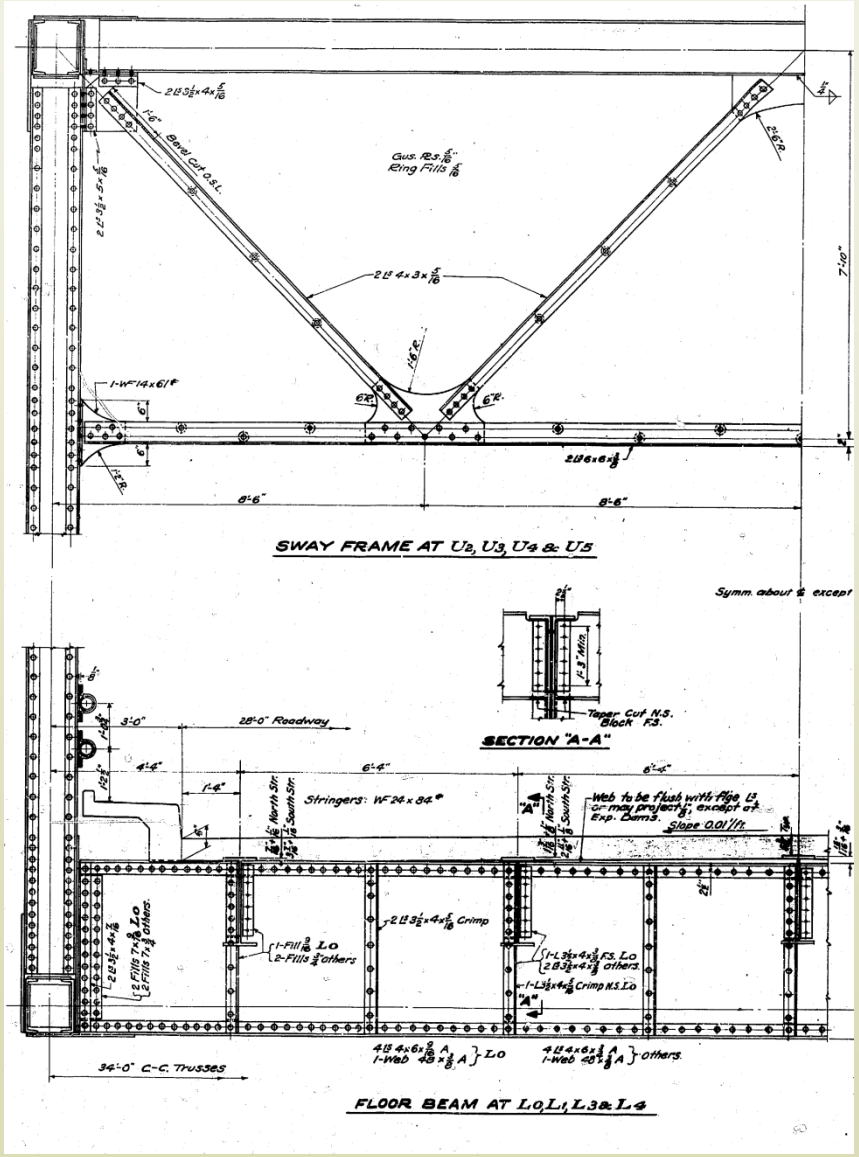
1. Determine Loads
2. Modeling the Structure in SAP2000
3. Triage Spreadsheet Input
4. Reporting Results



Parametrix

1. Determine Loads

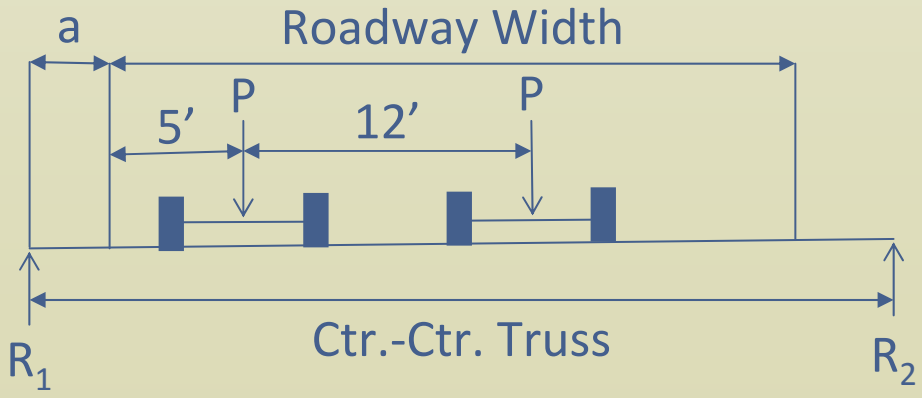
- Dead Loads
  - Tributary Dead Loads
    - Deck
    - Barriers
    - Sidewalks
    - Utilities
    - Floor Beams
    - Stringers
    - Lateral Bracing
    - Sway Frames
  - Member Self Weight
    - Calculated by SAP



Parametrix

Determine Loads (Continued)

- Live Loads for LFR Analysis
  - Loads
    - HS20 Design Truck
    - AASHTO Legal Trucks
    - WSDOT Overload Trucks
  - Distribution of Live Loads (Per Lever Rule)
    - HS20 and Legal Loads

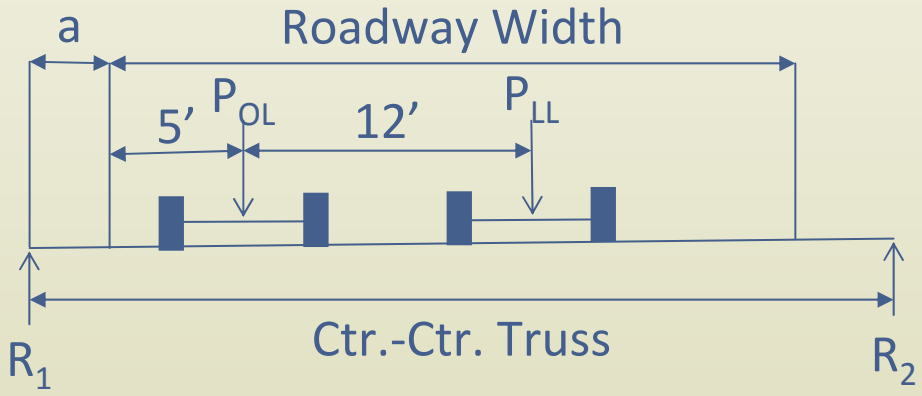


DF = R_1 / (2*P)

Parametrix

Determine Loads (Continued)

- Overloads with Legal Loads



a = Distance From CL Truss to Face of Curb or Rail

$R_{1\_OL} = P_{OL} * (\text{Ctr-Ctr Truss} - a - 5') / \text{Ctr-Ctr Truss}$

$R_{1\_LL} = P_{LL} * (\text{Ctr-Ctr Truss} - a - 17') / \text{Ctr-Ctr Truss}$

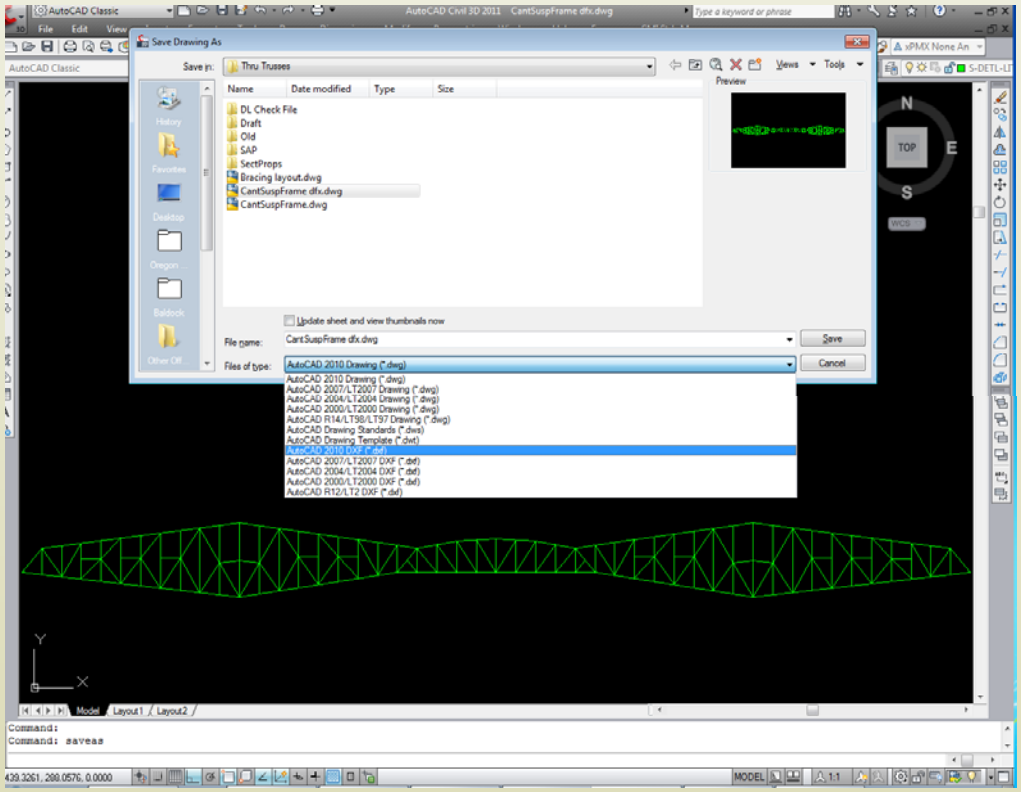
$DF_{OL} = R_{1\_OL} / P_{OL}$ **$DF_{LL} = R_{1\_LL}/P_{LL}$**

2. Modeling the Structure in SAP2000

- General Assumptions:
  - Truss Members are pin-connected at all gusset plates
  - Bridge deck and stringers act as simple span beams from floor beam to floor beam (panel pt to panel pt)
  - Only dead and vehicle live loads are analyzed
  - Load Factors, Impact Factors, and Live Load Distribution Factors **are not** incorporated into the SAP model

Modeling the Structure (Continued)

- Define Geometry
  - Utilizing AutoCAD to create a DXF file of the truss geometry to import into SAP is convenient.
  - Draw elements on a defined layer other than the default “O” layer



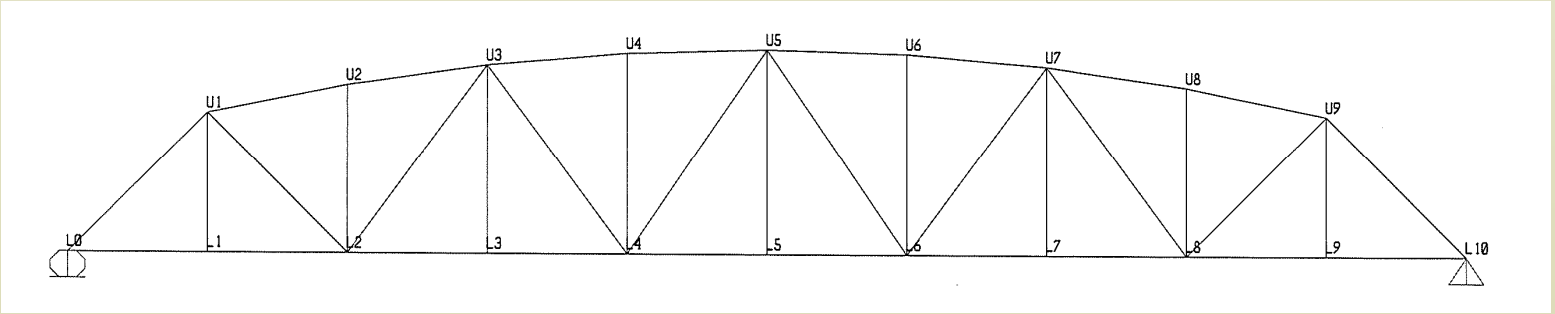
Parametrix

Modeling the Structure (Continued)

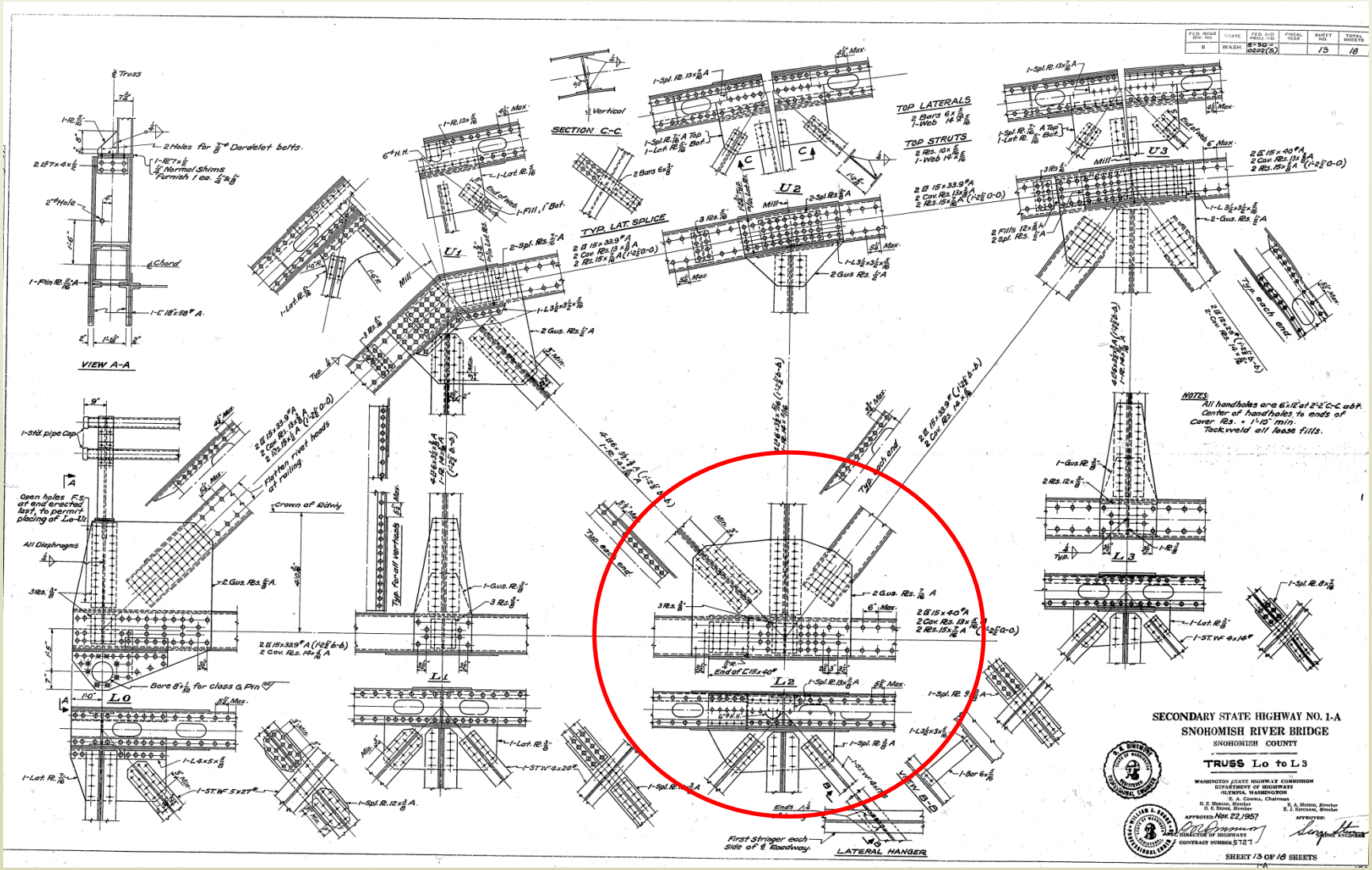
- Frame Sections
  - Only member cross sectional areas are required
- Load Patterns & Assignments
  - Dead Point Loads (tributary loads)
  - Self Weight Loads (apply self weight multiplier)
  - Live Loads
    - Flow of forces
      - Wheel loads carried longitudinally by the deck and stringers to the floor beams and then distributed transversely to each truss as a dynamic point load at the nodes

Modeling the Structure (Continued)

- Use a weight less second member for the vehicle lane
  - Area of member = zero
- Run Analysis and Export Output
  - Export output to an Excel spreadsheet to use the auto filter, copy, and paste features to expedite inputting member loads in the Triage Spreadsheet



Triage Spreadsheet Input



Parametrix

Triage Spreadsheet Input (Continued)

Gusset Plate Inputs & Summary

Sheet Information

Rated By	Company	Date	Bridge ID	Gusset ID	Number of Connections	Include Rivets?	Condition Factor, ϕc	Redundancy Factor, ϕs	Comments
SB	Parametrix	5/11/2011	9_118	L2	5	Y	1	1	
								ϕs equals 1 for LFR	

LL Distribution Factors

AASHTO & Legal Trucks	OL Trucks	Legal Truck w/OL
1.225	0.789	0.436

Forces entered into spreadsheet shall be based on a single lane distribution.

Clear User Inputs

LL Distribution factor for Design & Legal truck shall be based on the number of lanes multiplied by the appropriate reduction factor.

LL Distribution factor for one OL placed in lane closest to truss multiplied by the appropriate reduction factor.

LL Distribution factor for Legal Truck w/OL assumes legal loads are placed in lanes adjacent to OL truck multiplied by the appropriate reduction factor.

LL Input and RF Summary

Load Case ID	Live Loads					Minimum RF	Controlling Connection ID	Controlling Resistance Type	Operating RF for LFR only	
	Truck Type	Overload?	γLL	Impact Factor (I)	Rating Method				γLL	Minimum RF
1	HS20	N	2.17	0.118	LFR	0.49	L2-U3	Buckling	1.3	0.82
2	A1	N	2.17	0.118	LFR	1.01	L2-U3	Buckling	1.3	1.69
3	A2	N	2.17	0.118	LFR	0.74	L2-U3	Buckling	1.3	1.24
4	A3	N	2.17	0.118	LFR	0.69	L2-U3	Buckling	1.3	1.15
5	NRL	N	2.17	0.118	LFR	0.65	L2-U3	Buckling	1.3	1.09
6	Legal Lane	N	2.17	0.118	LFR	0.64	L2-U3	Buckling	1.3	1.07
7	OL1	Y	1.3	0.1	LFR	0.96	L2-U3	Buckling	1.3	0.96
8	OL2	Y	1.3	0.1	LFR	0.49	L2-U3	Buckling	1.3	0.49

Plate Material & Dimension Inputs

Gusset Plate Properties		Wind Gusset Plate Properties		Splice Plate Properties		Rivet Properties	
Fy_gp (ksi)	50	Fy_wp (ksi)	50	Fy_sp (ksi)	50	Fu_r (ksi)	24
Thickness, tgp (in)	0.4375						
Num Plates, np	2						

Table 6A.6.12.5.1-1—Factored Shear Strength of Rivets: φF_{vu}

Rivet Type or Year of Construction	F_{us} ksi	$\varphi_s F_u R_1$	if L ≤ 50", $\varphi_s F_u R_1 R_2$	if L > 50", $\varphi_s F_u R_1 R_2$
Unknown rivet type and origin	50 ksi	27 ksi	Varies	20 ksi
Carbon Steel, ASTM A141, or ASTM A 502 Grade I	60 ksi	32 ksi	Varies	24 ksi
ASTM A 502 Grade II	80 ksi	43 ksi	Varies	32 ksi

Parametrix

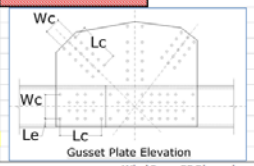
Triage Spreadsheet Input (Continued)

Triage Procedure Connection Inputs

Rated By	SB
Company	Parametrix
Date	5/11/2011
Bridge ID	9_118

Connection Information

Connection ID	Chord or Web?	Splice PL's?	Wind Bracing GP?	Comp. or Tension?	Milled to Bear, Y/N?
L1-L2	Chord	Y	Y	Tension	



Gusset Plate Elevation

Gusset Plate Connection

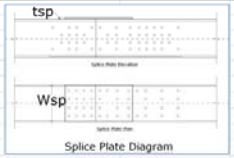
Wc (in)	9	2*Lc tan 30 + Wc	N/A
Lc (in)	18.5	Is Plate Width < 2*Lc tan 30 + Wc?	
Le (in)	3		
Plate Width (in)		Plate Width valid only for web members and when < 2*Lc tan 30 +Wc	

Individual Splice Plate Dimensions

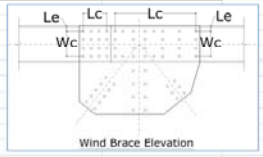
Splice ID	Wsp (in)	tsp (in)
(2) C15x40 Web	12.000	1.040
Top Plate	13.000	0.375

Wind Brace GP Dimensions

Brace ID	Wc (in)	Lc (in)	Le (in)	twp (in)
Bottom Plate	10	12	2	0.375



Splice Plate Diagram



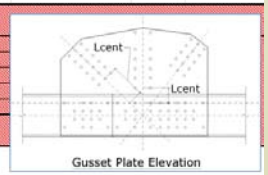
Wind Brace Elevation

Summary of Yielding Resistance Calculations

Agp_ch (in^2)	19.85			
Awp (in^2)	7.10	»	Rn (k)	1278.8
ΣAspl (in^2)	17.36			

Buckling Resistance Inputs

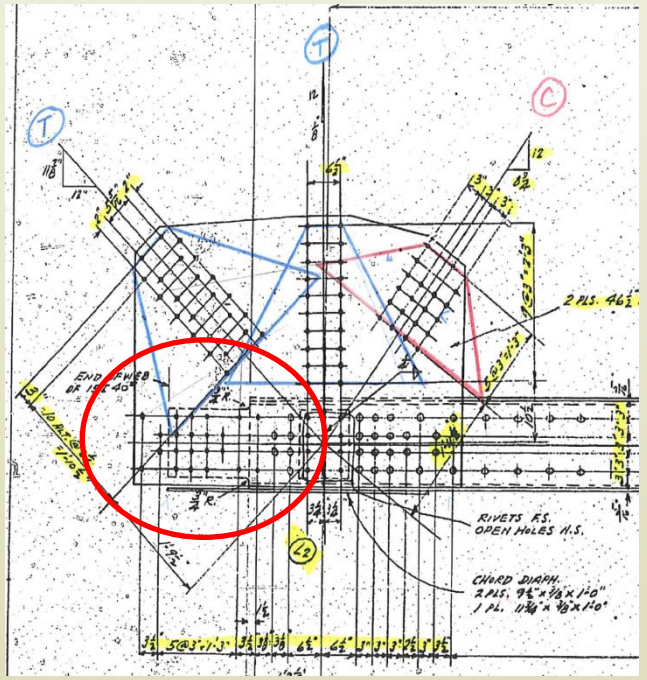
Buckling Input		Summary of Buckling Resistance Calculations					
Centroidal Length, L_cent (in)	L_Whit45 (in)	Ig (in^4)	Ag (in^2)	ϕc			
	30.50	0.426	26.69		»	Rn (k)	
Whitmore Length Manual Input (in)	rs (in)	L_cent (in)	λ	κ		N/A	
	0.126	0.000	0.000				
Does the L_Whit45 exceed the actual width of the plate?							



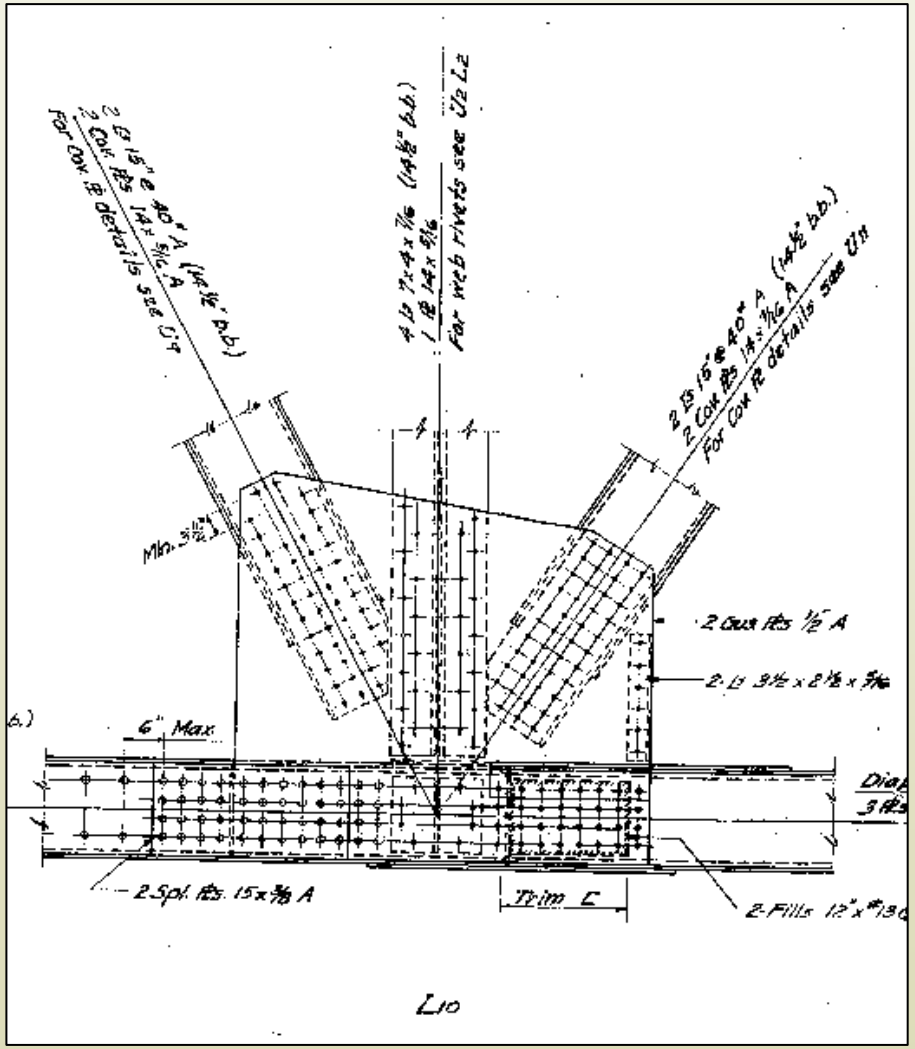
Gusset Plate Elevation

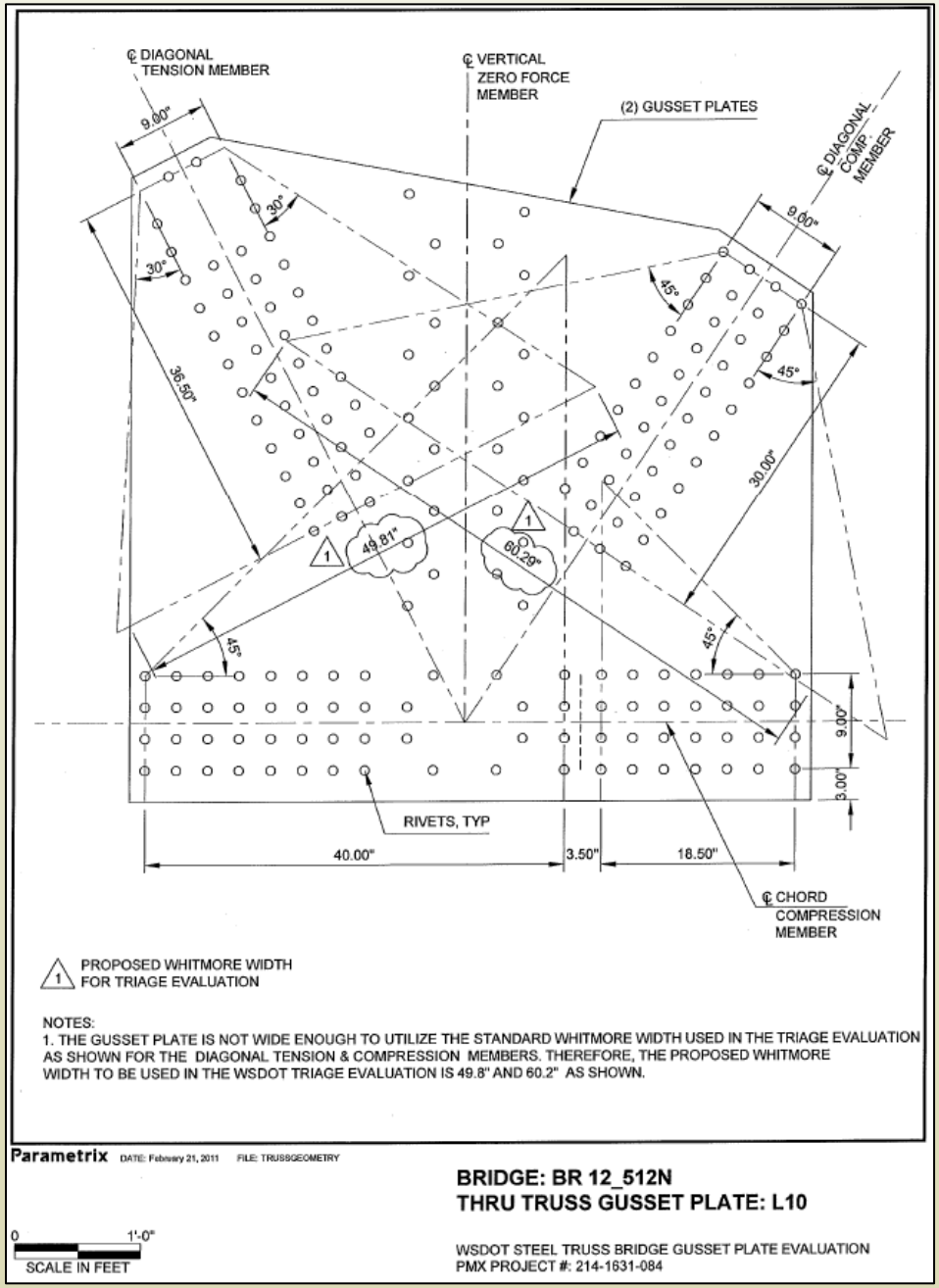
Rivet Input

Rivet Diameter, D_r (in)	# of Single Shear Rivets, nss	# of Double Shear Rivets, nds		Rivet Resistance Rn (k)
0.875	38	32	»	1472.0



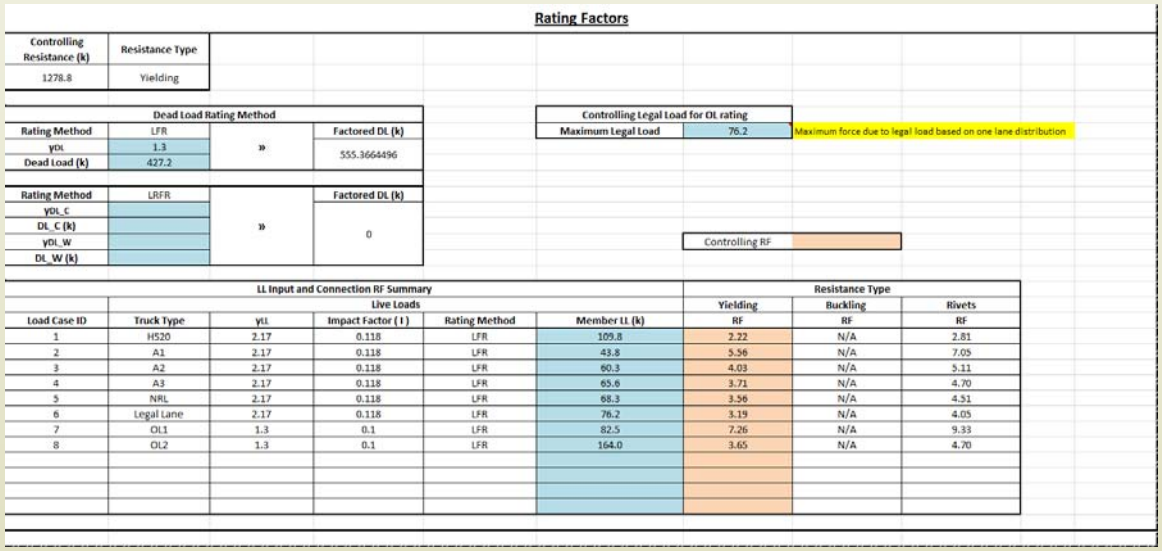
Parametrix


6" Max.
2-Spl. Pls. 15x⅜ A
Trim C
2-Fills 12"x
L10


℄ DIAGONAL TENSION MEMBER
℄ VERTICAL ZERO FORCE MEMBER
(2) GUSSET PLATES
℄ DIAGONAL COMP. MEMBER
9.00"
30°
30°
36.50"
45°
45°
45°
45°
30.00"
49.81"
60.29"
1
1
9.00"
3.00"
RIVETS, TYP
40.00"
3.50"
18.50"
℄ CHORD COMPRESSION MEMBER
1 PROPOSED WHITMORE WIDTH FOR TRIAGE EVALUATION
NOTES:
1. THE GUSSET PLATE IS NOT WIDE ENOUGH TO UTILIZE THE STANDARD WHITMORE WIDTH USED IN THE TRIAGE EVALUATION AS SHOWN FOR THE DIAGONAL TENSION & COMPRESSION MEMBERS. THEREFORE, THE PROPOSED WHITMORE WIDTH TO BE USED IN THE WSDOT TRIAGE EVALUATION IS 49.8" AND 60.2" AS SHOWN.
Parametrix DATE: February 21, 2011 FILE: TRUSSGEOMETRY
0 1'-0"
SCALE IN FEET
BRIDGE: BR 12_512N
THRU TRUSS GUSSET PLATE: L10
WSDOT STEEL TRUSS BRIDGE GUSSET PLATE EVALUATION
PMX PROJECT #: 214-1631-084

Parametrix

Triage Spreadsheet Input (Continued)



Rating Factors

Controlling Resistance (k)	Resistance Type
1278.8	Yielding

Dead Load Rating Method

Rating Method	LFR	»	Factored DL (k)
γDL	1.3		555.3664496
Dead Load (k)	427.2		

Rating Method	LRFR	»	Factored DL (k)
γDL_C			0
DL_C (k)			
γDL_W			
DL_W (k)			

Controlling Legal Load for OL rating		
Maximum Legal Load	76.2	Maximum force due to legal load based on one lane distribution

Controlling RF

LL Input and Connection RF Summary

	Live Loads					Resistance Type		
						Yielding	Buckling	Rivets
Load Case ID	Truck Type	γLL	Impact Factor (I)	Rating Method	Member LL (k)	RF	RF	RF
1	H520	2.17	0.118	LFR	109.8	2.22	N/A	2.81
2	A1	2.17	0.118	LFR	43.8	5.56	N/A	7.05
3	A2	2.17	0.118	LFR	60.3	4.03	N/A	5.11
4	A3	2.17	0.118	LFR	65.6	3.71	N/A	4.70
5	NRL	2.17	0.118	LFR	68.3	3.56	N/A	4.51
6	Legal Lane	2.17	0.118	LFR	76.2	3.19	N/A	4.05
7	OL1	1.3	0.1	LFR	82.5	7.26	N/A	9.33
8	OL2	1.3	0.1	LFR	164.0	3.65	N/A	4.70

Parametrix

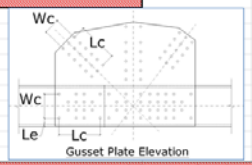
Triage Spreadsheet Input (Continued)

Triage Procedure Connection Inputs

Rated By	SB
Company	Parametrix
Date	5/11/2011
Bridge ID	9_118

Connection Information

Connection ID	Chord or Web?	Splice PL's?	Wind Bracing GP?	Comp. or Tension?	Milled to Bear, Y/N?
L2-U3	Web	N	N	Compression	



Gusset Plate Elevation

Gusset Plate Connection

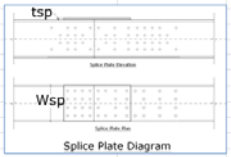
Wc (in)	9	2*Lc tan 30 + Wc	26.32
Lc (in)	15	Is Plate Width <	N
Le (in)		2*Lc tan 30 + Wc?	
Plate Width (in)		Plate Width valid only for web members and when < 2*Lc tan 30 +Wc	

Individual Splice Plate Dimensions

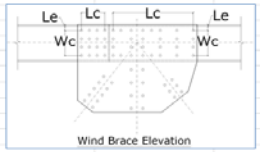
Splice ID	Wsp (in)	tsp (in)

Wind Brace GP Dimensions

Brace ID	Wc (in)	Lc (in)	Le (in)	twp (in)



Splice Plate Diagram



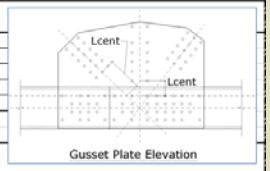
Wind Brace Elevation

Summary of Yielding Resistance Calculations

Agp_wb (in^2)	23.03			
Awp (in^2)	0.00	»	Rn (k)	664.8
ΣAspi (in^2)	0.00			

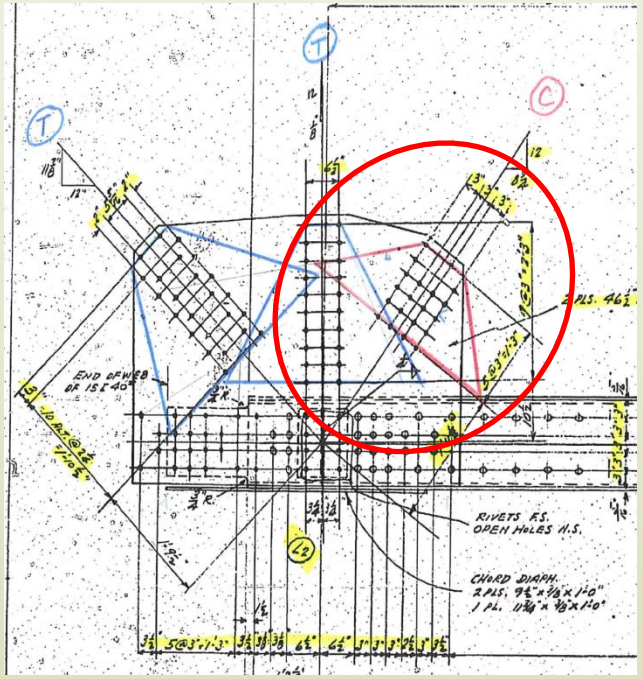
Buckling Resistance Inputs

Buckling Input		Summary of Buckling Resistance Calculations					
Centroidal Length, L_cent (in)		L_Whit45 (in)	Ig (in^4)	Ag (in^2)	ϕc		Rn (k)
17.93		34.50	0.482	30.19	0.9	»	339.5
Whitmore Length Manual Input (in)		rs (in)	L_cent (in)	λ	K		
34.50		0.126	17.930	3.521	1.0		
Does the L_Whit45 exceed the actual width of the plate?		Y					



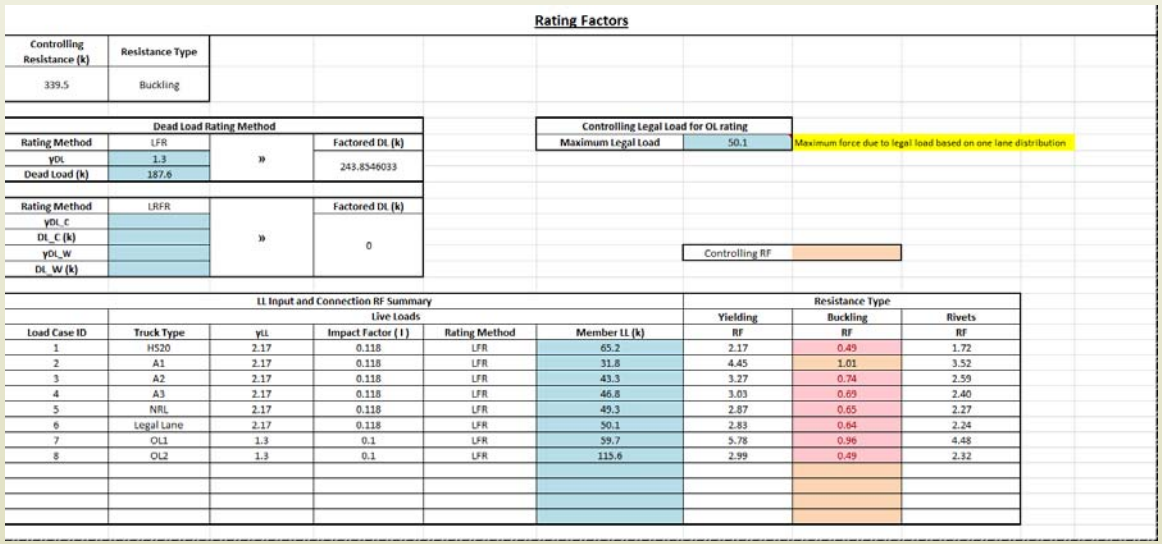
Gusset Plate Elevation

Rivet Input				Rivet Resistance
Rivet Diameter, D_r (in)	# of Single Shear Rivets, nss	# of Double Shear Rivets, nds	»	Rn (k)
0.875	40			577.3



Parametrix

Triage Spreadsheet Input (Continued)



Rating Factors

Controlling Resistance (k)	Resistance Type
339.5	Buckling

Dead Load Rating Method

Rating Method	LFR		Factored DL (k)
γDL	1.3	»	243.8546033
Dead Load (k)	187.6		

Rating Method	LRFR		Factored DL (k)
γDL_C			
DL_C (k)		»	0
γDL_W			
DL_W (k)			

Controlling Legal Load for OL rating

Maximum Legal Load	50.1	Maximum force due to legal load based on one lane distribution

Controlling RF

LL Input and Connection RF Summary

	Live Loads					Resistance Type		
						Yielding	Buckling	Rivets
Load Case ID	Truck Type	γLL	Impact Factor (I)	Rating Method	Member LL (k)	RF	RF	RF
1	H520	2.17	0.118	LFR	65.2	2.17	0.49	1.72
2	A1	2.17	0.118	LFR	31.8	4.45	1.01	3.52
3	A2	2.17	0.118	LFR	43.3	3.27	0.74	2.59
4	A3	2.17	0.118	LFR	46.8	3.03	0.69	2.40
5	NRL	2.17	0.118	LFR	49.3	2.87	0.65	2.27
6	Legal Lane	2.17	0.118	LFR	50.1	2.83	0.64	2.24
7	OL1	1.3	0.1	LFR	59.7	5.78	0.96	4.48
8	OL2	1.3	0.1	LFR	115.6	2.99	0.49	2.32

Parametrix

Reporting Results

Gusset Plate Inputs & Summary

Sheet Information

Rated By	Company	Date	Bridge ID	Gusset ID	Number of Connections	Include Rivets?	Condition Factor, ϕc	Redundancy Factor, ϕs	Comments
SB	Parametrix	5/11/2011	9_118	L2	5	Y	1	1	
								ϕs equals 1 for LFR	

LL Distribution Factors			
AASHTO & Legal Trucks	OL Trucks	Legal Truck w/OL	
1.225	0.789	0.436	Forces entered into spreadsheet shall be based on a single lane distribution.
			LL Distribution factor for Design & Legal truck shall be based on the number of lanes multiplied by the appropriate reduction factor.
			LL Distribution factor for one OL placed in lane closest to truss multiplied by the appropriate reduction factor.
			LL Distribution factor for Legal Truck w/OL assumes legal loads are placed in lanes adjacent to OL truck multiplied by the appropriate reduction factor.

Clear User Inputs

LL Input and RF Summary

Load Case ID	Live Loads					Minimum RF	Controlling Connection ID	Controlling Resistance Type	Operating RF for LFR only	
	Truck Type	Overload?	γLL	Impact Factor (I)	Rating Method				γLL	Minimum RF
1	HS20	N	2.17	0.118	LFR	0.49	L2-U3	Buckling	1.3	0.82
2	A1	N	2.17	0.118	LFR	1.01	L2-U3	Buckling	1.3	1.69
3	A2	N	2.17	0.118	LFR	0.74	L2-U3	Buckling	1.3	1.24
4	A3	N	2.17	0.118	LFR	0.69	L2-U3	Buckling	1.3	1.15
5	NRL	N	2.17	0.118	LFR	0.65	L2-U3	Buckling	1.3	1.09
6	Legal Lane	N	2.17	0.118	LFR	0.64	L2-U3	Buckling	1.3	1.07
7	OL1	Y	1.3	0.1	LFR	0.96	L2-U3	Buckling	1.3	0.96
8	OL2	Y	1.3	0.1	LFR	0.49	L2-U3	Buckling	1.3	0.49

Plate Material & Dimension Inputs

Gusset Plate Properties		Wind Gusset Plate Properties		Splice Plate Properties		Rivet Properties	
Fy_gp (ksi)	50	Fy_wp (ksi)	50	Fy_sp (ksi)	50	Fu_r (ksi)	24
Thickness, tgp (in)	0.4375						
Num Plates, np	2						

- Fast/Efficient
- Yielding Vs. Buckling
- Rivets

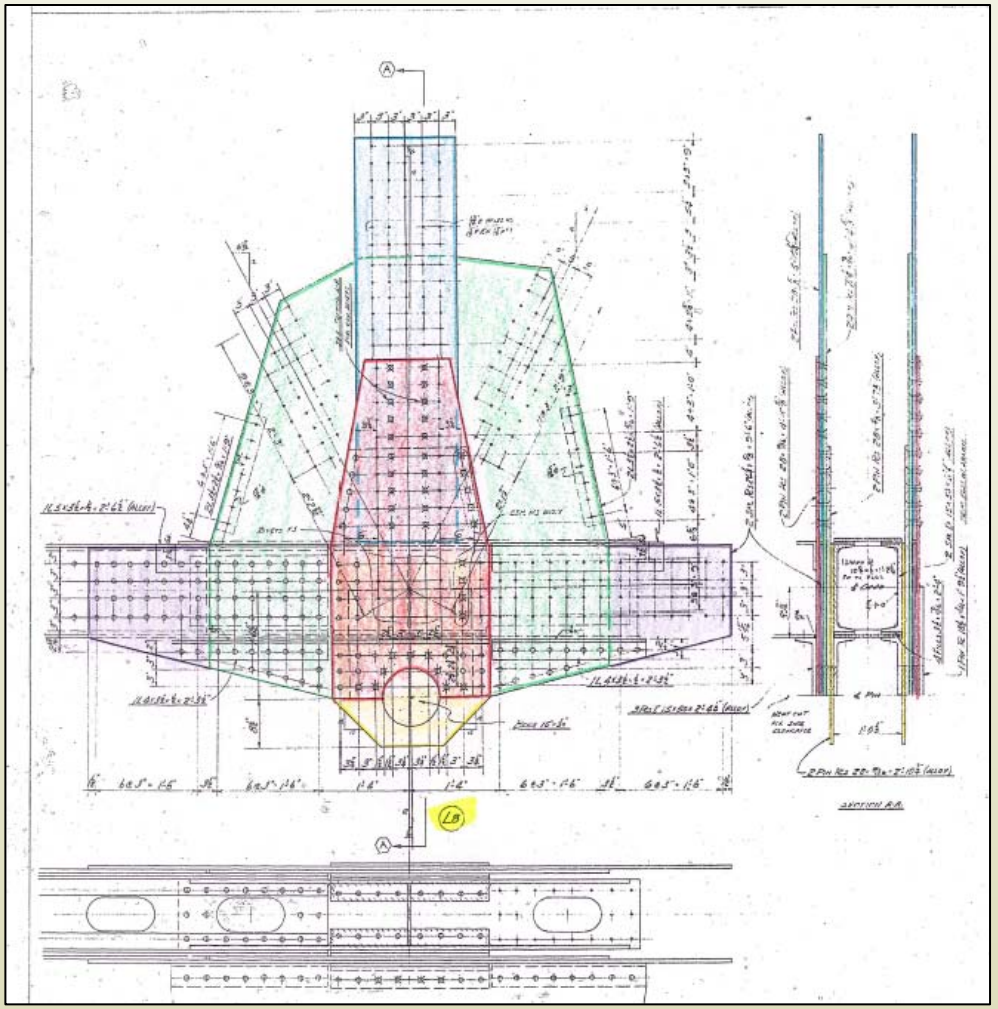
Parametrix

Challenges

- Multi-span trusses
- Nested Plates
- Whitmore Widths
- Bugs

Future

- Spreadsheet Updates
- Comparison w/FHWA method



Parametrix