Reed College Central Plant Upgrade
CALCULATIONS
SUBMITTAL

REVISION 0

REGISTERED PROFESSIONAL
ENGINEER
92725
OREGON
SEP. 12, 2011
MARIA EUGENIA CHUMBITA GARCIA

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CoreBrace Project #6903

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JAMES G. PIERSON, INC.
CONSULTING STRUCTURAL ENGINEERS
PORTLAND, OREGON

BY: Peter Gollery DATE: 04/29/2025

Reed College Central Plant Upgrade

Calculation Submittal Package

Description

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Calculation Submittal Package

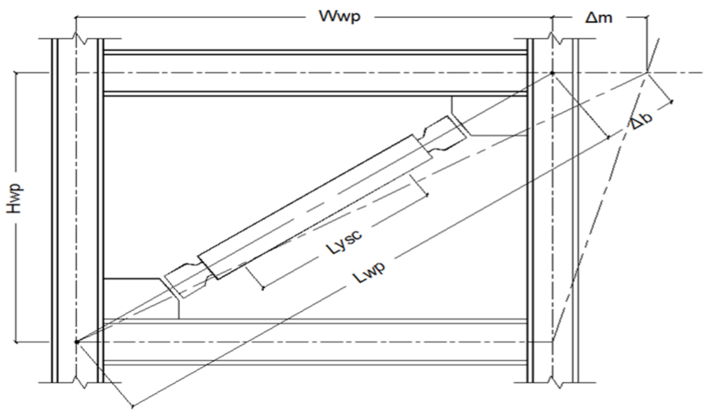
<u>Description</u>

Section 1. Strain, β, and ω Determination and Submittal Tables

Strain and Overstrength Calculation

Example Mark #: 1901

Line 3+, Grid E.5-D.9, Level 2



1.0 DESIGN CRITERIA

Width Between Workpoints	W_{wp}:	88.00 in	*(2235 mm)*
Height Between Workpoints	H_{wp}:	121.93 in	*(3097 mm)*
Yielding Core Length	L_{ysc}:	69.29 in	*(1760 mm)*
Workpoint Length Along Diagonal $L_{wp} = \sqrt{(W_{wp}^2+H_{wp}^2)}$	L_{wp}:	150.37 in	*(3819 mm)*
Yield Stress of Core Material for Establishing Area	$F_{y\text{-}min}$:	39 ksi	*(269 MPa)*
Maximum Yield Stress of Core Material	$F_{y\text{-}max}$:	46 ksi	*(317 MPa)*
Modulus of Elasticity	E:	29000 ksi	*(199955 MPa)*
LRFD Resistance Factor	ϕ_{BRB}:	0.90	
Deflection Amplification Factor	C_d:	5.00	
Demand Capacity Ratio	DCR:	1.00	
Importance Factor	I_E:	1.00	
Redundancy Factor	ρ:	1.00	
Specified Story Drift to Consider (Typically 1.0% Minimum unless NLRHA) *The displacements and strains assocaited with this value will later be multiplied by 2, so 2% minimum is typically being considered.*	SSD:	1.00%	
Area of Yielding Steel Core	A_{sc}:	4.00 in²	*(2581 mm²)*

1.1 STRAIN CALCULATION

Minimum Yield Force in Steel Core $(F_{y\text{-}min} \cdot A_{sc})$	$P_{ysc,min}$:	156 kip	*(694 kN)*
Maximum yield Force in Steel Core $(F_{y\text{-}max} \cdot A_{sc})$	$P_{ysc,max}$:	184 kip	*(818 kN)*
Final Width Between Workpoints after Specified Story Drift			
$W_f = W_{wp}+(SSD \cdot H_{wp})$	W_f :	89.22 in	*(2266 mm)*
$\Delta_{mSSD} = W_f - W_{wp}$ (for reference only)	Δ_{mSSD}:	1.22 in	*(31 mm)*
Final WP Length Along Diagonal After Specified Story Drift			
$L_f = \sqrt{(W_f^2+H_{wp}^2)}$	L_f :	151.09 in	*(3838 mm)*
Yielding Core Elongation at Specified Story Drift $(L_f - L_{wp})$	Δ_{bSSD}:	0.72 in	*(18 mm)*
Core Strain at Considered Story Drift (Δ_{bSSD}/L_{ysc})	ε_{bSSD}:	1.03%	
Core Strain at Design Story Drift (Cd*Yield Strain)			
Force for Elastic Drift Determination $P_d=\phi P_{ysc,min}/(\rho \cdot I) \cdot DCR$	P_d:	140 kip	*(625 kN)*
Stiffness of Yeilding Core $K_{Lysc}=A_{sc} \cdot E/L_{ysc}$	K_{Lysc}:	1674 k/in	*(293 kN/mm)*
Core Deformation at Yield $\Delta_{by}=P_d/K_{Lysc}$	Δ_{by}:	0.08 in	*(2 mm)*
Core Deformation at Design Story Drift $\Delta_{bCd}=\Delta_{by} \cdot C_d$	Δ_{bCd}:	0.42 in	*(11 mm)*
Core Strain at Design Story Drift $\varepsilon_{bCd} = \Delta_{bCd}/L_{ysc}$ *Note, identical results are found by calculating the strain with the following equation,* *$\varepsilon_{bCd} = \phi \cdot C_d \cdot (F_y/E) \cdot DCR/(I_E \cdot \rho)$, and then backing out the deformation, $\Delta_{bCd} = \varepsilon_{bCd} \cdot L_{ysc}$*	ε_{bCd}:	0.61%	
$\Delta_{mCd} = \Delta_{bCd}/COS(TAN^{-1}(H_{wp}/W_{wp}))$ (for reference only)	Δ_{mCd}:	0.72 in	*(18 mm)*
Required Stroke at Each End of Brace (½ of 2x Max of Δ_{bCd} & Δ_{bSSD})	$c_{req'd}$:	0.72 in	*(18 mm)*
Provided Stroke Distance at Each End of Brace	c:	3.00 in	*(76 mm)*

Controlling Strain (Max of ε_{bSSD} & ε_{bCd})	$\varepsilon_{b,max}$:	1.03%	
Strain at $2\cdot\varepsilon_{b,max}$	$2\varepsilon_{b,max}$:	2.07%	

1.2 DETERMINE OVERSTRENGTH FACTORS AT ε_{max} - SEE BACKBONE CURVES

Qualifying Similarity Test per AISC 341 K3.3	Similarity (K3.3) Test:	10P	
Yield Force of Test Specimen	P_y:	86 kip	*(382 kN)*
Test Extrapolation Range Downward per AISC 341-16	Extrapolation Downward	83%	
Minimum Qualified Yield Force	$P_{y,min}$:	72 kip	*(318 kN)*
Test Extrapolation Range Upward per AISC 341-16	Extrapolation Upward	333%	
Maximum Qualified Yield Force	$P_{y,max}$:	286 kip	*(1273 kN)*
Compression Strength Adjustment Factor at ε_{max}	$\beta_{K3.3}$	1.19	
Strain Hardening Adjustment Factor at ε_{max}	$\omega_{K3.3}$	1.39	
Qualifying Sub-Assemblage Test per AISC 341 K3.2	Subassemblage (K3.2) Test	3P	
Yield Force of Test Brace	P_y:	376 kip	*(1673 kN)*
Compression Strength Adjustment Factor at ε_{max}	$\beta_{K3.2}$	1.14	
Strain Hardening Adjustment Factor at ε_{max}	$\omega_{K3.2}$	1.35	
Maximum Compression strength adjustment factor at ε_{max}	β_{max}	1.19	
Maximum Strain hardening adjustment factor at ε_{max}	ω_{max}	1.39	

These values may be increased for length effects where applicable. Design values may be larger.

Adjusted Brace Strength in Tension: $ABS_T = A_{sc}\cdot F_{y\text{-}max}\cdot\omega = P_{ysc,max}\cdot\omega$	**P_{uT}:**	**255 kip**	*(1134 kN)*
Adjusted Brace Strength in Compression: $ABS_C = A_{sc}\cdot F_{y\text{-}max}\cdot\beta\cdot\omega = P_{ysc,max}\cdot\beta\cdot\omega$	**P_{uC}:**	**304 kip**	*(1353 kN)*

1.3 BRACE ROTATIONAL DEMAND

2x Story Drift Rotation = $2*MAX(\Delta_{m1\%}, \Delta_{mCd})/H_{wp}$

$\delta = 2\cdot MAX(\Delta_{mSSD}, \Delta_{mCd})/H_{wp}$ Equal to Assumed (Conservative) Translational Demand — δ: 0.02 rad

Assumed story drift rotation is considered conservative based on the following:

$\Delta_m = \delta\cdot H$ *Maximum Story Drift for Project* — Δ_m: 2.44 in *(62 mm)*

$\Delta_t \le \Delta_m$ $\delta_t = \Delta_t/L_{wp}$ *Where Δ_t is the translation of the brace/beam joint and L_{wp} is the length of the brace*

$L_b \ge H$ *Where H is the story height*

$\Delta_m/H = \delta\cdot H/H = \delta =$ 0.02 rad

Since $\Delta_t \le \Delta_m$ and $L_b \ge H$ Then: $\Delta_t/L_b \le \Delta_m/H$ --> $\delta_t \le \delta$

$\theta_{CB} = \tan^{-1}(H_{wp}/W_{wp})$	*Angle between Horiz and BRB before rotation*	θ_{CB}:	0.946 rad	
$\Delta_t = \Delta_m\cdot\sin(\Theta_{CB})$	*Translation of brace/beam joint*	Δ_t:	1.98 in	*(50 mm)*
$\delta_t = \Delta_t/L_{wp}$	*Rotational demand on BRB*	δ_t:	0.013 rad	

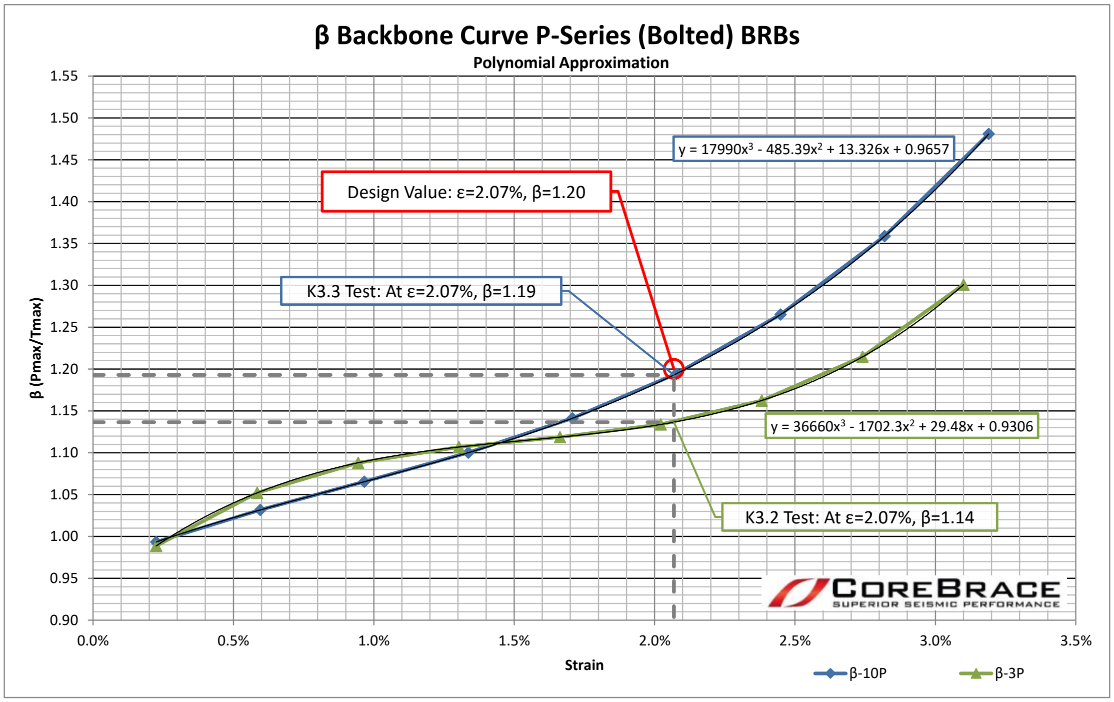
Alternate Method:

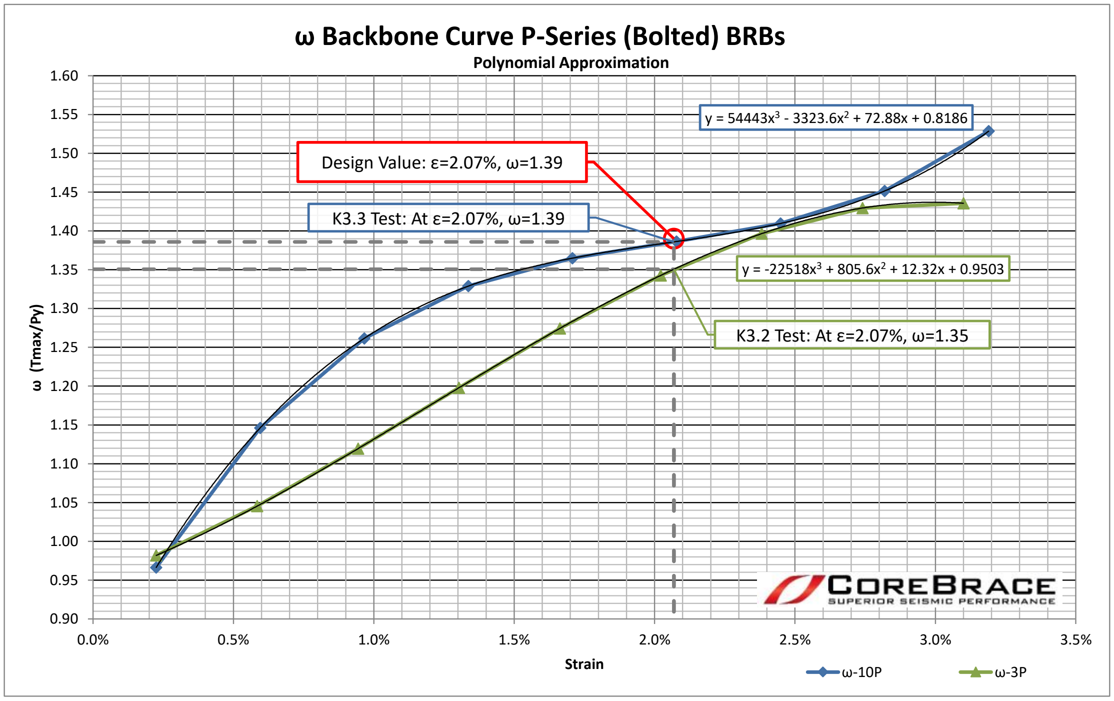
$\theta'_{CB} = \tan^{-1}(H_{wp}/(W_{wp}+\Delta_m))$	*Angle between Horiz and BRB after rotation*	θ'_{CB}:	0.933 rad
$\delta_{t\text{-}alt} = \theta_{CB} - \theta'_{CB}$		$\delta_{t\text{-}alt}$:	0.013 rad

Therefore 0.02 Radians is Conservative

Tested Capacity from Test Report Must Equal 0.013 Radians. -- CoreBrace OK

1.4 BACKBONE CURVES





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COREBRACE STRAIN CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR

Job: 6903

Specimen ID and Location						SECTION 1.0 DESIGN CRITERIA														SECTION 1.1 STRAIN CALCULATION																
						Workpoint				Design Constant										Yield in Core		Story Drift											Strain			
EOR-ID	Line	Grids	Lvls	Mark	Qty	W_{WP}	H_{WP}	L_{ysc}	L_{WP}	F_{ysc_min}	F_{ysc_max}	E	ϕ_{BRB}	C_d	DCR	I	ρ	SSD	A_{SC}	P_{ysc_min}	P_{ysc_max}	W_F	Δ_{mSSD}	L_F	Δ_{bSSD}	ε_{bSSD}	P_d	K_{Lysc}	Δ_{by}	Δ_{bCd}	ε_{bCd}	Δ_{mCd}	$c_{req'd}$	c	$\varepsilon_{b,max}$	$2\varepsilon_{b,max}$
#		#	#	#	#	in	in	in	in	ksi	ksi	ksi						%	in^2	kip	kip	in	in	in	in	%	kips	k/in	in	in	%	in	in	in	%	%
BRB-4.00	3+	E.5-D.9	2	1901	1	88.0	121.9	69.3	150.4	39.0	46.0	29000	0.90	5.0	1.00	1.00	1.00	1.00%	4.00	156.0	184.0	89.2	1.22	151.1	0.72	1.03%	140	1674	0.08	0.42	0.61%	0.72	0.82	3.00	1.03%	2.07%
BRB-4.00	3+	E.5-D.9	1	1902	1	88.0	126.0	71.5	153.7	39.0	46.0	29000	0.90	5.0	1.00	1.00	1.00	1.00%	4.00	156.0	184.0	89.3	1.26	154.4	0.72	1.01%	140	1623	0.09	0.43	0.61%	0.76	0.83	3.00	1.01%	2.03%

COREBRACE STRAIN CALCULATIONS

CoreBrace
SUPERIOR SEISMIC PERFORMANCE

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						SECTION 1.2 DETERMINE OVERSTRENGTH FACTORS AT ε_{max}													SECTION 1.3 BRACE ROTATIONAL DEMAND						
						Axial Test Specimen per AISC 341 K3.3					Sub Test Specimen per AISC 341 K3.2				Design				Story Drift Rotation					Alt method	
EOR-ID #	Line	Grids #	Lvls #	Mark #	Qty #	Py kip	Test Specimen for "Py min" / "Py max"	Test Used	β	ω	Test Used	Py kip	β	ω	β	ω	P_{uT} kip	P_{uC} kip	δ rad	Δ_m in	θ_{CB} rad	Δ_t in	δ_t rad	θ'_{CB} rad	$\delta_{t\text{-}alt}$ rad
BRB-4.00	3+	E.5-D.9	2	1901	1	85.82	10P / 10P	10P	1.19	1.39	3P	376.20	1.14	1.35	1.20	1.39	255.8	306.9	0.02	2.44	0.95	1.98	0.013	0.93	0.013
BRB-4.00	3+	E.5-D.9	1	1902	1	85.82	10P / 10P	10P	1.19	1.38	3P	376.20	1.13	1.34	1.19	1.38	253.9	302.2	0.02	2.52	0.96	2.07	0.013	0.95	0.013
														Max	1.20	1.39									

Reed College Central Plant Upgrade

Calculation Submittal Package

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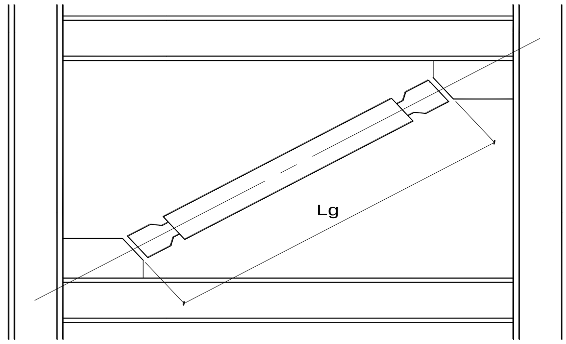
Section 2.	**Casing Buckling Calculations** **Casing Buckling Summary Tables**

Buckling Calculation

Example Mark #: 1901

Line 3+, Grid E.5-D.9, Level 2



2.0 DESIGN CRITERIA

Tip of gusset to tip of gusset is set as buckling length	L_{gg}:	115.13 in	*(2924 mm)*
Compresssion Strength Adjustment Factor	β:	1.2	
Strain Hardening Adjustment Factor	ω:	1.39	
Upper Bound Yield Strength of Brace ($A_{sc} \cdot F_{y\text{-}max}$)	$P_{ysc\text{-}max}$:	184.0 kip	*(818 kN)*
Upper Bound Yield Stress of Core Material	$F_{y\text{-}max}$:	46 ksi	*(317 MPa)*
Area of Steel Core	A_{sc}:	4.00 in²	*(2581 mm²)*
Ultimate Load (Adjusted Brace Strength in Compression): $P_{uC} = (P_{ysc\text{-}max} \cdot \beta \cdot \omega) = ABS_C$	P_{uC}:	306.9 kip	*(1365 kN)*
Modulus of Elasticity	E:	29000 ksi	*(199955 MPa)*
Model Brace as Pinned Both Ends (conservative)	k:	1.0	
Casing Moment of Inertia **t8x1/4**	I_c:	70.7 in⁴	*(2943 cm⁴)*

2.1 Euler Buckling

Solving Euler's buckling equation for required moment of inertia:

$$I_{Ig} = \frac{FS_B \cdot P_{uC} \cdot (k \cdot L_{gg})^2}{\pi^2 E}$$

	I_{Ig}:	18.0 in⁴	*(750 cm⁴)*

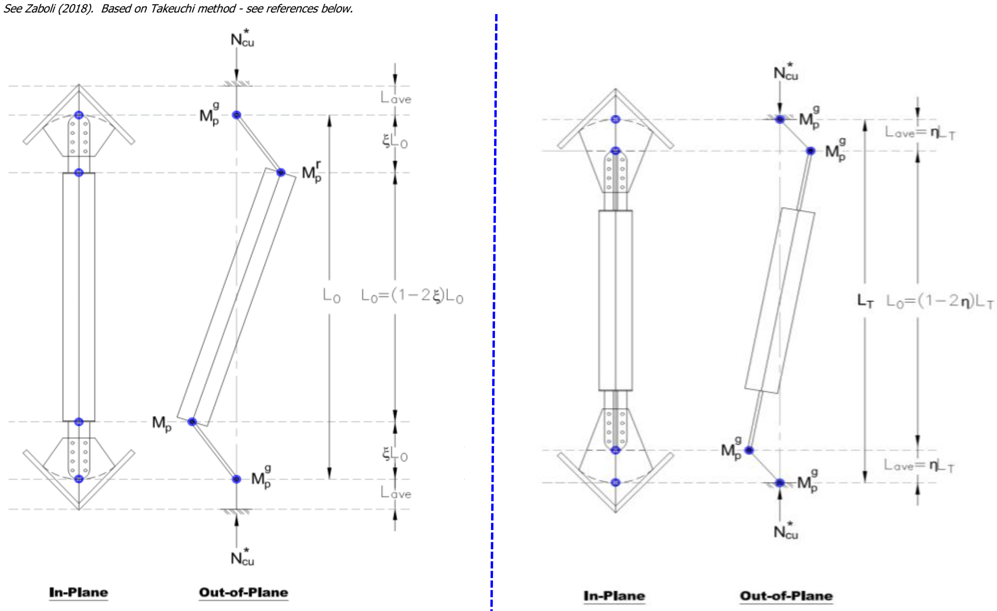
Where:

FS_B = Factor of Safety Against Buckling: *Verified by Testing*

	FS_B:	1.27	
Unity Check:	I'_g/I_C:	0.25	**OK**

2.2 Global Stability (Notional Load Yield Line Method) - Asymmetrical Modes

See Zaboli (2018). Based on Takeuchi method - see references below.

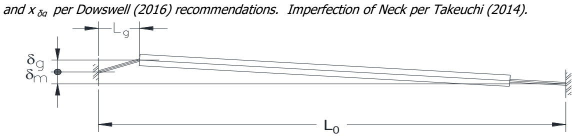


Over-the-Yield Line (OYL) - Asymmetrical Mode | **Under-the-Yield Line (UYL) - Asymmetrical Mode**

2.2.1 NLYL Method Design Criteria

Overall Brace Length	L_0:	125.25 in	*(3181 mm)*
Additional Out-of-Plane Force on BRB *(half assumed to go to each end)*:	$F_{Add'l\text{-}OOP}$	0.0 kip	*(0 kN)*
Initial Imperfection of Neck Insertion Zone	θ_0:	0.005 rad	
Assumed Out-of-Plumbness of Brace: $\delta_m/L_0 = 1/x_{\delta m}$	$x_{\delta m}$:	500	
Assumed Out-of-Flattness of Gusset Plate: $\delta_g/L_g = 1/x_{\delta g}$	$x_{\delta g}$:	100	

Values of $x_{\delta m}$ and $x_{\delta g}$ per Dowswell (2016) recommendations. Imperfection of Neck per Takeuchi (2014).



Initial Imperfection per Dowswell (2016)

Critical Gusset Dimensions: Top Gusset

Top Gusset is Chev?		$Chev_{Top}$:	FALSE	
Top Gusset is Stiffened?		$Stiff_{Top}$:	FALSE	
Is gusset stiffened sufficiently for Kb to be reduced? Can be "FALSE" even if stiffeners are present.				
Stiffener Width		$W_{stiff,top}$:	-	-
Stiffener Thickness		$t_{stiff,top}$:	-	-
Gusset Thickness		$t_{g,top}$:	1.00 in	*(25 mm)*
Projected Stiffener Plastic Section Modulus *(Proj per Dowswell. All stiff's combined.)*		$Z_{stiff,top}$:	-	-
Yield Strength of Gusset Material		$F_{yg,top}$:	50 ksi	*(345 MPa)*
Length from WL Intersection w/Beam or Col along WL to Tip of Brace		a_{top}:	5.66 in	*(144 mm)*
Clear from Col to Lug Edge		b_{top}:	1.09 in	*(28 mm)*
Clear from Beam to Lug Edge		c_{top}:	4.91 in	*(125 mm)*
Controlling Bendline Length, Gusset Edge to Brace Tip:	Bm Side	$L_{b,top}$:	12.26 in	*(311 mm)*
	Col Side	$L_{c,top}$:	13.04 in	*(331 mm)*

Critical Gusset Dimensions: Bottom Gusset

Bottom Gusset is Chev?	V_{Bot}:	FALSE	
Bottom Gusset is Stiffened?	$Stiff_{Bot}$:	FALSE	
Is gusset stiffened sufficiently for Kb to be reduced? Can be "FALSE" even if stiffeners are present.			
Stiffener Width	$W_{stiff,bot}$:	-	-
Stiffener Thickness	$t_{stiff,bot}$:	-	-
Gusset Thickness	$t_{g,bot}$:	1.00 in	*(25 mm)*
Projected Stiffener Plastic Section Modulus *(Proj per Dowswell. All stiff's combined.)*	$Z_{stiff,bot}$:	-	-

Yield Strength of Gusset Material		$F_{yg,bot}$:	50 ksi	*(345 MPa)*
Length from WL Intersection w/Beam or Col along WL to Tip of Brace		a_{bot}:	5.79 in	*(147 mm)*
Clear from Col to Lug Edge		b_{bot}:	1.17 in	*(30 mm)*
Clear from Beam to Lug Edge		c_{bot}:	4.61 in	*(117 mm)*
Controlling Bendline Length, Gusset Edge to Brace Tip:	Bm Side	$L_{b,bot}$:	12.31 in	*(313 mm)*
	Col Side	$L_{c,bot}$:	12.97 in	*(329 mm)*

Core Dimensions and Properties

Ultimate Stress of Core Material	F_{usc}:	66 ksi	*(455 MPa)*
Core Width at Neck Section	W_t:	4.00 in	*(102 mm)*
Core Thickness	t_{sc}:	1.00 in	*(25 mm)*
Neck Insertion Length for Out-of-Plane Buckling Direction	L_{in}:	9.73 in	*(247 mm)*

Note that L_{in}/W_t = Embedment Ratio = 2.43

Lug and Bolt Pattern Dimensions

Width of Lug Plate	W_L:	7.50 in	*(191 mm)*
Width of Lug at Neck Section	W_1:	4.98 in	*(127 mm)*
Length of Lug on Gusset Measured to Square Projection	L'_{Lg}:	11.25 in	*(286 mm)*
Transition Length, W_L to W_1	a:	4.00 in	*(102 mm)*
Stroke Length, End of Transition to Casing	c:	3.00 in	*(76 mm)*
Lug Thickness	t_L:	0.63 in	*(16 mm)*
Yield Strength of Lug Material	F_{yL}:	50 ksi	*(345 MPa)*
Ultimate Strength of Lug Material	F_{uL}:	65 ksi	*(448 MPa)*
Number of Bolts in Inner Row Along Brace Axis	n_i:	3	
Number of Bolts in Outer Row Along Brace Axis	n_o:	0	
Bolt Spacing	s:	4.00 in	*(102 mm)*
Plate Edge to CL of Bolt	e_{perp}:	1.63 in	*(41 mm)*

Restrainer (Casing) Size and Properties

Restrainer Section Name	Section:	t8x1/4	
Yield Stress of Casing Material	F_{yc}:	46 ksi	*(317 MPa)*
Youngs Modulus of Casing Material	E_c:	29000 ksi	*(199955 MPa)*
Casing is Square/Rectangular?	Sq_{Cas}:	TRUE	
Casing Height (Dimension Viewed in Elevation)	H_c:	8.00 in	*(203 mm)*
Casing Width (Dimension Viewed in Plan & Overall Dimension for p Sections)	W_c:	8.00 in	*(203 mm)*
Casing Thickness	t_c:	0.25 in	*(6 mm)*

Factor on Adjusted Brace Strength	F_{PUC}:	1.0
Capacity Reduction Factor, ϕ_{NLYL}	ϕ_{NLYL}:	1.0

Equal to 1.0 per Takeuchi (2014). Lower values can be used.
Zaboli (2018) is even more conservative than Takeuchi even with ϕ = 1.0.

2.2.2 NLYL Global Stability Method

Overstrength Compression Force in the Core of the BRB: $N^*_{cu} = F_{Pu} \cdot P_{uC}$	N^*_{cu}:	**306.9 kip**	*(1365 kN)*

NLYL Method Uses: N^*_{cu} = Overstrength Compression Capacity of the BRB. This requires an iterative solution.
The variant used here checks demand vs capacity based on applied load (Pu).

Length from End of Casing to Yield Line at Tip of Brace: $\xi L_0 = a + c + L'_{LG}$	ξL_0:	18.25 in	*(464 mm)*
Destabilizing Factor for OYL Method: $\xi = \xi L_0 / L_0$	ξ:	0.146	

Effective Length Factor for Brace including Gusset Stiffness Effect: k_b	k_b:	1.00
If $Stiff_{Top}$ AND $Stiff_{Bot}$ = TRUE, k_b = 0.7		
If $Stiff_{Top}$ AND $Stiff_{Bot}$ = FALSE, k_b = 1.0		
If $Stiff_{Top}$ OR $Stiff_{Bot}$ = FALSE, k_b = 0.85		

Stiffened Gusset Factor, λ = 1.19 for Stiffened Gusset or 1.0 for Unstiffened Gusset	λ_{top}:	1.00
	λ_{bot}:	1.00

Global Elastic Buckling Capacity of BRB, Incl Effect of Gusset PL: $N^B_{cr} = \pi^2 \cdot EI_c / (k_b \cdot L_0)^2$	N^B_{cr}:	**1289.9 kip**	*(5738 kN)*

Effective Width in Compression: $b_{ga} = 2 \cdot L_{Br} \cdot \tan(\theta_{disp}) + (W_L - 2 \cdot e_{perp})$

Lug Lap on Gusset: L_{Br}=IF(n_i>n_o,(n_i–1)·s,(n_o–0.5)·s)	L_{Br}:	8.00 in	*(203 mm)*
Dispersion Angle at Top Gusset	$\theta_{disp,top}$:	40.0°	
Dispersion Angle at Bottom Gusset	$\theta_{disp,bot}$:	40.0°	

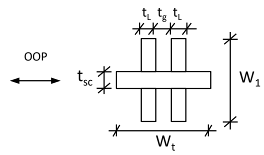
Dispersion angle based on 30° for V or Chev, 40° otherwise per NLYL Methodology.

Effective Compression Width, Top Gusset	$b_{ga,top}$:	17.68 in	*(449 mm)*
Effective Compression Width, Bottom Gusset	$b_{ga,bot}$:	17.68 in	*(449 mm)*

Average Gusset Buckling Length: L_{ave} = min[(a+min(b,c))/2, (a+b+c)/3]	$L_{ave,top}$:	3.38 in	*(86 mm)*
See Dowswell (2006) and Zaboli (2018)	$L_{ave,bot}$:	3.48 in	*(88 mm)*

Nominal Axial Capacity of Gusset Plate: $N^g_s = b_{ga} \cdot t_g \cdot F_{yg}$	$N^g_{s,top}$:	**883.8 kip**	*(3931 kN)*
	$N^g_{s,bot}$:	**883.8 kip**	*(3931 kN)*

Euler Buckling Capacity of Gusset Plate: $N_e = \pi^2 \cdot E \cdot (b_{ga} \cdot t_g^3/12)/L_{ave}^2$	$N_{e,top}$:	**36952.6 kip**	*(164372 kN)*
	$N_{e,bot}$:	**34824.2 kip**	*(154905 kN)*
Plastic Moment Capacity of Gusset Plates			
Total Bendline Length: $b_{gf} = L_b + L_c$	$b_{gf,top}$:	25.30 in	*(643 mm)*
	$b_{gf,bot}$:	25.27 in	*(642 mm)*
Plastic Section Modulus: $Z_g = b_{gf} \cdot t_g^2/4 + Z_{stiff}$	$Z_{g,top}$:	6.32 in³	*(103642 mm³)*
	$Z_{g,bot}$:	6.32 in³	*(103536 mm³)*
Plastic Moment Capacity: $M^g_{zy} = Z_g \cdot F_{yg}$	$M^g_{zy,top}$:	**316 k-in**	*(35.7 kN-m)*
	$M^g_{zy,bot}$:	**316 k-in**	*(35.7 kN-m)*
Reduced Plastic Moment Capacity of Gusset Plate Including Axial Force Effect:	$\mathbf{M^g_{p,top}}$:	**278 k-in**	*(31.4 kN-m)*
$M^g_p = \lambda \cdot \phi_{NLYL} \cdot M^g_{zy}[1-(N^*cu/(\phi_{NLYL} \cdot N^g_s))^2] \geq 0$	$\mathbf{M^g_{p,bot}}$:	**278 k-in**	*(31.4 kN-m)*
Axial Yield Strength of Neck at Web Zone: $N^n_{wy} = 2 \cdot (W_1 - t_{sc}) \cdot t_L \cdot F_{y,L}$	N^n_{wy}:	248.9 kip	*(1107 kN)*
Axial Yield Strength of Neck: $N^n_y = W_t \cdot t_{sc} \cdot F_{ymax} + 2 \cdot (W_1 - t_{sc}) \cdot t_L \cdot F_{y,L}$	N^n_y:	432.9 kip	*(1926 kN)*
Axial Ultimate Strength of Neck: $N^n_u = W_t \cdot t_{sc} \cdot F_{u,sc} + 2 \cdot (W_1 - t_{sc}) \cdot t_L \cdot F_{u,L}$	N^n_u:	587.5 kip	*(2613 kN)*
OOP Plastic Section Modulus of Steel Core (W_t) at Neck Section: $Z_{Wt,oop} = t_{sc} \cdot W_t^2/4$	$Z_{Wt,oop}$:	4.0 in³	*(65548 mm³)*
OOP Plastic Section Modulus of Lugs (W_1) at Neck Sect: $Z_{W1,oop} = [W_1 - t_{sc}] \cdot ((2 \cdot t_L + t_g)^2 - t_g^2)/4$	$Z_{W1,oop}$:	4.0 in³	*(66273 mm³)*



Section at Neck

Out-of-Plane Plastic Moment Capacity of Neck: $M^n_{zv} = Z_{WT,oop} \cdot F_{ymax} + Z_{W1,oop} \cdot F_{y,L}$	M^n_{zy}:	**386 k-in**	*(43.6 kN-m)*
Reduced Restrainer Moment Transfer Capacity Determined by Neck + Core	$M_p^{r-neck,top}$:	280.8 k-in	*(31.7 kN-m)*
Plate, Including Axial Force Effect.	$M_p^{r-neck,bot}$:	280.8 k-in	*(31.7 kN-m)*

$M_p^{r-neck} = \phi_{NLYL} \cdot M^n_{zv} \cdot \mathbf{[}1 - \mathbf{(}N^*_{cu}/(\phi_{NLYL} \cdot (N^n_u)\mathbf{)}^{exp}\mathbf{]}$

Exponent, exp = 2.0 Use N^n_y if Gst is Not Stiffened? FALSE

Per Takeuchi (2014), N^n_u is used in the denominator. Other methods use N^n_y in the denominator if the gusset is unstiffened.

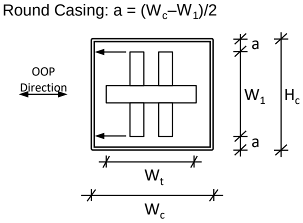
Plastic Section Modulus of Restrainer, Z_{rp}	Z_{rp}:	22.5 in³	*(369221 mm³)*
Square / Rectangular Section: $Z_{rp} = H_c \cdot W_c^2/4 - (H_c - 2 \cdot t_c) \cdot (W_c - 2 \cdot t_c)^2/4$			
Round Casing Section: $Z_{rp} = W_c^3/6 - (W_c - 2 \cdot t_c)^3/6$			
Nominal Plastic Moment Capacity of Restrainer: $M^r_{zv} = Z_{rp} \cdot F_{yc}$	M^r_{zy}:	1036 k-in	*(117.1 kN-m)*
Embed Length Calibration Factor: $\alpha^r_p = 4.15 - 1.5 \cdot (L_{in}/W_t) = 4.15 - 1.5 \cdot L_{in}/W_t \geq 1.5$	α^r_p:	1.50	

See Takeuchi (2014). While this increases as embedment ratio (L_{in}/W_t) decreases, the net effect of a decreasing embedment ratio decreases M_p^{r-rest}, and this factor only slows the decrease.

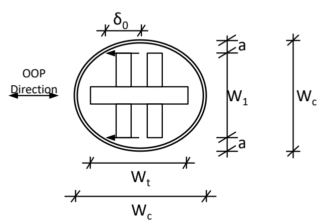
Distance between the shear force application point and the outer surface of the restraint tube, a

See Matsui (2010) for calculation of square and round restrainer properties.

Sq/Rect Casing: $a = (H_c - W_1)/2$	a:	1.51 in	*(38 mm)*
Round Casing: $a = (W_c - W_1)/2$			



Square Restrainer



Round Restrainer

Distance between the Core Plate Surface and the Shear Force Application Point when the Shear Force is not Present, δ_0. Not Applicable to Square/Rect Restrainers.

See Matsui (2010) and Takeuchi (2017). Eqn from Takeuchi (2017) Ch 4

$\delta_0 = W_c/2 \cdot \sin[\cos^{-1}((W_c - 2 \cdot a)/(W_c - 2 \cdot t_c))]$	δ_0:	2.99 in	*(76 mm)*

The Lateral Deflection of the Restraint Tube at the In-Plane Stress Yielding. Not Applicable to Square/Rect Restrainers.

See Matsui (2010) and Takeuchi (2017). Eqn from Takeuchi (2017) Ch 4

$\delta_y = \sqrt{[(\pi \cdot W_c \cdot F_{yc}/(4 \cdot E_c) + W_c/2 \cdot \cos^{-1}((W_c - 2a)/(W_c - 2t_c)))^2 - a^2]}$	δ_y:	3.03 in	*(77 mm)*

Elastic Rotational Stiffness of Restrainer about Rib End:

Round Casing: $K_{Rr1,Round} = 2 \cdot F_{vc} \cdot t_c \cdot L_{in}^3/(3 \cdot \sqrt{[a^2+\delta_v^2]}) \cdot \delta_v/(\delta_v - \delta_0) \geq 0$ — $K_{Rr1,Round}$: 148989 k-in/rad (1.68E+04 kN-m/rad)

Square/Rect Casing: $K_{Rr1,Rect} = E_c \cdot H_c \cdot t_c^3 \cdot L_{in}^3/(3 \cdot (2 \cdot H_c \cdot a^3 - 3 \cdot a^4)) \geq 0$ — $K_{Rr1,Rect}$: 28213 k-in/rad (3.19E+03 kN-m/rad)

Post-Yielding Rotational Stiffness of Restrainer about Rib End:

Round Casing: $K_{Rr2,Round} = 0$

Square/Rect Casing: $K_{Rr2,Rect} = 0.11 \cdot F_{vc} \cdot H_c^3 \cdot (L_{in}/W_t)^3 \geq 0$ — $K_{Rr2,Rect}$: 37260 k-in/rad (4.21E+03 kN-m/rad)

Yield Angle of Circular Casing: $\theta_{y,Round} = (\delta_v - \delta_0)/L_{in}$ — $\theta_{y,Round}$: 0.004359 rad

Pseudo Initial Yield Angle of the Rect Casing: $\theta'_{y1} = 0.00164 \cdot (F_{vc}/E_{casing}) \cdot (H_c/t_c) \cdot (W_t/L_{in})$ — θ'_{y1}: 0.000034 rad

Angle at Which Plastic Hinge Occurs: $\theta_{y2} = H_c/L_{in} \cdot \sqrt{[(F_{vc}/(2 \cdot E_{casing}))^2 + (a \cdot F_{vc}/(H_c \cdot E_{casing}))]}$ — θ_{y2}: 0.014240 rad

See Matsui (2010) and Takeuchi (2017) ch 4

Reduced Restrainer Moment Transfer Capacity Determined by Restrainer Section at Rib:

Round Casing: $M_p^{r-rest} = MIN[M^r_{zv}, \alpha^r_p \cdot K_{Rr1,Round} \cdot \theta_{y,Round}]$ — M_p^{r-rest}: 795 k-in *(89.9 kN-m)*

Square/Rect Casing: $M_p^{r-rest} = MIN[M^r_{zv}, \alpha^r_p \cdot (K_{Rr1,Rect} \cdot \theta'_{v1} + K_{Rr2,Rect} \cdot (\theta_{v2} - \theta'_{v1}))]$

Controlling Restrainer Moment Transfer Capacity: $M^r_p = Min\{M_p^{r-neck,t/b}, M_p^{r-rest}\}$

Top End of Brace Controlled By: **Neck Capacity**	**$M^r_{p,top}$:**	**280.8 k-in**	*(31.7 kN-m)*
Bottom End of Brace Controlled By: **Neck Capacity**	**$M^r_{p,bot}$:**	**280.8 k-in**	*(31.7 kN-m)*

2.2.3 Over the Yield Line (OYL) Global Buckling Capacity

Total Initial Imperfection with Plastic Hinge at End of Casing: $\theta_{i,OYL}$ — $\theta_{i,OYL}$: 0.0171 rad

$\theta_{i,OYL} = \delta_m/L_0 + \delta_g/L_g + \theta_0$

Moment Amplification Factor to Account for 2nd Order Effects: $\delta_{s,OYL}$ — $\delta_{s,OYL}$: 1.3122

$\delta_{s,OYL} = 1/(1 - N^*_{cu}/N^B_{cr}) \geq 1.0$

Reports as "Error" if result is is less than 1.0, which occurs when applied load (N^*_{cu}) exceeds BRB elastic buckling capacity (N^B_{cr}).

Notional Load Applied at Brace End: $N_{OYL} = N^*_{cu} \cdot \theta_{i,OYL} + F_{Add'l-OOP}/2$ — N_{OYL}: 5.3 kip *(23 kN)*

$$N\xi L_0 \delta_s \leq (1-2\xi) M_p^g + M_p^r$$ Iterative Solution

$$\frac{N\xi L_0 \delta_s}{(1-2\xi) M_p^g + M_p^r} \leq 1.0$$ DCR

Demand: $D = N_{OYL} \xi L_0 \delta_{s,OYL}$	**D:**	**126.0 k-in**	*(14.2 kN-m)*
Capacity: $C_{top} = (1-2\xi) M^g_{p,top} + M^r_{p,top}$	**C_{top}:**	**477.9 k-in**	*(54.0 kN-m)*
$C_{bot} = (1-2\xi) M^g_{p,bot} + M^r_{p,bot}$	**C_{bot}:**	**477.7 k-in**	*(54.0 kN-m)*
Stability Index (SI): $D/C_{OYL} = D/[\min\{C_{top}, C_{bot}\}]$	**SI_{OYL}:**	**0.26**	**OK**

2.2.4 Under the Yield Line (UYL) Global Buckling Capacity

Total Initial Imperfection with Plastic Hinge at End of Casing: $\theta_{i,UYL}$ — $\theta_{i,UYL}$: 0.0271 rad

$\theta_{i,UYL} = \delta_m/L_0 + 2 \cdot \delta_g/L_g + \theta_0$

Moment Amplification Factor to Account for 2nd Order Effects: $\delta_{s,OYL}$

$\delta_{s,UYL,top} = 1/(1 - N^*_{cu}/N_{e,top}) \geq 1.0$ — $\delta_{s,UYL,top}$: 1.008

$\delta_{s,UYL,bot} = 1/(1 - N^*_{cu}/N_{e,bot}) \geq 1.0$ — $\delta_{s,UYL,bot}$: 1.009

Reports as "Error" if result is is less than 1.0, which occurs when applied load (N^*_{cu}) exceeds gusset elastic buckling capacity (N_e).

Notional Load Applied at Brace End: $N_{UYL} = N^*_{cu} \cdot \theta_{i,UYL} + F_{Add'l-OOP}/2$ — N_{UYL}: 8.3 kip *(37 kN)*

Total Length, $L_T = L_{ave,bot} + L_0 + L_{ave,Top}$ — L_T: 132.11 in *(3356 mm)*

Destabilizing Factor for UYL Method: $\eta = (1 - L_0/L_T)/2$ — η: 0.026

$$N L_{ave} \delta_s \theta = (2-2\eta) M_p^g \Rightarrow M_p^g \geq \frac{N L_{ave} \delta_s}{(2-2\eta)} = M_y^*$$ Iterative Solution

$$\frac{M_y^*}{M_p^g} \leq 1.0$$ Stability Index (SI)

$M^*_{y,top} = N_{UYL} \cdot L_{ave,top} \cdot \delta_{s,UYL,top}/(2-2\eta)$	**$M^*_{y,top}$:**	**14.6 k-in**	*(1.6 kN-m)*
$M^*_{y,bot} = N_{UYL} \cdot L_{ave,bot} \cdot \delta_{s,UYL,bot}/(2-2\eta)$	**$M^*_{y,bot}$:**	**15.0 k-in**	*(1.7 kN-m)*
DCR = $\max\{M^*_{y,top}/M^g_{p,top}, M^*_{y,top}/M^g_{p,top}\}$	**SI_{top}:**	**0.05**	**OK**
	SI_{bot}:	**0.05**	**OK**
	SI_{UYL}:	**0.05**	**OK**

Interaction Equation Form of General Solution:

$$\left(\frac{N_{cu}^*}{\phi N_s^g}\right)^2 + \frac{M_y^*}{\lambda \phi M_{zy}^g} \le 1 \qquad \text{Interaction Equation}$$

*Interaction equation will produce results that equal 1.0 at for same value of N*cu as the UYL DCR equation but it is less senstive (less volatile) to small changes in N*cu. Neither the DCR nor the Int Eqn produces results that are linear with respect to N*cu (i.e. a Int Eqn value = 0.5 is not capableof handling 2x N*cu). An interaction eqn solution is not possible for the OYL method.*

Int_{top}:	**0.17**	**OK**
Int_{bot}:	**0.17**	**OK**
Int_{UYL}:	**0.17**	**OK**

2.2.5 NLYL Summary

Global stability in the Asymmetrical Mode is controlled by the lesser of the capacities determined by the OYL and UYL methods.

OYL:	**SI_{OYL}:**	**0.26**	**OK**
UYL:	**SI_{UYL}:**	**0.05**	**OK**
UYL_{INT}:	**Int_{UYL}:**	**0.17**	**OK**

Summary: **OK**

2.2.6 References

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Zaboli, B. Clifton, G.C. & Cowie K. (2018), BRBF and CBF gusset plates: Out-of-plane stability design using a simplified notional load yield line (NLYL) method. Journal of the Structural Engineering Society of NZ, 31(1), 64-76

CASING BUCKLING CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Casing Profile				Section 2.0 Design Criteria										Section 2.1 Euler Buckling		
EOR-ID	Line	Grids	Lvls	Mark	Qty	Type	H_c	W_c	t_c	L_{gg}	β	ω	$P_{ysc,max}$	$F_{ysc,max}$	A_{SC}	P_{uC}	E	k	I_c	I_{lg}	FS	$\frac{I_{lg}'}{I_c}$
#		#	#	#	#		in	in	in	in			kips	ksi	in²	kips	ksi		in⁴	in⁴	Buckling	
BRB-4.00	3+	E.5-D.9	2	**1901**	1	t	8	8	0.2500	115.13	1.20	1.39	184	46.0	4.0	307	29000	1.0	70.7	18.0	1.27	0.25
BRB-4.00	3+	E.5-D.9	1	**1902**	1	t	8	8	0.2500	117.13	1.19	1.38	184	46.0	4.0	302	29000	1.0	70.7	18.4	1.27	0.26

	Section 2.2.1 NLYL Method Design Criteria																--
	Overall Brace Length					Critical Gusset Dimensions for Top Gusset											
EOR-ID	L_0	$F_{Add'l-OOP}$	θ_0	δ_m/L_0	δ_g/L_g	Is Chev Top	Stiffened Gusset Top	$W_{stiff,g,top}$	$t_{stiff,g,top}$	$t_{g,top}$	$Z_{g,top}$	$F_{yg,top}$	a_{top}	b_{top}	c_{top}	$L_{b,top}$	$L_{c,top}$
#	in	kip	rad	rad	rad	T/F	T/F	in	in	in	in³	ksi	in	in	in	in	in
BRB-4.00	125.3	0.0	0.005	0.002	0.010	FALSE	FALSE	-	-	1.0	6.3	50	5.7	1.1	4.9	12.3	13.0
BRB-4.00	127.3	0.0	0.005	0.002	0.010	FALSE	FALSE	-	-	1.0	6.3	50	5.7	1.0	4.8	12.3	12.8

CASING BUCKLING CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Section 2.2.1 NLYL Method Design Criteria												
						Critical Gusset Dimensions for bottom Gusset												
EOR-ID	Line	Grids	Lvls	Mark	Qty	Is V Bot	Stiffened Gusset Bot	$W_{stiff,g,bot}$	$t_{stiff,g,bot}$	$t_{g,bot}$	$Z_{g,bot}$	$F_{yg,bot}$	a_{bot}	b_{bot}	c_{bot}	$L_{b,bot}$	$L_{c,bot}$	
#		#	#	#	#	T/F	T/F	in	in	in	in³	ksi	in	in	in	in	in	
BRB-4.00	3+	E.5-D.9	2	**1901**	1	FALSE	FALSE	-	-	1.0	6.3	50.0	5.8	1.2	4.6	12.3	13.0	
BRB-4.00	3+	E.5-D.9	1	**1902**	1	FALSE	FALSE	-	-	1.0	7.2	50.0	6.8	1.6	7.2	13.8	14.9	

EOR-ID	--					Section 2.2.1 NLYL Method Design Criteria											--
	Core Dimensions and Properties					Lug and Bolt pattern Dimensions											
	F_{usc}	W_t	t_{sc}	L_{in}	OOP Embed Ratio	W_L	W_1	L'_{Lg}	a	c	t_L	F_{yL}	F_{uL}	n_i	n_o	s	e_{perp}
#	ksi	in	in	in	Ratio	in	in	in	in	in	in	ksi	ksi	#	#	in	in
BRB-4.00	66.0	4.0	1.000	9.7	2.4	7.5	5.0	11.3	4.0	3.0	0.6	50.0	65.0	3	0	4.0	1.6
BRB-4.00	66.0	4.0	1.000	9.6	2.4	7.5	4.9	11.3	4.0	3.0	0.6	50.0	65.0	3	0	4.0	1.6

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CASING BUCKLING CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Section 2.2.1 NLYL Method Design Criteria								
						Casing Size and Properties							Strength Factors	
EOR-ID	Line	Grids	Lvls	Mark	Qty	Casing	F_{yc}	E_{casing}	Casing is Sq/Rect?	H_c	W_c	t_c	F_{PUC}	ϕ
#		#	#	#	#	Size	ksi	ksi		in	in	in		
BRB-4.00	3+	E.5-D.9	2	**1901**	1	t8x1/4	46.0	29000	TRUE	8.0	8.0	0.25	1.00	1.0
BRB-4.00	3+	E.5-D.9	1	**1902**	1	t8x1/4	46.0	29000	TRUE	8.0	8.0	0.25	1.00	1.0

		Section 2.2.2 NLYL Global Stability Method													
		General Design Parameters													
EOR-ID	Mark	N^*_{cu}	ξL_0	ξ	λ_{top}	λ_{bot}	N^B_{cr}	L_{Br}	$\theta_{disp,top}$	$\theta_{disp,bot}$	$b_{ga,top}$	$b_{ga,bot}$	$L_{ave,top}$	$L_{ave,bot}$	$N^g_{s,top}$
#	#	kip	in				kip	in	degree	degree	in	in	in	in	kip
BRB-4.00	**1901**	307	18.25	0.15	1.00	1.00	1290	8.0	40	40	17.7	17.7	3.4	3.5	884
BRB-4.00	**1902**	302	18.25	0.14	1.00	1.00	1250	8.0	40	40	17.7	17.7	3.4	4.2	884

		--										
		Gusset Capacity										
EOR-ID	Mark	$N^g_{s,bot}$	$N_{e,top}$	$N_{e,bot}$	$b_{gf,top}$	$b_{gf,bot}$	$Z_{g,top}$	$Z_{g,bot}$	$M^g_{zy,top}$	$M^g_{zy,bot}$	$M^g_{p,top}$	$M^g_{p,bot}$
#	#	kip	kip	kip	in	in	in³	in³	kip-in	kip-in	kip-in	kip-in
BRB-4.00	**1901**	884	36953	34824	25.3	25.3	6.32	6.32	316	316	278	278
BRB-4.00	**1902**	884	37402	23987	25.0	28.8	6.26	7.19	313	360	276	318

		Section 2.2.2 NLYL Global Stability Method						--	
		Restrainer Capacity Based on Moment Capacity of Neck							
EOR-ID	Mark	N^n_{wy}	N^n_y	N^n_u	Z_{WT}	Z_{W1}	M^n_{zy}	$M_p^{r\text{-}neck,top}$	$M_p^{r\text{-}neck,bot}$
#	#	kip	kip	kip	in³	in³	kip-in	kip-in	kip-in
BRB-4.00	**1901**	249	433	588	4.00	4.04	386	281	281
BRB-4.00	**1902**	244	428	581	4.00	3.97	382	279	279

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CASING BUCKLING CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR

Job: 6903

Specimen ID and Location						Section 2.2.2 NLYL Global Stability Method														
						Restrainer Capacity Based on Mom Txfr Cap of Rest													Controlling Rest Cap	
EOR-ID	Line	Grids	Lvls	Mark	Qty	Z_{rp}	M^r_{zy}	α^r_p	a	δ_0	δ_y	$K_{Rr1,Round}$	$K_{Rr1,Rect}$	$K_{Rr2,Rect}$	$\theta_{y,Round}$	θ'_{y1}	θ_{y2}	$M_p^{r\text{-}rest}$	$M^r_{p,bot}$	$M^r_{p,top}$
#		#	#	#	#	in³	kip-in		in	in	in	(k-in)/rad	(k-in)/rad	(k-in)/rad	rad	rad	rad	kip-in	kip-in	kip-in
BRB-4.00	3+	E.5-D.9	2	**1901**	1	22.5	1036	1.50	1.51	2.99	3.03	148989	28213	37260	0.0044	0.000034	0.0142	795	281	281
BRB-4.00	3+	E.5-D.9	1	**1902**	1	22.5	1036	1.50	1.55	3.03	3.07	126682	25621	36153	0.0050	0.000035	0.0146	789	279	279

	Section 2.2.3 Over the Yield Line (OYL) Global Buckling Capacity								Section 2.2.4 Under the Yield Line (UYL) Global Buckling Capacity			
	Over the Yield Line Buckling (Asymm Mode)								Under the Yield Line Buckling (Asymm Mode)			
Mark	$\theta_{i,OYL}$	$\delta_{s\ OYL}$	N_{OYL}	Stability Index Max	Demand	Capacity$_{top}$	Capacity$_{bot}$	Stability Index	$\theta_{i,UYL}$	$\delta_{s,UYL,bot}$	$\delta_{s,UYL,top}$	N_{UYL}
#	rad	*M Mag factor*	kip	OYL	kip-in	kip-in	kip-in	OYL	rad	*M Mag factor*	*M Mag factor*	kip
1901	0.017	1.31	5.3	**0.26**	126.0	477.9	477.7	0.3	0.03	1.01	1.01	8.3
1902	0.017	1.32	5.2	**0.26**	125.0	476.1	505.5	0.3	0.03	1.01	1.01	8.2

	Section 2.2.4 Under the Yield Line (UYL) Global Buckling Capacity										Section 2.2.5			
	Demand Capacity Ratio							Interaction Equation			NLYL Summary			
Mark	L_T	η	$M^*_{y,top}$	$M^*_{y,bot}$	Stability Index Top	Stability Index Bot	Stability Index UYL	Int_{top}	Int_{bot}	Int_{UYL}	SI_{OYL}	SI_{UYL}	Int_{UYL}	Check ≤ 1
#	in		kip-in	kip-in										OK/NG
1901	132.1	0.03	14.6	15.0	0.05	0.05	0.05	0.2	0.2	0.2	0.26	0.05	0.17	OK
1902	134.8	0.03	14.3	17.9	0.05	0.06	0.06	0.2	0.2	0.2	0.26	0.06	0.17	OK

Reed College Central Plant Upgrade

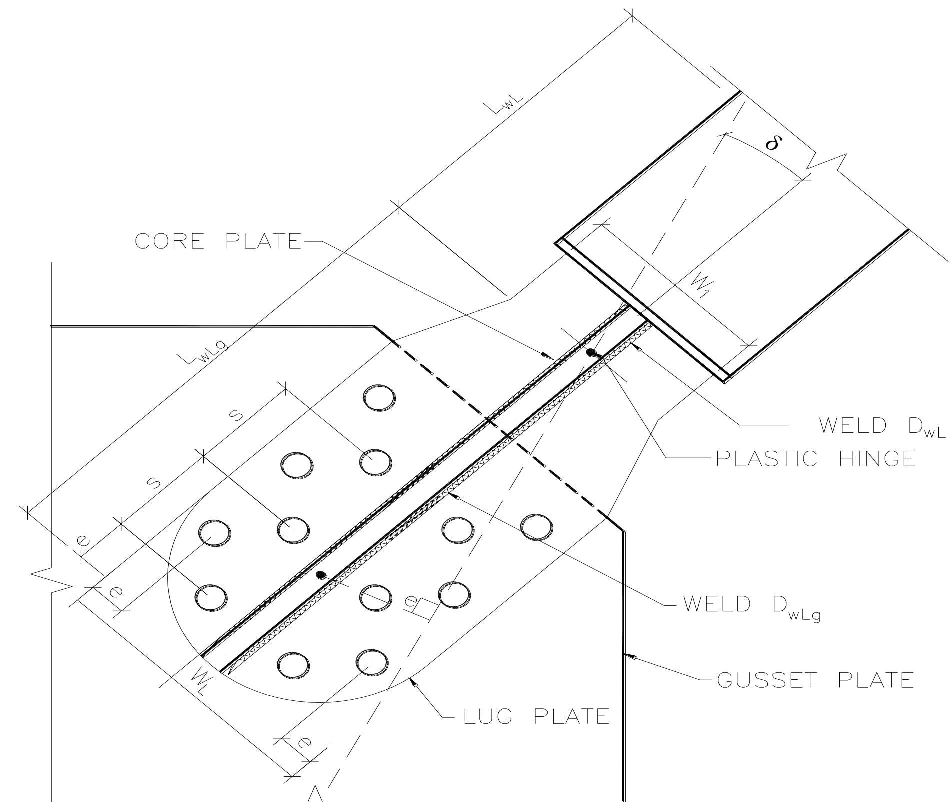
Calculation Submittal Package

Description

Section 3. **Brace End Connection Sample Calculation**
End Connection Summary Table

Brace Connection

Example Mark #: 1901
Line 3+, Grid E.5-D.9, Level 2



WELD CONFIGURATION

3.0 DESIGN CRITERIA Example Mark #: 1901

Compresssion Strength Adjustment Factor	β:	1.2	
Strain Hardening Adjustment Factor	ω:	1.39	
Area of (Yielding) Steel Core (as Spec'd on Drawings)	A_{sc}:	4.00 in²	*(2581 mm²)*
Upper Bound Compressive Yield Stress of Core Material	$F_{y\text{-}max}$:	46 ksi	*(317 MPa)*
Note: *Ry factor not applicable since Fy of core material will be established based on results of coupon tests.*			
Core Plate Ultimate Tensile Strength *Based on Coupon Test History*	F_{usc}:	66 ksi	*(455 MPa)*
Axial Design Load: Connection Strain Hardening Factor	CF:	1.00	
$P_{ysc\text{-}max} = A_{sc} \cdot F_{y\text{-}max}$	$P_{ysc\text{-}max}$:	184.0 kip	*(818 kN)*
$P_{uT\text{-}max} = CF \cdot P_{ysc\text{-}max} \cdot \omega$	$P_{uT\text{-}max}$:	255.8 kip	*(1138 kN)*
$P_{uC\text{-}max} = CF \cdot P_{ysc\text{-}max} \cdot \beta \cdot \omega$	$P_{uC\text{-}max}$:	306.9 kip	*(1365 kN)*

Core Dimensions:	At Lug Connection	W_t:	4.00 in	*(102 mm)*
Lug Dimensions:	Width of Lug Plate	W_L:	7.50 in	*(191 mm)*
	At Extension Exit from Casing (Transv. Stiffener)	W_1:	4.98 in	*(127 mm)*
	Plate Edge to CL of Bolt	e:	1.63 in	*(41 mm)*
Bolt Specifications:	Number of Bolts in Inside Row	n_i:	3	
	Number of Bolts in Outside Row	n_o:	0	
	Total Number of Bolts at Each End $2(n_i + n_o)$	n_b:	6	
	Bolt Spacing	s:	4.00 in	*(102 mm)*
	Bolt Gage	g:	0.00 in	*(0 mm)*
	Bolt Diameter	d_b:	1.125 in	*(29 mm)*
	Standard Bolt Hole $d_s = d_b + x_{std}$ x_{std} = 1/8 " (3.2mm)	d_s:	1.250 in	*(32 mm)*
	Slip Plane (Single Shear = 1, Double Shear = 2)	n_s:	2	

3.1.0 Bolt Shear - LRFD J3.6

LRFD Resistance Factor	ϕ_v:	0.75	
Bolt Shear Strength $F_{nv} = F_{ub}$*0.625*0.9*TCF*CLF *0.625 = V//T Ratio, 0.9 = Base Connection Length Factor for Non-Uniformity of Loading*	F_{nv}:	64.8 ksi	*(447 MPa)*
Bolt Grade and Ultimate Tensile Strength for Shear **Gr A490/F3148**	F_{ub}:	144 ksi	*(993 MPa)*
Bolt Thread Condition (N = Include, X = Exclude)	BTC:	N	
Thread Condition Factor TCF: IF BTC = "X" then 1.0, IF BTC = "N" then 0.8	TCF:	0.80	
Connection Length Factor Table J3.2 Note b *(For L'_{Lg} > 38")*	CLF:	1.00	
Connection Length	L'_{Lg}:	8.00 in	*(203 mm)*
Bolt Shear Capacity $\phi r_v = \phi_v F_{nv} n_s A_b$	ϕr_v:	96.6 kip	*(430 kN)*
Bolt Area $A_b = \pi d_b^2/4$	A_b:	0.994 in²	*(641 mm²)*
Bolt Group Shear Strength $\phi R_v = (n_i + n_o) \cdot 2 \cdot \phi r_v$	ϕR_v:	579.7 kip	*(2579 kN)*
Demand-Capacity Ratio $DCR_{Shear} = P_{uc\text{-}max}/R_v$	DCR_{Shear}:	0.53	

3.2.0 Bolt Friction - LRFD J3.8

LRFD Resistance Factor for Slip	ϕ_s:	0.85	
Min Bolt Tensile Area $A_{Tb\_min} = \pi/4 \cdot (d-0.9743/n)^2$, where n = threads/in	A_{Tb_min}:	0.763 in²	*(492 mm²)*
Factor for fillers	h_f:	1.00	
Mean Slip Coefficient	μ:	0.30	
Bolt Pretension Adjustment Factor, f_T **Gr A490/F3148** *Accounts for fact that some bolt grades, such as F3148, have a specified Tb greater than that associated with Fub alone. If the combined grade A490/F3148 is specified and A490's are used, then Tb would be equal to that for the grade and FnV would be conservatively low by $1/f_T$.*	f_T:	1.04	
Fastener Tension $T_b = 0.7 \cdot f_T \cdot F_{ub} \cdot A_{Tb\_min}$	T_b:	80 kip	*(356 kN)*
Bolt Tension Factor	D_u:	1.13	
Bolt Slip Capacity $\phi r_s = \phi_s \mu D_u h_f T_b n_s$	ϕr_s:	46.2 kip	*(205 kN)*
Bolt Group Slip Capacity $\phi R_s = n_b \cdot \phi r_s$	ϕR_s:	277.1 kip	*(1233 kN)*
Demand-Capacity Ratio $DCR_{Slip} = P_{ysc\text{-}max}/\phi R_s$	DCR_{Slip}:	0.66	

3.3.0 Bearing Strength at Bolt Holes - LRFD J3.10

LRFD Resistance Factor for Bearing or Tearout	$\phi_{brg\text{-}V}$:	0.75	

3.3.1 Bearing Strength at Gusset Plate

Additional Diameter of Hole in Gusset Plate	ovs_g:	0.19 in	*(5 mm)*
Thickness of Gusset Plate:	t_g:	1.00 in	*(25 mm)*
Thickness of Repad Plate for Design:	t_r:	0.00 in	*(0 mm)*
Gusset Plate Tensile Strength	F_{ug}:	65 ksi	*(448 MPa)*
Clear Distance Between Edge of Bolt Holes $L_{csg} = s - (d_s + ovs_g)$	L_{csg}:	2.563 in	*(65 mm)*
Number of Occurances of L_{cs} per Side If n_o = 0 Then $n_{cs} = n_i - 1$, Otherwise $n_{cs} = n_i - ½ + n_o - 1$	n_{cs}:	2.0	

Clear Distance Between Plate Edge and Bolt Hole

$L_{ceq} = e - (d_s + ovs_q)/2$ | L_{ceq}: 0.906 in *(23 mm)*

Number of Occurances of L_{ce} per Side

If $n_o = 0$ Then $n_{ce} = 1$, Otherwise $n_{ce} = 2$ | n_{ce}: 1.0

Clear Distance of Bolt Group $L_{cq} = 2 \cdot (n_{ce} \cdot L_{ceq} + n_{cs} \cdot L_{csq})$ | L_{cq}: 12.06 in *(306 mm)*

Gusset Plate Bearing Strength at Bolt Holes

$\phi R_{n\text{-}brq}$ = min of: | $\phi R_{n\text{-}brq}$: 705.7 kip *(3139 kN)*

$\phi_{brq} 1.2 \cdot L_{cq} \cdot (t_q+2t_r) \cdot F_{uq}$ = 705.7 kip (Clear Dist/Tear-Out Controlled)

$\phi_{brq} 2.4 \cdot d_b \cdot n_b \cdot (t_q+2t_r) \cdot F_{uq}$ = 789.8 kip (Bearing/Ovalization Controlled)

Bearing Strength Stress Ratio

$DCR_{brg\text{-}g} = P_{uc\text{-}max}/\phi_{brg} R_{n\text{-}brg}$ | $DCR_{brg\text{-}g}$: 0.43

Slip checked at serviceability limit state.

3.3.2 Bearing Capacity at Lug Plates

Additional Diameter of Holes in Lug Beyond Standard Hole Diam | ovs_L: 0.00 in *(0 mm)*

Lug Plate Thickness | t_L: 0.63 in *(16 mm)*

Lug Plate Tensile Strength | F_{uL}: 65 ksi *(448 MPa)*

Clear Distance Between Edge of Bolt Holes

$L_{csL} = s - (d_s + ovs_L)$ | L_{csL}: 2.750 in *(70 mm)*

Clear Distance Between Plate Edge and Bolt Hole

$L_{ceL} = e - (d_s + ovs_q)/2$ | L_{ceL}: 1.000 in *(25 mm)*

Clear Distance of Bolt Group $L_{cL} = 2 \cdot (n_{ce} \cdot L_{ceL} + n_{cs} \cdot L_{csL})$ | L_{cL}: 13.00 in *(330 mm)*

Lug Plate Bearing Strength at Bolt Holes

$\phi R_{n\text{-}brg}$ = min of: | $\phi R_{n\text{-}brg}$: 950.6 kip *(4229 kN)*

$\phi_{brq} 1.2 \cdot L_{cL} \cdot t_L \cdot F_{uL} \cdot n_s$ = 950.6 kip *(4229 kN)* (Clear Dist/Tear-Out Controlled)

$\phi_{brq} 2.4 \cdot d_b \cdot n_b \cdot t_L \cdot F_{uL} \cdot n_s$ = 987.2 kip *(4391 kN)* (Bearing/Ovalization Controlled)

Bearing Strength Stress Ratio

$DCR_{brg\text{-}L} = P_{uc\text{-}max}/\phi_{brg} R_{n\text{-}brg}$ | $DCR_{brg\text{-}L}$: 0.32

3.3.3 Combined Bolt Bearing/Tear-out/Bolt Shear at Lug and Gusset (Bolt by Bolt Method)

Extreme (Edge) Bolts - "Edge Bolts" Use Lceg, "Field Bolts" use Lcsg

Brace in Tension (T):

Free Edge Bolt when: Lug Field Bolt (LFB) or Gusset Edge Bolt (GEB)

Other Edge Bolt when: Lug Edge Bolt (LEB) or Gusset Edge Bolt (GFB)

Brace in Compression (C):

Free Edge Bolt when: Lug Field Bolt (LFG) or Gusset Edge Bolt (GFB)

Other Edge Bolt when: Lug Field Bolt (LFG) or Gusset Edge Bolt (GFB)

At all Conditions Check Min of Bearing, Edge Tear-out, and Bolt Shear

Gusset

G. Edge Bolts on n_i Row: $\phi_{brq\text{-}V} \cdot (t_q+2t_r) \cdot F_{uq} \cdot MIN[1.2 \cdot L_{ceq}, 2.4 \cdot d_b]$	GEB_{ni}:	53.0 kip	*(236 kN)*
G. Edge Bolts on n_o Row: $\phi_{brq\text{-}V} \cdot (t_q+2t_r) \cdot F_{uq} \cdot MIN[1.2 \cdot (L_{ceq}+0.5s), 2.4 \cdot d_b]$	GEB_{no}:	0.0 kip	*(0 kN)*
GEB Capacity = 0 Unless $n_o > 0$			
G. Field Bolts on n_i Row: $\phi_{brq\text{-}V} \cdot (t_q+2t_r) \cdot F_{uq} \cdot MIN[1.2 \cdot L_{csq}, 2.4 \cdot d_b]$	GFB_{ni}:	131.6 kip	*(585 kN)*
G. Field Bolts on n_o Row: $\phi_{brq\text{-}V} \cdot (t_q+2t_r) \cdot F_{uq} \cdot MIN[1.2 \cdot (L_{csq}+0.5s), 2.4 \cdot d_b]$	GFB_{no}:	0.0 kip	*(0 kN)*
GFB Capacity = 0 Unless $n_o > 0$			

Lug

L. Edge Bolts on n_i Row: $\phi_{brq\text{-}V} \cdot t_L \cdot F_{uL} \cdot MIN[1.2 \cdot L_{ceL}, 2.4 \cdot d_b]$*2Lugs	LEB_{ni}:	73.1 kip	*(325 kN)*
L. Edge Bolts on n_o Row: $\phi_{brq\text{-}V} \cdot t_L \cdot F_{uL} \cdot MIN[1.2 \cdot (L_{ceL}+0.5s), 2.4 \cdot d_b]$*2Lugs	LEB_{no}:	0.0 kip	*(0 kN)*
LEB Capacity = 0 Unless $n_o > 0$			
L. Field Bolts on n_i Row: $\phi_{brq\text{-}V} \cdot t_L \cdot F_{uL} \cdot MIN[1.2 \cdot L_{csL}, 2.4 \cdot d_b]$*2Lugs	LFB_{ni}:	164.5 kip	*(732 kN)*
L. Field Bolts on n_o Row: $\phi_{brq\text{-}V} \cdot t_L \cdot F_{uL} \cdot MIN[1.2 \cdot (L_{csL}+0.5s), 2.4 \cdot d_b]$*2Lugs	LFB_{no}:	0.0 kip	*(0 kN)*
LFB Capacity = 0 Unless $n_o > 0$			

Sum of Extreme Bolt Capacities (at each end of each line):

Tension: 2[MIN(LFB,ϕr_v or GEB,ϕr_v) + MIN(LEB,ϕr_v or GFB,ϕr_v)]	$\phi R_{n\text{-}TE}$:	252.3 kip	*(1122 kN)*
Compression: 2[2*MIN(LFB,ϕr_v or GFB,ϕr_v)]	$\phi R_{n\text{-}CE}$:	386.5 kip	*(1719 kN)*
Note Brace in Compression Results in "Field Bolt" Condition for all Extreme Bolts			

Sum of Remaining Field Bolt Capacities:

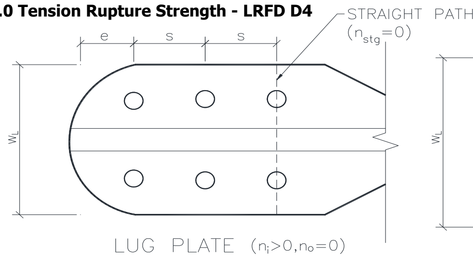
At Gusset: 2[MAX(n_i-2,0)*min(GFB_{ni},ϕr_v) + MAX(n_o-2,0)*min(GFB_{no},ϕr_v)]:	$\phi R_{n\text{-}GF}$:	193.2 kip	*(860 kN)*
At Lug: 2[MAX(n_i-2,0)*min(LFB_{ni},ϕr_v) + MAX(n_o-2,0)*min(LFB_{no},ϕr_v)]:	$\phi R_{n\text{-}LF}$:	193.2 kip	*(860 kN)*

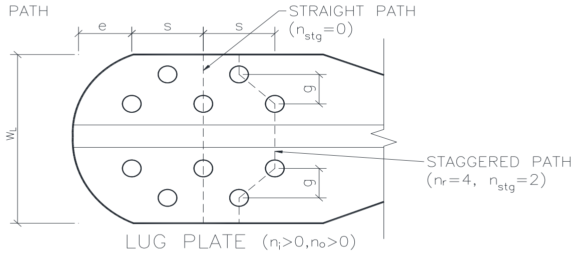
Total Tension Capacity at Gusset:	$\phi R_{n\text{-}TG}$:	445.5 kip	*(1982 kN)*
Total Compression Capacity at Gusset:	$\phi R_{n\text{-}CG}$:	579.7 kip	*(2579 kN)*
Total Tension Capacity at Lug:	$\phi R_{n\text{-}TL}$:	445.5 kip	*(1982 kN)*
Total Compression Capacity at Lug:	$\phi R_{n\text{-}CL}$:	579.7 kip	*(2579 kN)*

Bearing/Tearout Strength Stress Ratio:

$DCR_{brg/Tear\text{-}G} = MAX(P_{uc\text{-}max}/\phi R_{n\text{-}CG}, P_{uT\text{-}max}/\phi R_{n\text{-}TG})$	$DCR_{brg/Tear\text{-}G}$:	0.57	
$DCR_{brg/Tear\text{-}L} = MAX(P_{uc\text{-}max}/\phi R_{n\text{-}CL}, P_{uT\text{-}max}/\phi R_{n\text{-}TL})$	$DCR_{brg/Tear\text{-}L}$:	0.57	

3.4.0 Tension Rupture Strength - LRFD D4





LRFD Resistance Factor for Tension Rupture	ϕ_{tr}:	0.75	
Thickness of Yielding Core	t_{sc}:	1.00 in	*(25 mm)*
Shear Lag Factor (Table D3.1 Case 2)	U:	0.95	
Overslot in Lug for Gusset	OSL_g:	0.19 in	*(5 mm)*

Net Area Subject to Tension (Use AISC D3 for Staggered Bolt Net Area)

Number of Rows of Bolts If n_o = 0, then n_r = 2, otherwise n_r = 4	n_r:	2	
Stagger Adjustment Term (AISC D4.3b)			
If n_o = 0, then stg = 0, otherwise stg = $(s/2)^2/(4g)$	stg	0.00 in	*(0 mm)*
Number of Staggers $n_{stg} = n_r - 2$	n_{stg}:	0	
Net Area of Lug Transverse to Line of Force			
Staggerd Path: $A_{ntLb1} = 2t_L \cdot [W_L - n_r \cdot (d_s + ovs_L + 1/16) + n_{stg} \cdot stg]$	A_{ntLb1}:	6.09 in²	*(3931 mm²)*
Straight Path: $A_{ntLbx} = 2t_L \cdot [W_L - 2 \cdot (d_s + ovs_L + 1/16)]$	A_{ntLbx}:	6.09 in²	*(3931 mm²)*
$A_{ntLb} = \min(A_{ntLb1}, A_{ntLbx})$	A_{ntLb}:	6.09 in²	*(3931 mm²)*
Net Area of Lug Stiffener			
$A_{ntLc} = t_{sc} \cdot [W_t - (t_g + 2 \cdot t_L + OSL_g)]$	A_{ntLc}:	1.56 in²	*(1008 mm²)*

Lug Plate Tension Rupture Strength

$\phi R_{n\text{-}tr} = \phi_{tr} \cdot U \cdot (F_{uL} \cdot A_{ntLb} + F_{usc} \cdot A_{ntLc})$	$\phi R_{n\text{-}tr}$:	355.1 kip	*(1579 kN)*

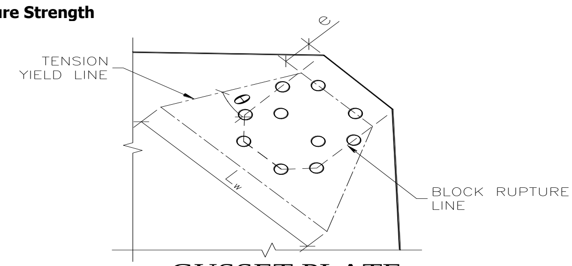
Tension Rupture Stress Ratio

$DCR_{tr} = P_{ut\text{-}max}/\phi R_{n\text{-}tr}$	DCR_{tr}:	0.72	

3.5.0 Block Rupture Strength - LRFD J4.3

LRFD Resistance Factor	ϕ_{blk}:	0.75	
Block Shear Shear-Lag Factor	U_{bs}:	1.00	

3.5.1 Gusset Block Rupture Strength



GUSSET PLATE

Gusset Plate Yield Strength	F_{yg}:	50 ksi	*(345 MPa)*
Gusset Plate Edge Distance	e:	1.63 in	*(41 mm)*

Gross Area Subject to Shear

If	Then			
$n_o = 0$	$L_{qv\text{-}g} = (n_i - 1)\cdot s + e$	$L_{qv\text{-}g}$:	9.63 in	*(244 mm)*
$n_o = n_i$	$L_{qv\text{-}g} = (n_o - 1)\cdot s + \sqrt{(s/2)^2 + g^2} + e$			
Otherwise	$L_{qv\text{-}g} = (n_o - ½)\cdot s + \sqrt{(s/2)^2 + g^2} + e$			

$A_{qv\text{-}g} = 2\cdot L_{qv\text{-}g}\cdot(t_g + 2\cdot t_r)$ — $A_{qv\text{-}g}$: 19.25 in² *(12419 mm²)*

Net Area Subject to Shear

Number of Bolt Holes in Shear Path

If $n_o = 0$, Then $n_{na\text{-}g} = n_i - ½$, Otherwise $n_{na\text{-}g} = n_o + ½$ — $n_{na\text{-}g}$: 2.5

Length to be RL $L_{nv\text{-}g} = (d_s + ovs_g + 1/16)\cdot n_{na\text{-}g}$ — $L_{nv\text{-}g}$: 3.75 in *(95 mm)*

$A_{nv\text{-}g} = A_{qv\text{-}g} - 2\cdot L_{nv\text{-}g}\cdot(t_g + 2\cdot t_r)$ — $A_{nv\text{-}g}$: 11.75 in² *(7581 mm²)*

Gross Area Subject to Tension

$L_{qt\text{-}g} = W_L - 2\cdot(e + g)$ — $L_{qt\text{-}g}$: 4.25 in *(108 mm)*

Note: g = 0 if $n_o = 0$

$A_{qt\text{-}g} = L_{qt\text{-}g}\cdot(t_g + 2\cdot t_r)$ — $A_{qt\text{-}g}$: 4.25 in² *(2742 mm²)*

Net Area Subject to Tension

$L_{nt\text{-}g} = (d_s + ovs_g + 1/16)$ — $L_{nt\text{-}g}$: 1.50 in *(38 mm)*

$A_{nt\text{-}g} = A_{qt\text{-}g} - L_{nt\text{-}g}\cdot(t_g + 2\cdot t_r)$ — $A_{nt\text{-}g}$: 2.75 in² *(1774 mm²)*

Gusset Plate Block Rupture Strength

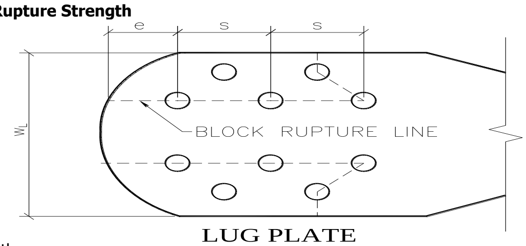
Shear Rupture Term	$0.6\cdot F_{ug}\cdot A_{nv\text{-}g}$	SRT:	458.3 kip	*(2038 kN)*
Shear Yield Term	$0.6\cdot F_{yg}\cdot A_{qv\text{-}g}$	SYT:	577.5 kip	*(2569 kN)*
Tension Rupture Term	$U_{bs}\cdot F_{ug}\cdot A_{nt\text{-}g}$	TRT:	178.8 kip	*(795 kN)*

$\phi R_{n\text{-}blk\text{-}g} = \phi[\min(SRT, SYT) + TRT]$ — $\boxed{\phi R_{n\text{-}blk\text{-}g}\text{: } 477.8\text{ kip}}$ *(2125 kN)*

Block Shear Strength Stress Ratio at Gusset

$DCR_{blk\text{-}g} = P_{ut\text{-}max}/\phi R_{n\text{-}blk\text{-}g}$ — $\boxed{DCR_{blk\text{-}g}\text{: } 0.54}$

3.5.2 Lug Plates Block Rupture Strength



LUG PLATE

Lug Plate Yield Strength — F_{yL}: 50 ksi *(345 MPa)*

Gross Area Subject to Shear

If	Then			
$n_o = 0$	$L_{qv\text{-}L} = (n_i - 1)\cdot s + e$	$L_{qv\text{-}L}$:	9.63 in	*(244 mm)*
Otherwise	$L_{qv\text{-}L} = (n_i - 1)\cdot s + \sqrt{(s/2)^2 + g^2} + e$			

$A_{qv\text{-}L} = 4\cdot L_{qv\text{-}L}\cdot t_L$ — $A_{qv\text{-}L}$: 24.06 in² *(15524 mm²)*

Net Area Subject to Shear

If $n_o = 0$, Then $n_{na\text{-}L} = n_i - ½$, Otherwise $n_{na\text{-}L} = n_i + ½$ — $n_{na\text{-}L}$: 2.5

$L_{nv\text{-}L} = (d_s + ovs_L + 1/16)\cdot n_{na\text{-}L}$ — $L_{nv\text{-}L}$: 3.28 in *(83 mm)*

$A_{nv\text{-}L} = A_{qv\text{-}L} - 4\cdot L_{nv\text{-}L}\cdot t_L$ — $A_{nv\text{-}L}$: 15.86 in² *(10232 mm²)*

Gross Area Subject to Tension

$A_{qt\text{-}L} = 4\cdot e\cdot t_L$ — $A_{qt\text{-}L}$: 4.06 in² *(2621 mm²)*

Net Area Subject to Tension

$L_{nt\text{-}L} = (d_s + ovs_L + 1/16)/2$ — $L_{nt\text{-}L}$: 0.66 in *(17 mm)*

$A_{nt\text{-}L} = A_{qt\text{-}L} - L_{nt\text{-}L}\cdot t_L\cdot 4$ — $A_{nt\text{-}L}$: 2.42 in² *(1562 mm²)*

Lug Plate Block Rupture Strength

Shear Rupture Term	$0.6\cdot F_{uL}\cdot A_{nv\text{-}L}$	SRT:	618.5 kip	*(2751 kN)*
Shear Yield Term	$0.6\cdot F_{yL}\cdot A_{qv\text{-}L}$	SYT:	721.9 kip	*(3211 kN)*
Tension Rupture Term	$U_{bs}\cdot F_{uL}\cdot A_{nt\text{-}L}$	TRT:	157.4 kip	*(700 kN)*

$\phi R_{n\text{-}blk\text{-}L} = \phi[\min(SRT, SYT) + TRT]$ — $\boxed{\phi R_{n\text{-}blk\text{-}L}\text{: } 582.0\text{ kip}}$ *(2589 kN)*

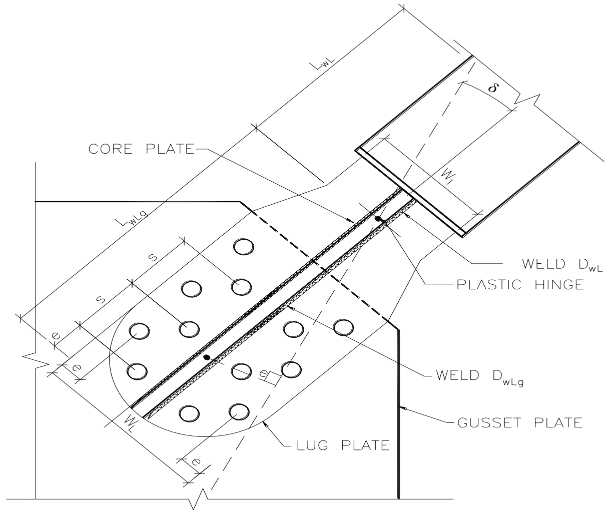
Block Shear Strength Stress Ratio at Lug

$DCR_{blk\text{-}L} = P_{ut\text{-}max}/\phi R_{n\text{-}blk\text{-}L}$

$DCR_{blk\text{-}L}$:	0.44

3.6.0 Weld Design

Assume plastic hinge forms in core just outside casing to accommodate story drift rotation δ



WELD CONFIGURATION

LRFD Resistance Factor	ϕ_{Weld}:	0.75	
Upper Bound Compressive Yield Stress of Core Material	$F_{ysc\text{-}max}$:	46 ksi	*(317 MPa)*
Weld Material Minimum Yield Strength for BRB Components	$F_{exx,BRB}$:	70 ksi	*(483 MPa)*
Length of Lug to Core Weld at Bolt Pattern	L_{wLg}:	15.25 in	*(387 mm)*
Length of Lug to Core Weld beyond Bolt Pattern	L_{wL}:	25.46 in	*(647 mm)*
Weld Both Sides of Lug Beyond Bolt Pattern?	WBS:	TRUE	
Width of Steel Yielding Core	W_{sc}:	4.00 in	*(102 mm)*
Width of Stiffener at Lug	W_s:	0.78 in	*(20 mm)*
Thickness of Stiffener at Lug	t_s:	1.00 in	*(25 mm)*

3.6.1 Weld Size Required at Bolt Pattern

Percent of Core Stub Capacity at Lug Allowed to be Transferred thru that Section (max 100%). — $\%A_{sc\text{-}stub}$: 100%

Max Force in Stiffener at Lug

$P_{wLg} = P_{uC\text{-}max} \cdot W_s/W_{sc} \cdot \min(\%A_{sc\text{-}Stub}, 1.0)$ — P_{wLg}: 59.9 kip *(267 kN)*

**Conservative for sizing weld*

Min Weld Size Based on Material Thickness — $D_{wLg\text{-}min}$: 4.00 (16ths) *(6 mm)*

IF	Then
$\min(t_L, t_s) \leq$ ½"	$D_{wLg\text{-}min} = 3^{16ths}$
$\min(t_L, t_s) \leq$ ¾"	$D_{wLg\text{-}min} = 4^{16ths}$
Otherwise	$D_{wLg\text{-}min} = 5^{16ths}$

Weld Size Based on Required Force

$D'_{wLg} = P_{wLg}/(\phi_{Weld} \cdot 0.6 \cdot F_{exx} \cdot 0.7071 \cdot 2 \cdot L_{wLg}) \cdot 16$ — D'_{wLg}: 1.41 (16ths) *(2 mm)*

Required Weld Size

D_{wLg}:	4.00	*(6 mm)*
D_{wLg}:	4.00 (16ths)	*(6 mm)*
D_{wLg}:	1/4 "	*(6 mm)*

Base Metal Thickness Check

$t_{min}/t_{L,sc}$ = Max of: — $DCR_{Weld\text{-}Lg}$: 0.37

$1 \cdot F_{EXX,BRB} \cdot 0.7071 \cdot (D_{wLg}/16)/(F_{uL} \cdot t_L)$ = 0.305

$2 \cdot F_{EXX,BRB} \cdot 0.7071 \cdot (D_{wLg}/16)/(F_{usc} \cdot t_s)$ = 0.375

3.6.2 Weld Size Required Beyond Bolt Pattern

Yield Strength of Stub Section

$F_{Y\text{-}wLg} = W_s \cdot t_s \cdot F_{ysc\text{-}max} \cdot \min(\%A_{sc\text{-}Stub}, 1.0)$ | $F_{Y\text{-}wLg}$: 35.9 kip *(160 kN)*

**Conservative for determining force in section before stub*

Force in Weld Beyond Bolt Group

$P_{wL} = P_{uC\text{-}max} - 2 \cdot F_{Y\text{-}wLg}$ | P_{wL}: 235.0 kip *(1045 kN)*

Weld Size Based on Required Force

$D'_{wL} = P_{wL}/(\phi_{Weld} \cdot 0.6 \cdot F_{exx} \cdot 0.7071 \cdot 4 \cdot L_{wL}) \cdot 16$ | D'_{wL}: 1.66 (16ths) *(3 mm)*

Required Weld Size	D_{wL}:	4.00 (16ths)	*(6 mm)*
Note that minimum weld size here equal to minimum size req'd at bolt	D_{wL}:	4.00 (16ths)	*(6 mm)*
pattern ($D_{wLg\text{-}min}$) since lug and core thickness are the same as at that location.	D_{wL}:	1/4 "	*(6 mm)*

Base Metal Thickness Check

Factor for Weld Both Sides (WBS) Beyond Bolt Pattern:

IF WBS = TRUE Then WBSF = 2, Otherwise WBSF = 1 | WBSF: 2

$t_{min}/t_{L,sc}$ = Max of: | $DCR_{Weld\text{-}L}$: 0.61

$WBSF \cdot F_{EXX,BRB} \cdot 0.7071 \cdot (D_{wL}/16)/(F_{uL} \cdot t_L)$ = 0.609

$2 \cdot F_{EXX,BRB} \cdot 0.7071 \cdot (D_{wL}/16)/(F_{usc} \cdot t_{sc})$ = 0.375

3.6.3 Weld Around Lug in Lieu of Bolting

Weld Material Minimum Yield Strength for Lug to Gusset (Alt Weld) | $F_{exx,Gst}$ 70 ksi *(483 MPa)*

Length of Sides of Lug Only | L_{Ls}: 32.54 in *(826 mm)*

$L_{Ls} = (L_{Lg} - W_L/2 - Tol_{LLs}) \cdot 4$ Tol_{LLS} = 0.50 in *(13 mm)*

Length Around Lug (Including Sides) | L_{rs}: 56.10 in *(1425 mm)*

$L_{Lr+s} = L_{Ls} + \pi \cdot (W_L/2) \cdot 2$

Plastic Section Modulus of Core Extension (Section Just Outside Casing)

$Z_+ = (2t_L \cdot W_1^2 + (W_t - 2t_L) \cdot t_{sc}^2)/4$ | Z_+: 8.44 in³ *(138371 mm³)*

Force Couple to Resist Plastification of Core Extension $F_R = Z_+ * F_{yL}/W_L$ | F_R: 56.3 kip *(250 kN)*

Required Weld if Welded Around Lug	D_{rs}:	5.37	*(9 mm)*
$D_{rs} = (P_{uC\text{-}max} + 2 \cdot F_R)/(L_{rs} \cdot 0.7071 \cdot 0.6 \cdot \phi_{Weld} \cdot F_{exx,Gst}) * 16$	D_{rs}:	6.00 (16ths)	*(10 mm)*
	D_{rs}:	3/8 "	*(10 mm)*
Required Weld if Welded Around Sides of Lug Only	D_s:	9.26	*(15 mm)*
$D_s = (P_{uC\text{-}max} + 2 \cdot F_R)/(L_{Ls} \cdot 0.7071 \cdot 0.6 \cdot \phi_{Weld} \cdot F_{exx,Gst}) * 16$	D_s:	10.00 (16ths)	*(16 mm)*
	D_s:	5/8 "	*(16 mm)*

3.7.0 Summary

3.1.0 Bolt Shear	DCR_{Shear}:	0.53
3.2.0 Bolt Friction	DCR_{Slip}:	0.66
3.3.1 Bolt Bearing - Gusset Plate	$DCR_{brg\text{-}g}$:	0.43
3.3.2 Bolt Bearing - Lug Plates	$DCR_{brg\text{-}L}$:	0.32
3.3.3 Combined Bolt Bearing & Tearout - Gusset	$DCR_{brg/Tear\text{-}G}$:	0.57
3.3.3 Combined Bolt Bearing & Tearout - Lug	$DCR_{brg/Tear\text{-}L}$:	0.57
3.4.0 Tension Fracture - Lug Plates	DCR_{tr}:	0.72
3.5.1 Block Rupture - Gusset Plate	$DCR_{blk\text{-}g}$:	0.54
3.5.2 Block Rupture - Lug Plates	$DCR_{blk\text{-}L}$:	0.44
3.6.1 Weld Strength at Bolt Pattern	$DCR_{Weld\text{-}Lg}$:	0.37
3.6.2 Weld Strength Beyond Bolt Pattern	$DCR_{Weld\text{-}L}$:	0.61
	Max:	0.72

END CONNECTION CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location					
EOR-ID #	Line	Grids #	Lvls #	Mark #	Qty #
BRB-4.00	3+	E.5-D.9	2	**1901**	1
BRB-4.00	3+	E.5-D.9	1	**1902**	1

Mark	Section 3.0 Design Criteria																				
	β	ω	A_{sc} in²	F_{y-max} ksi	$F_{u,sc}$ ksi	CF	$P_{ysc-max}$ kip	P_{uT-max} kip	P_{uC-max} kip	W_T in	W_L in	W_1 in	e in	n_i	n_o	n_b	s in	g in	d_b in	d_s in	n_s
1901	1.20	1.39	4.00	46	66	1.0	184	256	307	4.000	7.50	4.98	1.625	3	0	6	4.000	0.000	1.125	1.25	2
1902	1.19	1.38	4.00	46	66	1.0	184	254	302	4.000	7.50	4.90	1.625	3	0	6	4.000	0.000	1.125	1.25	2

Mark	Section 3.1.0 Bolt Shear - LRFD J3.6										
	ϕ_v	F_{nv} ksi	$F_{u,bolt}$ ksi	BTC	TCF	CLF	L'_{Lg} in	ϕr_v kip	A_b in²	ϕR_v kip	DCR_{Shear}
1901	0.75	64.8	144	N	0.80	1.00	8.0	96.6	0.994	580	0.53
1902	0.75	64.8	144	N	0.80	1.00	8.0	96.6	0.994	580	0.52

Mark	Section 3.2.0 Bolt Friction - LRFD J3.8									
	ϕ_s	A_{Tb_min} in²	h_f	μ	f_T	T_b kip	D_u	ϕr_s kip	ϕR_s kip	DCR_{Slip}
1901	0.85	0.76	1.00	0.30	1.04	80	1.13	46	277	1.11
1902	0.85	0.76	1.00	0.30	1.04	80	1.13	46	277	1.09

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END CONNECTION CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Section 3.3.0 Bearing Strength at Bolt Holes - LRFD J3.10

Specimen ID and Location						Gen	Section 3.3.1 Bearing Strength at Gusset Plate											
EOR-ID	Line	Grids	Lvls	Mark	Qty	$\phi_{brg\text{-}V}$	os_g	t_g	t_{r_Des}	F_{ug}	L_{cs}	n_{cs}	L_{ce}	n_{ce}	L_{cg}	$\phi R_{n\text{-}brg}$	$DCR_{brg\text{-}g}$
#		#	#	#	#		in	in	in	ksi	in		in		in	kip	
BRB-4.00	3+	E.5-D.9	2	**1901**	1	0.75	0.19	1.00	0.000	65	2.56	2.00	0.91	1.00	12.1	706	0.43
BRB-4.00	3+	E.5-D.9	1	**1902**	1	0.75	0.19	1.00	0.000	65	2.56	2.00	0.91	1.00	12.1	706	0.43

Mark	Section 3.3.2 Bearing Capacity at Lug Plates							
	os_L	t_L	F_{uL}	L_{csL}	L_{ceL}	L_{cL}	$\phi R_{n\text{-}brg}$	$DCR_{brg\text{-}L}$
#	in	in	ksi	in	in	in	kip	
1901	0.000	0.63	65	2.75	1.00	13.0	951	0.32
1902	0.000	0.63	65	2.75	1.00	13.0	951	0.32

Mark	Section 3.3.3 Combined Bolt Bearing/ Tear-out/ Bolt Shear at Lug and Gusset (Bolt by Bolt Method)																			
	GEB_{ni}	GEB_{no}	GFB_{ni}	GFB_{no}	LEB_{ni}	LEB_{no}	LFB_{ni}	LFB_{no}	$\phi R_{n\text{-}T,Edge}$	$\phi R_{n\text{-}C,Edge}$	$\phi R_{n\text{-}G,Field}$	$\phi R_{n\text{-}L,Field}$	$\phi R_{n\text{-}TG}$	$\phi R_{n\text{-}CG}$	$\phi R_{n\text{-}TL}$	$\phi R_{n\text{-}CL}$	$\frac{P_u}{\phi R_{n\text{-}G}}$	$\frac{P_u}{\phi R_{n\text{-}L}}$
#	kip	kip	kip	kip	kip	kip	kip	kip	kip	kip	kip	kip	kip	kip	kip	kip		
1901	53	0	132	0	73	0	165	0	252	386	193	193	446	580	446	580	0.57	0.57
1902	53	0	132	0	73	0	165	0	252	386	193	193	446	580	446	580	0.57	0.57

END CONNECTION CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Section 3.4.0 Tension Rupture Strength - LRFD D4												
EOR-ID #	Line	Grids #	Lvls #	Mark #	Qty #	ϕ_{tr}	t_{sc} in	U	OSL_g in	n_r	stg in	n_{stg}	A_{ntLb1} in^2	A_{ntLbx} in^2	A_{ntLb} in^2	A_{ntLc} in^2	ϕR_{n-tr} kip	DCR_{tr}
BRB-4.00	3+	E.5-D.9	2	**1901**	1	0.75	1.000	0.95	0.19	2	0.00	0	6.09	6.09	6.09	1.56	355	0.72
BRB-4.00	3+	E.5-D.9	1	**1902**	1	0.75	1.000	0.95	0.19	2	0.00	0	6.09	6.09	6.09	1.56	355	0.72

	Section 3.5.0 Block Rupture Strength - LRFD J4.3																	
	General		Section 3.5.1 Gusset Block Rupture Strength															
Mark #	ϕ_{blk}	U_{bs}	F_{yg} ksi	L_{gv-g} in	$A_{gv,g}$ in^2	n_{na-g}	L_{nv-g} in	$A_{nv,g}$ in^2	L_{gt-g} in	$A_{gt,g}$ in^2	L_{nt-g} in	$A_{nt,g}$ in^2	SRT kip	SYT kip	TRT kip	$\phi R_{n,g}$ kip	$\frac{P_u}{\phi R_{n,g}}$
1901	0.75	1.0	50	9.6	19.3	2.5	3.75	11.8	4.3	4.3	1.5	2.8	458	578	179	478	0.54
1902	0.75	1.0	50	9.6	19.3	2.5	3.75	11.8	4.3	4.3	1.5	2.8	458	578	179	478	0.53

	Section 3.5.0 Block Rupture Strength - LRFD J4.3 (cont.)													
	Section 3.5.2 Lug Plates Block Rupture Strength													
Mark #	F_{yL} ksi	L_{gv-L} in	$A_{gv,L}$ in^2	n_{na-L}	L_{nv-L} in	$A_{nv,L}$ in^2	$A_{gt,L}$ in2	L_{nt-L} in	$A_{nt,L}$ in2	SRT kip	SYT kip	TRT kip	$\phi R_{n,L}$ kip	$\frac{P_u}{\phi R_{n,L}}$
1901	50	9.6	24.1	2.5	3.28	15.9	4.1	0.7	2.4	619	722	157	582	0.44
1902	50	9.6	24.1	2.5	3.28	15.9	4.1	0.7	2.4	619	722	157	582	0.44

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END CONNECTION CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Section 3.6.0 Weld Design																										
						Weld Design Criterial									Section 3.6.1 Weld Size Required at Bolt Pattern						3.6.2 Weld Size Beyond Pattern					3.6.3 Weld Around Lug in Lieu of Bolting						
EOR-ID	Line	Grids	Lvls	Mark	Qty	Φ_{Weld}	$F_{ysc-max}$	$F_{exx,BRB}$	L_{wLg}	L_{wL}	Weld 2	W_{sc}	W_s	t_s	$\%A_{sc-stub}$	P_{wLg}	D_{wL-min}	$D_{wLg-req'd}$	D_{wLg}	$\underline{t_{min}}$	F_{Y-wLg}	P_{wL}	$D_{wL-req'd}$	D_{wL}	$\underline{t_{min}}$	$F_{exx,Gst}$	L_{Ls}	L_{Lr+s}	Z	F_R	D_{rs}	D_s
#		#	#	#	#		ksi	ksi	in	in	Sides?	in	in	in		kip	16ths	16ths	16ths	$t_{g,sc}$	kip	kip	16ths	16ths	$t_{g,sc}$	ksi	in	in	in^3	kip	16ths	16ths
BRB-4.00	3+	E.5-D.9	2	**1901**	1	0.75	46	70	15	25	TRUE	4.00	0.78	1.00	100%	60	4.0	1.4	4	0.37	36	235	1.7	4	0.61	70	33	56	8.4	56	6.0	10.0
BRB-4.00	3+	E.5-D.9	1	**1902**	1	0.75	46	70	15	25	TRUE	4.00	0.78	1.00	100%	59	4.0	1.4	4	0.37	36	230	1.6	4	0.61	70	33	56	8.2	55	6.0	10.0

Reed College Central Plant Upgrade

Calculation Submittal Package

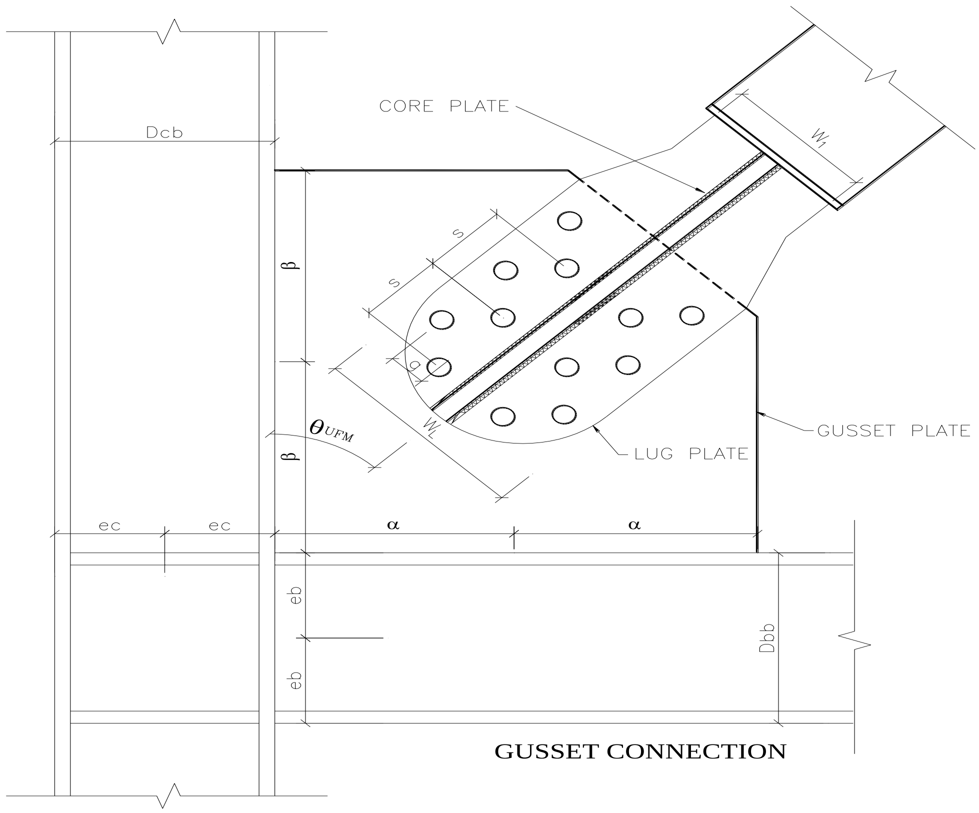
Description

Section 4. **Bottom Gusset Beam to Column Flange (Strong-Axis) Connection Sample Calculation**
Top and Bottom Connection Summary Tables

Bottom Gusset Connection

(Top Connection Similar)

Example Mark #: 1901
Line 3+, Grid E.5-D.9, Level 2



GUSSET CONNECTION

Uniform Force Method - AISC 360 - Bracing Section

4.0 DESIGN CRITERIA

Area of Yielding Steel Core	A_{sc}:	4.00 in²	*(2581 mm²)*
Maximum Yield Stress of Core Material	$F_{y\text{-}max}$:	46 ksi	*(317 MPa)*
Compresssion Strength Adjustment Factor	β:	1.2	
Strain Hardening Adjustment Factor	ω:	1.39	
Connection Strain Hardening Factor	CF:	1.00	
Adjusted Brace Strength (Design Axial Load) in Compression ($CF \cdot \beta\omega F_{y\text{-}max} A_{sc}$)	P_{uc}:	306.9 kip	*(1365 kN)*
Adjusted Brace Strength (Design Axial Load) in Tension ($CF \cdot \omega F_{y\text{-}max} A_{sc}$)	P_{ut}:	255.8 kip	*(1138 kN)*
Width of Lug	W_L:	7.50 in	*(191 mm)*
Column Depth	D_{cb}:	8.00 in	*(203 mm)*
Column Web Thickness	t_{wc}:	0.75 in	*(19 mm)*
Column Flange Thickness	t_{fc}:	0.38 in	*(10 mm)*
Column Flange Width	b_{fc}:	8.00 in	*(203 mm)*
Column Web Doubler Plate Thickness (one side)	t_{wcPL}:	0.00 in	*(0 mm)*
Beam Depth	D_{bb}:	8.00 in	*(203 mm)*
Nominal Depth of Beam	DN_{bb}:	8.00 in	*(203 mm)*
Beam Web Thickness	t_{wb}:	0.75 in	*(19 mm)*
Beam Flange Thickness	t_{fb}:	0.38 in	*(10 mm)*
Beam Flange Width	b_{fb}:	8.00 in	*(203 mm)*
Beam Distance from Outer Face of Flange to Toe of Fillet	k_{desb}:	1.00 in	*(25 mm)*
Column Distance from Outer Face of Flange to Toe of Fillet	k_{desc}:	1.00 in	*(25 mm)*
Beam Web Doubler Plate Thickness (one side)	t_{wbPL}:	0.00 in	*(0 mm)*
Angle Between the Beam and Brace CL	θ_{CB}:	0.946 rad	*54.2°*
Angle Between the Column and Brace CL	θ_{UFM}:	0.625 rad	*35.8°*
Min Clear Distance from Face of Beam to Edge of Lug	$b_{bot\text{-}Bm}$:	1.00 in	*(25 mm)*
Min Clear Distance from Face of Column to Edge of Lug	$b_{bot\text{-}Col}$:	1.17 in	*(30 mm)*
Gusset Extension to Beam	Ext_B:	1.00 in	*(25 mm)*
Gusset Extension to Column	Ext_C:	0.75 in	*(19 mm)*
Distance from Last Bolt to Start of Radius on Lug	b_r:	0.99 in	*(25 mm)*
Bolt Edge Distance	e:	1.63 in	*(41 mm)*
Provided Stroke Distance at Each End of Brace	c:	3.00 in	*(76 mm)*
Distance Between End of Core and Gusset	a:	4.00 in	*(102 mm)*

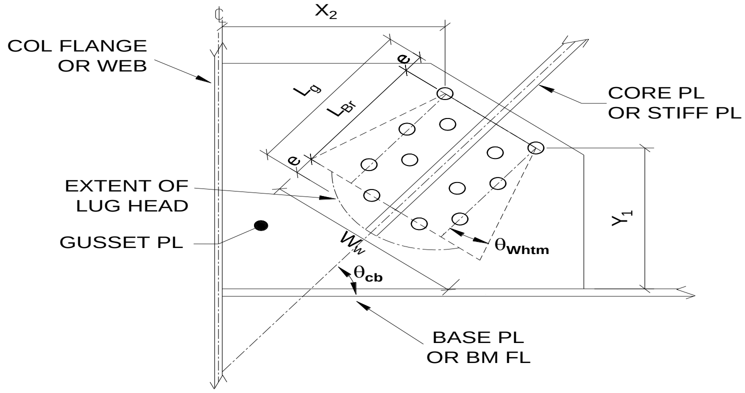
4.1.0 GEOMETRY CALCULATIONS - UNIFORM FORCE METHOD

Length from WP to Bottom Tip of Brace

Length from WP to Outside Edge of Col along WorkLine			
$L_{cb} = (D_{cb}/2)/COS(\theta_{CB})$	L_{cb}:	6.84 in	*(174 mm)*
Length from Edge of Column to Tip of CB along WL			
$L_{1cb} = [b_{bot\text{-}Col} + (W_L/2)]/COS(\theta_{CB}) - (e + b_r)$	L_{1cb}:	5.79 in	*(147 mm)*
Length from WP to Top Edge of Beam along WL			
$L_{bb} = (DN_{bb}/2)/SIN(\theta_{CB})$	L_{bb}:	4.93 in	*(125 mm)*
Length from Edge of Beam to Tip of CB along WL			
$L_{1bb} = [b_{bot\text{-}Bm} + (W_L/2)]/SIN(\theta_{CB}) - (e + b_r)$	L_{1bb}:	3.24 in	*(82 mm)*
Controling Length is MAX($L_{cb}+L_{1cb}$, $L_{bb}+L_{1bb}$)	L_{tb}:	12.63 in	*(321 mm)*

Length from Square Projection to Edge of Gusset (CB Lap on Gusset)			L_q:	11.25 in	*(286 mm)*
Horizontal Distance from Column to WP ($D_{cb}/2$)			e_c:	4.00 in	*(102 mm)*
Vertical Distance from Beam to WP ($DN_{bb}/2$)			e_b:	4.00 in	*(102 mm)*
Minimum Weld on Column from Geometry $L_{gc\_min} = (L_{tb} + L_g)\cdot SIN(\theta_{CB}) + (W_L/2 + Ext_C)\cdot COS(\theta_{CB}) - DN_{bb}/2$			L_{gc_min}:	17.99 in	*(457 mm)*
Minimum Weld on Beam from Geometry $L_{gb\_min} = (L_{tb} + L_g)\cdot COS(\theta_{CB}) + (W_L/2 + Ext_B)\cdot SIN(\theta_{CB}) - D_{cb}/2$			L_{gb_min}:	13.82 in	*(351 mm)*
Dist from Face of Col Fl to Centriod of Gusset-to-Beam Connection (UFM) $\alpha_{min} = L_{gb\_min}/2$	α_{min}	6.91 in *(176 mm)*			
α_{Hand} = Hand Input Value to Force	α_{Hand}	6.91 in *(176 mm)*			
If Hand Input Value is Different from α_{min} use Hand Input Value			α_{min}:	6.91 in	*(176 mm)*
Inside Weld Deducts:			$WD_{Bm,In}$:	1.50 in	*(38 mm)*
Outside Weld Deducts:			$WD_{Bm,Out}$:	0.50 in	*(13 mm)*
α Dist for Weld (1/2 of the actual weld length used for design)			α_q:	5.91 in	*(150 mm)*
α Dist from face of column to mid point on beam welds $\alpha_{bar} = WD_{Bm,In} + \alpha_q$			α_{bar}:	7.41 in	*(188 mm)*
Dist from Face of Beam Fl to Centriod of Gusset-to-Column Connection (UFM) $\beta_{min} = L_{gc\_min}/2$	β_{min}	9.00 in *(229 mm)*			
β_{Hand} = Hand Input Value to Force	β_{Hand}	9.00 in *(229 mm)*			
If Hand Input Value is Different from β_{min} use Hand Input Value			β_{min}:	9.00 in	*(229 mm)*
Inside Weld Deducts:			$WD_{Col,In}$:	1.50 in	*(38 mm)*
Outside Weld Deducts:			$WD_{Col,Out}$:	0.50 in	*(13 mm)*
β Dist for Weld (1/2 of the actual weld length used for design)			β_q:	8.00 in	*(203 mm)*
β from face of beam to mid point on column welds $\beta_{bar} = WD_{Col,In} + \beta_q$			β_{bar}:	9.50 in	*(241 mm)*
Constants for Connections not in Equilibrium $K = e_b TAN(\theta_{UFM}) - e_c$			K:	-1.11 in	*(-28 mm)*
$K' = \alpha_{bar}[TAN(\theta_{UFM}) + \alpha_{bar}/\beta_{bar}]$			K':	11.13 in	*(283 mm)*
$D = (TAN(\theta_{UFM}))^2 + (\alpha_{bar}/\beta_{bar})^2$			D:	1.13	
Final values of α and β $\alpha_{nE} = [K'*TAN(\theta_{UFM}) + K(\alpha_{bar}/\beta_{bar})^2]/D$			α_{nE}:	6.51 in	*(165 mm)*
$\beta_{nE} = [K' - K*TAN(\theta_{UFM})]/D$			β_{nE}:	10.56 in	*(268 mm)*
$r = \sqrt{((\alpha_{nE} + e_c)^2 + (\beta_{nE} + e_b)^2)}$			r:	17.96 in	*(456 mm)*

4.2.0 GUSSET STRESS CALCULATIONS - AISC 360



4.2.1 WHITMORE SECTION STRESS CHECK

LRFD Resistance Factor	ϕ_W:	0.90	
Number of Bolts in Inside Row	n_i:	3	
Number of Bolts in Outside Row	n_o:	0	
Total Number of Bolts at Each End $2(n_i + n_o)$	n_b:	6	
Bolt Spacing	s:	4.00 in	*(102 mm)*
Minimum Yield Strength of Gusset	F_{yg}:	50 ksi	*(345 MPa)*
Minimum Tensile Strength of Gusset	F_{ug}:	65 ksi	*(448 MPa)*
Thickness of Gusset Plate	t_g:	1.00 in	*(25 mm)*
Thickness of Repad Plate for Design:	t_r:	0.00 in	*(0 mm)*
Whitmore Angle	θ_{Whtm}:	30.0°	*0.524 rad*
Total Length Between Outer Bolt Holes $L_{Br} = L_g - 2e$	L_{Br}:	8.00 in	*(203 mm)*
Vertical Distance to Top Bolt on Beam Side of CL $Y_1 = L_{gc\text{-}min} - (W_L + Ext_C - e)\cdot COS(\theta_{CB}) - e\cdot SIN(\theta_{CB})$	Y_1:	12.80 in	*(325 mm)*
Horizontal Distance to Top Bolt on Column Side of CL $X_2 = L_{gb\text{-}min} - (W_L + Ext_B - e)\cdot SIN(\theta_{CB}) - e\cdot COS(\theta_{CB})$	X_2:	7.30 in	*(185 mm)*
Whitmore Length if Not Limited by Beam or Column $h_{Br} = L_{Br}/COS(\theta_{Whtm})$	h_{Br}:	9.24 in	*(235 mm)*
Gusset Condition: FHG - Full Height Gusset; NFG - Non Full Height Gusset	FHG:	FALSE	
Whitmore Length if Limited by Beam	h_{Bm}:	12.86 in	*(327 mm)*

IF / Then
- FHG = TRUE: $h_{Bm} = h_{Br}$
- FHG = FALSE: $h_{Bm} = Y_1/SIN(\theta_{CB} + \theta_{Whtm})$

Whitmore Length if Limited by Column $h_{Col} = X_2/COS(\theta_{CB} - \theta_{Whtm})$	h_{Col}:	8.00 in	*(203 mm)*
Constrain Whitmore Section within Gusset Plate?	WSG:	FALSE	
Whitmore Area	A_W =	13.49 in²	*(8702 mm²)*

IF / Then
- WSG = TRUE: $A_w = [2\cdot min(h_{Br},h_{Bm},h_{Col})\cdot SIN(\theta_{Whtm})]\cdot t_g + (W_L - 2e)\cdot(t_g + 2t_r)$
- WSG = FALSE: $A_w = [2\cdot L_{BR}\cdot TAN(\theta_{Whtm})]\cdot t_g + (W_L - 2e)\cdot(t_g + 2t_r)$

Whitmore Capacity $\phi R_{n\text{-}W} = \phi_W\cdot A_W\cdot F_{yg}$	$\phi R_{n\text{-}W}$:	606.9 kip	*(2700 kN)*
Whitmore Stress Ratio $DCR_W = P_{ut}/\phi R_{n\text{-}W}$	DCR_W:	0.42	

4.2.2 Gusset Plate Buckling

LRFD Resistance Factor for Compression	ϕ_c:	0.90	
Modulus of Elasticity of Gusset Plate Material	E_{Gst}:	29000 ksi	*(199955 MPa)*
Effective Length Factor for Gusset Buckling	K_{qb}:	1.00	
Average Buckling Length *Average of L_1, L_2, & L_3. If average is less than zero, zero is used (Gusset is Elastic).*	L':	3.31 in	*(84 mm)*
Radius of Gyration of Gusset $r_q = \sqrt{(t_q^2/12)}$	r_q:	0.29 in	*(7 mm)*
Gusset Slenderness Parameter $\lambda = K_{qb} \cdot L'/(r_q \cdot \pi) \cdot \sqrt{(F_{yq}/E_{Gst})}$	λ:	0.15	
Gusset Buckling Capacity $\phi R_{n\text{-}gb} = \phi_c \cdot 0.658\text{^}(\lambda_c^2) \cdot F_{yg} \cdot A_w$	$\phi R_{n\text{-}gb}$:	601.1 kip	*(2674 kN)*
Gusset Buckling Capacity Ratio			
$DCR_{gb} = P_{uc}/\phi R_{n\text{-}gb}$	DCR_{gb}:	0.51	

4.2.3 Gusset Plate Buckling (Out-of-Plane)

LRFD Resistance Factor for Bending	ϕ_b:	0.90	

A. Consider Self Weight of Brace Out-of-Plane Acting on Gusset

Assumed Spectral Acceleration	S_A:	1.00 g	
Factor on S_A	F_{SA}	0.40	
Importance Factor	I_p:	1.00	
Brace Weight	Wt_{br}:	0.86 kip	*(3.8 kN)*
Additional Out-of-Plane Force on Gusset *(when present)*.	$F_{Add'l\text{-}OOP/End}$:	0.00 kip	*(0.0 kN)*
Out of Plane Force at Each End of Brace due to BRB Self Weight SW $F_{OOP} = F_{SA} \cdot S_A \cdot I_p \cdot Wt_{br}/2 + F_{Add'l\text{-}OOP/End}$	F_{OOP}:	0.173 kip	*(1 kN)*
Moment Arm $M_{Arm\_OOP} = L_q + a + 2 \cdot C$	M_{Arm_OOP}:	21.25 in	*(540 mm)*
Resulting Self Weight Out-of-Plane Moment SW $M_{OOP} = F_{OOP} \cdot M_{Arm\_OOP}$	M_{OOP}:	3.7 kip-in	*(415 kN-mm)*

B. Consider Adjusted Brace Strength at Out Of Plane Frame Deformation

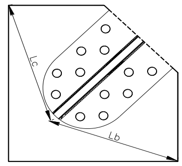
Story Drift Factor *(Usually 2x, But if considering 100% of ABS, Use only 1/3 of this)*	F_{SD}:	0.67	
Story Drift (See Stiffness Section for Calculation)	SD:	1.00%	
Drift Angle $\theta_{SD} = ATAN(SD \cdot F_{SD})$	θ_{SD}:	0.0067	(0.38°)
Percentage of Adjusted Brace Strength to Consider *Use either 100% ABS and 1/3 of 2xSD, or 30% ABS and 2xSD*	F_{ABS}:	100%	
Out of Plane component of F_{ABS}xAdjusted Brace Strength $P_H = F_{ABS} \cdot P_{uc} \cdot SIN(\theta_{SD})$	P_H:	2.05 kip	*(9.1 kN)*
Moment Arm (consider PH applied at centroid of BRB-gusset connection) $M_{Arm\_PH} = L_{Lq}/2$	M_{Arm_PH}:	5.63 in	*(143 mm)*
Resulting Horizontal Moment $M_{PH} = P_H \cdot M_{Arm\_PH}$	M_{PH}:	11.51 k-in	*(1301 kN-mm)*

C. Consider Total Moment from Part A and B

Total Out of Plane Moment

$M_u = M_{OOP} + M_{PH}$ | M_u: | 15 k-in | *(1716 kN-mm)*

Length of potential yielding line (disregarding concrete where occurs)



To Intersection with Column	L_c:	13.0 in	*(329 mm)*
To Intersection with Beam/BP	L_b:	12.3 in	*(313 mm)*
Total Length $L_t = L_c + L_b$	L_t:	25.3 in	*(642 mm)*

Plastic Modulus

$Z_q = L_t \cdot t_q^2/4$ | Z_q: | 6.32 in³ | *(103536 mm³)*

Design Flexural Strength

$\phi M_n = \phi_b \cdot Z_g \cdot F_{yg}$ | ϕM_n: | 284 k-in | *(32128 kN-mm)*

Gusset Flexure Capacity Ratio

$DCR_{gf} = M_u/\phi M_n$ | DCR_{gf}: | 0.05

Combined Gusset Buckling & Flexure DCR

IF $DCR_{gb} \geq 0.2$, $DCR_{gb+f} = DCR_{gb} + (8/9)DCR_{gf}$ | DCR_{gb+f}: | 0.56

IF $DCR_{gb} < 0.2$, $DCR_{gb+f} = (1/2)DCR_{gb} + DCR_{gf}$ | DCR_{gb+f}: | -

4.8.0 Summary

4.2.1 Whitmore Section Stress	DCR_{W}:	0.42
4.2.2 Gusset Plate Buckling	DCR_{gb}:	0.51
4.2.3 Gusset Plate Combined Buckling & Flexure	DCR_{gb+f}:	0.56
4.4.2 Column Web Shear Check	DCR_{cwv}:	n.a.
4.6.1A Gusset Weld Base Metal Check at Beam (Gusset)	DCR_{wbmbg}:	n.a.
Gusset Weld Base Metal Check at Beam (Flange)	DCR_{wbmbf}:	n.a.
4.6.1B Gusset Weld Base Metal Check at Column (Gusset)	DCR_{wbmcg}:	n.a.
Gusset Weld Base Metal Check at Column (Flange)	DCR_{wbmcf}:	n.a.
4.6.1C Beam Weld Filler Material Base Metal Compatability Check	$DCR_{wbm,Bm}$:	n.a.
Column Weld Filler Material Base Metal Compatability Check	$DCR_{wbm,Col}$:	n.a.
4.7.1 Beam Web Yield Check	DCR_{wyb}:	n.a.
4.7.1 Column Web Yield Check	DCR_{wyc}:	n.a.
4.7.2 Beam Web Crippling Check	DCR_{wcb}:	n.a.
4.7.2 Column Web Crippling Check	DCR_{wcc}:	n.a.

Provide Stiffener if DCR_{wyb} or DCR_{wcb} > 1.0

BEAM/COL FLANGE BOTTOM CONNECTION

Project: Reed College Central Plant Upgrade
Location: Portland, OR

Job: 6903

Specimen ID and Location						Section 4.0 Design Criteria																																
EOR-ID	Line	Grids	Lvls	Mark	Qty	A_{sc}	$F_{y\text{-}max}$	β	ω	CF	P_{uc}	P_{ut}	W_L	D_{cb}	t_{wc}	t_{fc}	b_{fc}	t_{wcPL}	D_{bb}	DN_{bb}	t_{wb}	t_{fb}	b_{fb}	k_{desb}	k_{desc}	t_{wbbPL}	$θ_{CB}$	$θ_{UFM}$	$b_{bot\text{-}Bm}$	$b_{bot\text{-}Col}$	Ext_B	Ext_C	b_r	e	c	a
#		#	#	#	#	in^2	ksi				kip	kip	in	in	in	in	in	in	in	in	in	in	in	in	in	in	rad	rad	in	in	in	in	in	in	in	in
BRB-4.00	3+	E.5-D.9	2	1901	1	4.00	46	1.20	1.39	1.00	307	256	7.50	8.0	0.75	0.38	8.00	0.00	8.0	8.0	0.75	0.38	8.00	1.00	1.00	0.00	0.95	0.63	1.00	1.17	1.00	0.75	0.99	1.63	3.0	4.0
BRB-4.00	3+	E.5-D.9	1	1902	1	4.00	46	1.19	1.38	1.00	302	254	7.50	8.0	0.75	0.38	8.00	0.00	5.0	5.0	5.00	2.50	5.00	1.00	1.00	0.00	0.96	0.61	1.00	1.62	1.50	4.00	0.99	1.63	3.0	4.0

BEAM/COL FLANGE BOTTOM CONNECTION

CoreBrace — SUPERIOR SEISMIC PERFORMANCE

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Section 4.1.0 Geometry Calculations - Uniform Force Method				
						Length WP to BOT Tip of BRB				
EOR-ID	Line	Grids	Lvls	Mark	Qty	L_{cb}	L_{1cb}	L_{bb}	L_{1bb}	L_{tb}
#		#	#	#	#	in	in	in	in	in
BRB-4.00	3+	E.5-D.9	2	1901	1	6.8	5.8	4.9	3.2	12.63
BRB-4.00	3+	E.5-D.9	1	1902	1	7.0	6.8	3.0	3.2	13.75

		Section 4.1.0 Geometry Calculations - Uniform Force Method (continued)																					
		Length from Square Projection to Edge of Gusset																					
EOR-ID	Mark	L_g	e_{Col}	e_{Bm}	$l_{gc,min}$	$l_{gb,min}$	α min	$WD_{Bm,In}$	$WD_{Bm,Out}$	α_g	α_{bar}	β min	$WD_{Col,In}$	$WD_{Col,Out}$	β_g	β_{bar}	K	K'	D	a_{nE}	β_{nE}	r
#	#	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in		in	in	in
BRB-4.00	1901	11.3	4.0	4.0	18.0	13.8	6.9	1.50	0.50	5.9	7.4	9.0	1.50	0.50	8.0	9.5	-1.1	11.1	1.13	6.5	10.6	18.0
BRB-4.00	1902	11.3	4.0	2.5	22.4	14.6	7.3	1.50	0.50	6.3	7.8	11.2	1.50	0.50	10.2	11.7	-2.3	10.7	0.93	6.9	13.1	19.1

		Section 4.2.0 Gusset Stress Calculations																				
		4.2.1 Whitmore Section Stress Check																				
EOR-ID	Mark	ϕ_W	n_i	n_o	n_b	s	F_{yg}	F_{ug}	t_g	t_{r_Des}	Whtm Ang	L_{Br}	Y1	X2	h_{Br}	Full Ht	h_{Bm}	h_{Col}	Constrain	A_{wh}	ϕR_{n-w}	P_{ut}
#	#		#	#	#	in	ksi	ksi	in	in	deg	in	in	in	in	Guss?	in	in	Whitmore	in^2	kip	ϕR_n
BRB-4.00	1901	0.9	3	0	6	4.00	50	65	1.00	0.00	30	8.00	12.80	7.30	9.24	FALSE	12.86	8.00	FALSE	13.5	607	0.42
BRB-4.00	1902	0.9	3	0	6	4.00	50	65	1.00	0.00	30	8.00	15.45	7.64	9.24	FALSE	15.50	8.44	FALSE	13.5	607	0.42

BEAM/COL FLANGE BOTTOM CONNECTION

Project: Reed College Central Plant Upgrade
Location: Portland, OR

Job: 6903

Specimen ID and Location														Section 4.2.3 Gusset Plate Buckling (Out-of-Plane)																						
						4.2.2 Gusset Plate Buckling								A. Consider Self Weight of Brace Out-of-Plane Acting on Gusset								B. Consider Adjusted Brace Strength Out Of Plane Frame Deformation							C. Consider Total Moment from Part A and B							
EOR-ID	Line	Grids	Lvls	Mark	Qty	ϕ_{gb}	E_{Gst}	K_{gb}	L'	r_g	λ	ϕR_{n-gb}	$\frac{P_{uc}}{\phi R_{n-gb}}$	S_A	Factor	I_p	Wt_{BRB}	$F_{Add'l-OOP/End}$	SW $F_{OOP\ (EA\ End)}$	$M_{Arm-OOP}$	SW M_{OOP}	Factor	SD	Drift Angle	Factor	P_H	M_{Arm_PH}	M_{PH}	M_u	L_c	L_b	L_t	Z_g	ϕMn	$\frac{Mu}{\phi Mn}$	DCR
#		#	#	#	#		ksi	in	in	in		kip		(SDS)	on S_A		kips	kips	kips	in	k-in	on SD	%	RAD	on ABS	kips	in	k-in	k-in	in	in	in	in^3	k-in		gb+f
BRB-4.00	3+	E.5-D.9	2	1901	1	0.90	29000	1.00	3.31	0.29	0.15	601	0.51	1.00	0.40	1.00	0.86	0.00	0.17	21.25	3.68	0.67	1.00%	0.01	100%	2.046	5.625	11.509	15.2	13.0	12.3	25.3	6.32	284	0.05	0.56
BRB-4.00	3+	E.5-D.9	1	1902	1	0.90	29000	1.00	4.91	0.29	0.23	594	0.51	1.00	0.40	1.00	0.88	0.00	0.18	21.25	3.74	0.67	1.00%	0.01	100%	2.014	5.625	11.331	15.1	14.9	13.8	28.8	7.19	324	0.05	0.55

BEAM/COL FLANGE TOP CONNECTION

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Section 4.0 Design Criteria																													
EOR-ID	Line	Grids	Lvls	Mark	Qty	A_{sc}	$F_{y\text{-}max}$	β	ω	CF	P_{uc}	P_{ut}	W_L	D_{ct}	t_{fc}	b_{fc}	t_{wcPL}	D_{bt}	DN_{bt}	t_{wb}	t_{fb}	b_{fb}	k_{desb}	k_{desc}	$t_{wbt,PL}$	$θ_{CB}$	$θ_{UFM}$	$b_{top\text{-}Bm}$	$b_{top\text{-}Col}$	Ext_B	Ext_C	b_r	e	c	a
#		#	#	#	#	in^2	ksi				kip	kip	in	in	in	in	in	in	in	in	in	in	in	in	in	rad	rad	in	in	in	in	in	in	in	in
BRB-4.00	3+	E.5-D.9	2	1901	1	4.00	46	1.20	1.39	1.00	307	256	7.50	8.0	0.38	-	0.00	8.0	8.0	0.75	0.38	-	1.00	1.00	0.00	0.95	0.63	1.00	1.09	1.00	0.90	0.99	1.625	3.0	4.0
BRB-4.00	3+	E.5-D.9	1	1902	1	4.00	46	1.19	1.38	1.00	302	254	7.50	8.0	0.38	-	0.00	8.0	8.0	0.75	0.38	-	1.00	1.00	0.00	0.96	0.61	1.00	1.01	1.00	0.35	0.99	1.625	3.0	4.0

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BEAM/COL FLANGE TOP CONNECTION

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						Length from WP to Tip of BRB					
EOR-ID	Line	Grids	Lvls	Mark	Qty	L_{ct}	L_{1ct}	L_{bt}	L_{1bt}	L_{tt}	L'_{tt}
#		#	#	#	#	in	in	in	in	in	in
BRB-4.00	3+	E.5-D.9	2	1901	1	6.8	5.7	4.8	3.1	12.5	-
BRB-4.00	3+	E.5-D.9	1	1902	1	7.0	5.7	4.9	3.2	12.7	-

	Section 4.1.0 Geometry Calculations - Uniform Force Method: Length from Square Projection to Edge of Gusset (CB Lap on Gusset)																						
Mark	L_g	e_{Col}	e_{Bm}	l_{gc_min}	l_{gb_min}	l_{gc_ext}	l_{gb_ext}	α min	$WD_{Bm,In}$	$WD_{Bm,Out}$	α_g	α_{bar}	β min	$WD_{Col,In}$	$WD_{Col,Out}$	β_g	β_{bar}	K	K'	D	α	β	r
#	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in	in		in	in	in
1901	11.25	4.0	4.0	17.98	13.75	-	-	6.87	1.50	0.50	5.87	7.37	8.99	1.50	0.50	7.99	9.49	-1.11	11.05	1.12	6.5	10.5	17.9
1902	11.25	4.0	4.0	17.97	13.60	-	-	6.80	1.50	0.50	5.80	7.30	8.99	1.50	0.50	7.99	9.49	-1.21	10.72	1.08	6.3	10.7	17.9

	Section 4.2.0 Gusset Stress Calculations: 4.2.1 Whitmore Section Stress Check																						
Mark	ϕ_w	n_i	n_o	n_b	s	F_{yg}	F_{ug}	t_g	t_{r_Des}	Whtm Ang	L_{Br}	Y1	X2	h_{Br}	Full Ht	h_{Bm}	h_{Col}	Constrain	A_{wh}	W'_{wh}	A'_{wh}	$\phi R_{n\text{-}W}$	P_u
#		#	#	#	in	ksi	ksi	in	in	deg	in	in	in	in	Guss?	in	in	Whitmore	in^2	in	in^2	Kip	ϕR_n
1901	0.90	3	0	6	4.00	50	65	1.00	0.00	30	8.00	12.7	7.2	9.2	FALSE	12.8	7.9	FALSE	13.5	12.2	12.2	607	0.42
1902	0.90	3	0	6	4.00	50	65	1.00	0.00	30	8.00	13.1	7.0	9.2	FALSE	13.1	7.8	FALSE	13.5	12.0	12.0	607	0.42

BEAM/COL FLANGE TOP CONNECTION

Project: Reed College Central Plant Upgrade
Location: Portland, OR
Job: 6903

Specimen ID and Location						4.2.2 Gusset Plate Buckling										Section 4.2.3 Gusset Plate Buckling (Out-of-Plane): A. Consider Self Weight of Brace Out-of-Plane Acting on Gusset								B. Consider Adjusted Brace Strength at Out-of-Plane Frame Deformation							C. Consider Total Moment from Part A and B							
EOR-ID	Line	Grids	Lvls	Mark	Qty	ϕ_{gb}	E_{Gst}	K_{gb}	L'	r_g	λ_c	$\phi R_{n\text{-}gb}$	P_{uc} / $\phi R_{n\text{-}gb}$	S_A	Factor on S_A	I_p	Wt_{BRB}	$F_{add'l\text{-}OOP/End}$	SW $F_{OOP\ (EA\ End)}$	$M_{Arm\text{-}OOP}$	SW M_{OOP}	Factor on SD	SD	Drift Angle	Factor on ABS	P_H	M_{Arm_PH}	M_{PH}	M_u	L_c	L_b	L_t	Z_g	ϕMn	Mu / ϕMn	DCR
#		#	#	#	#		ksi		in	in		kip		(SDS)			kips	kip	kips	in	k-in		%	RAD		kips	in	k-in	k-in	in	in	in	in^3	k-in		gb+f
BRB-4.00	3+	E.5-D.9	2	1901	1	0.90	29000	1.00	3.18	0.29	0.15	602	0.51	1.00	0.40	1.00	0.86	0.00	0.17	21.25	3.68	0.67	1.00%	0.01	100%	2.05	5.63	11.51	15.18	12.26	13.04	25.30	6.32	284.61	0.05	0.56
BRB-4.00	3+	E.5-D.9	1	1902	1	0.90	29000	1.00	3.24	0.29	0.15	601	0.50	1.00	0.40	1.00	0.88	0.00	0.18	21.25	3.74	0.67	1.00%	0.01	100%	2.01	5.63	11.33	15.07	12.27	12.77	25.04	6.26	281.75	0.05	0.55

Reed College Central Plant Upgrade

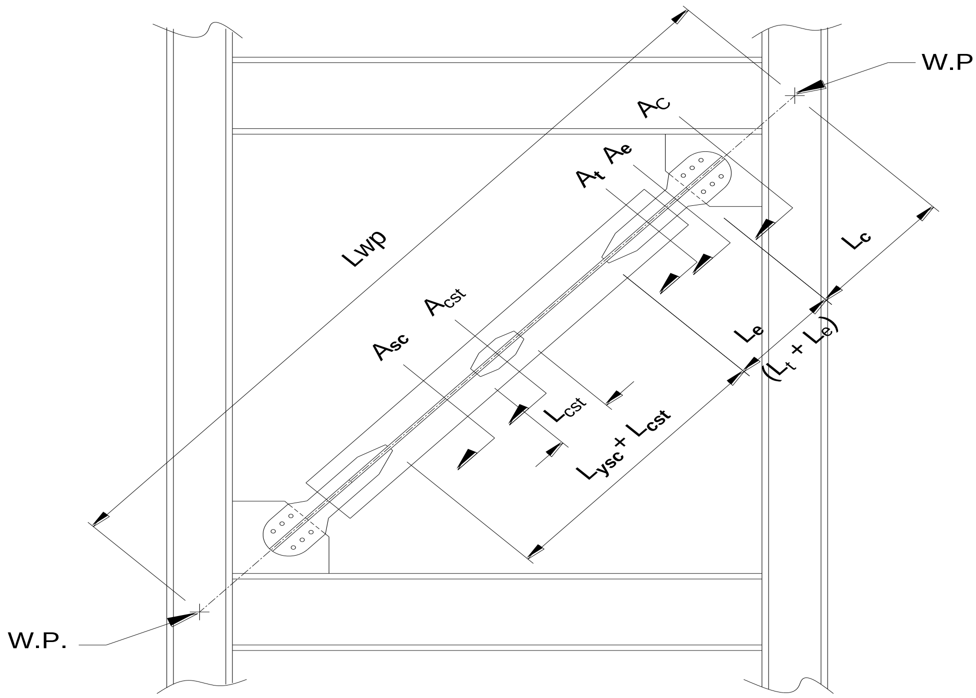
Calculation Submittal Package

<u>Description</u>

Section 7.	**Stiffness Sample Calculation** **Stiffness Tables**

Stiffness Calculation

Example Mark #: 1901
Line 3+, Grid E.5-D.9, Level 2



Stiffness Calculation

7.0 DESIGN CRITERIA

Length Between Work Points at Top and Bottom of Brace	L_{wp}:	150.4 in	*(3819 mm)*
Modulus of Elasticity	E:	29000 ksi	*(199955 MPa)*
Yielding Core Stiffness			
Yielding Core Length	L'_{ysc}:	69.3 in	*(1760 mm)*
Yielding Core Area	A_{ysc}:	4.00 in²	*(2581 mm²)*
Yielding Core Stiffness $K_{ysc} = A_{ysc} \cdot E/L_{ysc}$	K_{ysc}:	1674 k/in	*(293 kN/mm)*
End Zone Stiffness			
Length of Stiffener Plate Extension into Casing	L_e:	16.7 in	*(425 mm)*
End Zone Total Length $L_{eT} = 2L_e$	L_{eT}:	33.5 in	*(850 mm)*
End Zone Area	A_e:	8.98 in²	*(5792 mm²)*
End Zone Stiffness $K_e = A_e \cdot E/L_{eT}$	K_e:	7782 k/in	*(1363 kN/mm)*
Transition Zone Stiffness (Where Occurs)			
Length from End of Stiffener Plate to Middle of Final Transition	L_t:	0.0 in	*(0 mm)*
Transition Zone Total Length $L_{tT} = 2L_t$	L_{tT}:	0.0 in	*(0 mm)*
Transition Zone Area	A_t:	0.00 in²	*(0 mm²)*
Transition Zone Stiffness $K_t = A_t \cdot E/L_{tT}$	K_t:	--	--
Connection Stiffness			
Length of Connection from Work Point to End of Gusset	L_c:	23.8 in	*(605 mm)*
Connection Region Total Length $L_{cT} = 2 \cdot L_C$	L_{cT}:	47.6 in	*(1210 mm)*
Connection Area	A_c:	26.93 in²	*(17376 mm²)*
Connection Stiffness $K_c = A_c \cdot E/L_{cT}$	K_c:	16401 k/in	*(2872 kN/mm)*
Center Region Stiffness (Not Applicable Where $L_{cst} = 0$)			
Length of Center Region	L_{cst}:	0.0 in	*(0 mm)*
Area of Center Region	A_{cst}:	4.00 in²	*(2581 mm²)*
Center Stiffness $K_{cst} = A_{cst} \cdot E/L_{cst}$	K_{cst}:	--	--
Total Stiffness $K_{eff} = 1/(1/K_{ysc} + 1/K_e + 1/K_t + 1/K_c + 1/K_{cst})$	K_{eff}:	1271 k/in	*(223 kN/mm)*
Yielding Core Stiffness WP to WP $K_{LWP} = A_{ysc} \cdot E/L_{WP}$	K_{LWP}:	771 k/in	*(135 kN/mm)*
Stiffness Modification Factor $K_f = K_{eff}/K_{LWP}$	K_f:	1.65	

Length Verification

$$\frac{L_{ysc} + L_{eT} + L_{tT} + L_{cT} + L_{cst}}{L_{WP}} = 1.00$$

Should be 1.0 if all regions are accounted for.

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COREBRACE STIFFNESS CALCULATIONS

Project: Reed College Central Plant Upgrade
Location: Portland, OR

Job: 6903

Specimen ID and Location						General		Yielding Core Stiffness			End Zone Stiffness				Transition Zone Stiffness				Connection Stiffness				Center Region Stiffness			Total Stiffness & Check			
EOR-ID	Line	Grids	Lvls	Mark	Qty	L_{wp}	E	L'_{ysc}	A_{sc}	K_{ysc}	L_e	L_{eT}	A_e	K_e	L_t	L_{tT}	A_t	K_t	L_c	L_{cT}	A_c	K_c	L_{cst}	A_{cst}	K_{cst}	K_{Eff}	K_{LWP}	K_F	Length
#		#	#	#	#	in	ksi	in	in^2	k/in	in	in	in^2	k/in	in	in	in^2	k/in	in	in	in^2	k/in	in	in^2	k/in	k/in	k/in		Check
BRB-4.00	**3+**	**E.5-D.9**	**2**	**1901**	**1**	150	29000	69.3	4.00	1674	16.7	33.5	9.0	7782	0.0	0.0	0.00	-	23.8	48	26.9	16401	0.0	4.0	-	1271	771	1.65	1.0
BRB-4.00	**3+**	**E.5-D.9**	**1**	**1902**	**1**	154	29000	71.5	4.00	1623	16.6	33.3	8.9	7743	0.0	0.0	0.00	-	24.5	49	26.6	15787	0.0	4.0	-	1236	755	1.64	1.0