6300 Enterprise Lane
Madison, WI 53719
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drjengineering.org

DrJ ENGINEERING LLC

Design Calculations

City of Antigo
Remington Ballpark Seating Deck

Project Location:
Langlade Rd. Park
Antigo, WI 54409

Prepared for:
City of Antigo
Park, Recreation, and Cemetery Department
700 Edison Street
Antigo, WI 54409

Prepared by:
DrJ Engineering, LLC
6300 Enterprise Lane
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June 05, 2019

Report Issued: June 05, 2019

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Remington Ballpark Seating Deck

Design Criteria

Building Geometry		
Wall Length Parallel to Ridge, B	60.0	ft
Wall Length Normal to Ridge, L	15.0	ft
Typ. Wall Height	9.00	ft
Mean Roof Height, h	20.00	ft
Roof Pitch (rise per 12 units of run)	3	/12
Horizontal Distance from Eave to Ridge, W	5.75	ft
Roof Surface	Unobstructed Slippery Surfaces	

Wind Design Parameters		
Basic Wind Speed, V ASD	91	mph
Basic Wind Speed, V Ultimate	115	mph
Topographic Factor, K_{zt}	1.00	
Wind Directionality Factor, K_d	0.85	
Building Category	II	
Exposure Category	C	
Envelope	Open	
Method	MWFRS – Method 2 (Low Rise Building)	
Roof Type	Flat	

Dead Load		
Roof System	**15.0**	psf
Floor System	**15.0**	psf

Live Loads		
Roof Live Load	20.0	psf
Floor Live Load - No Reduction Permitted	100.0	psf

Deflection Requirements		
Roof Deflection - Snow	180.0	L/
Roof Deflection - Total	120.0	L/
Floor Deflection - Live	480.0	L/
Floor Deflection - Total	360.0	L/

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Building Planning		
Building Code	2015 IBC w/ WI Ammendments	
Weathering	Severe	
Frost Line Depth	48	in
Termite Infestation	Slite to Moderate	
County	Langlade	
Climate Zone	7	

Snow Design Parameters		
Ground Snow Load	50	psf
Exposure Category	Partially Exposed	
Thermal Factor	1.2	
Flat Roof Snow Load	42.00	psf
Sloped Roof Snow Load	42.00	psf

ASCE 7-10 -- Componenets and Cladding Load		
Zone 1 - Roof Field	12.98	psf
Zone 2 - Roof Edge	12.98	psf
Zone 3 - Roof Corner	12.98	psf
Zone 4 - Wall Field	25.95	psf
Zone 5 - Wall Corner	25.95	psf
Zone 1 - Roof Field	-23.36	psf
Zone 2 - Roof Edge	-44.12	psf
Zone 3 - Roof Corner	-67.48	psf
Zone 4 - Wall Field	-28.55	psf
Zone 5 - Wall Corner	-36.34	psf

Soil Properties		
Soil Type	CL, ML, MH, and CH	
Presumptive Load-Bearing Values of Soil	1500	psf

Seismic Design Criteria		
Seismic Design Category	A	
Short Period Spectral Response, S_{DS}	0.051	%g
1-Sec Spectral Response, S_{D1}	0.048	%g

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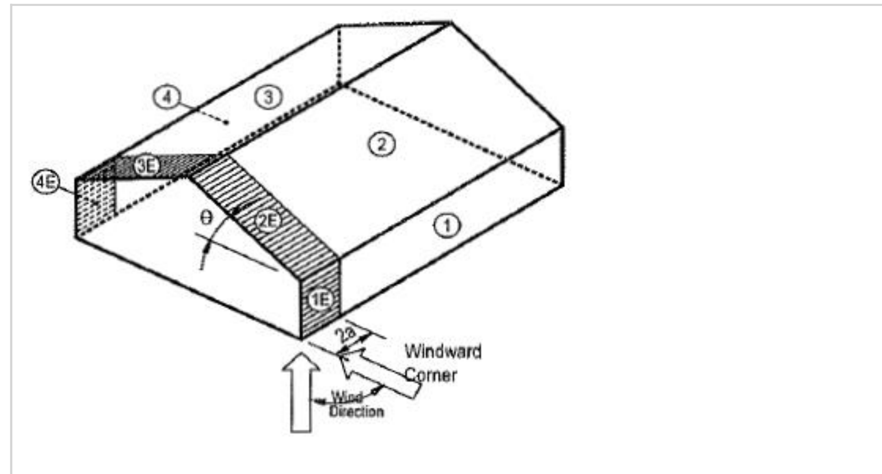
Wind Pressures from ASCE 7-10, Chapter 28 - Part 1: Low Rise Building

Building Geometry:		
Roof Type	Gable	
Building Width, B	60.00	ft
Building Length, L	15.00	ft
Mean Roof Height, h	20.00	ft
Roof Pitch (rise per 12 units of run)	3	/12

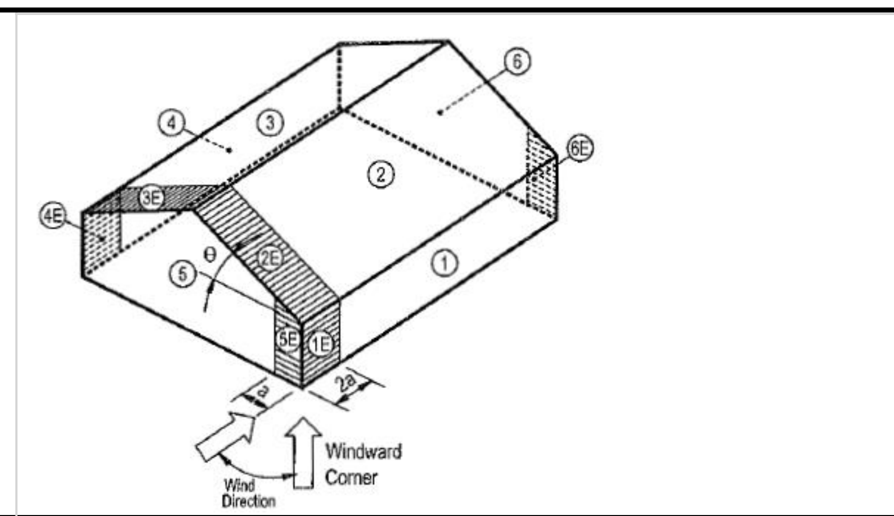
Wind Design Parameters:		
Basic Wind Speed, V_{ult}	115	mph
Topographic Factor, K_{zt}	1.00	
Wind Directionality Factor, K_d	0.85	
Building Category	II	
Exposure Category	C	
Envelope	Open	

Calculated Values:		
Roof Angle, θ	14.036	deg
Importance Factor, I	1.00	
3-s Gust Speed Power Law Exponent, α	9.5	
Nom. Height of Atm. Boundary, z_g	900	
Internal Pressure Coefficient, GC_{pi}	0	
Vel. Press. Exp. Coefficient, K_h	0.902	
Velocity Pressure, q_h	25.95	psf
a	3.0	ft

Load Case A



Load Case B



Load Case A:

	Wall "E"			Wall			Roof "E"			Roof		
Zone	1E	4E	Net	1	4	Net	2E	3E	Net	2	3	Net
External Pressure Coefficients, GC_{pf}	0.72	-0.56		0.48	-0.37		-1.07	-0.63		-0.69	-0.44	
Positive Internal Pressure, psf	18.8	-14.4	33.25	12.4	-9.7	22.13	-27.8	-16.3	-16.26	-17.9	-11.3	-11.32
Negative Internal Pressure, psf	18.8	-14.4	33.25	12.4	-9.7	22.13	-27.8	-16.3	-16.26	-17.9	-11.3	-11.32
Zero Internal Pressure, psf	18.8	-14.4	33.25	12.4	-9.7	22.13	-27.8	-16.3	-16.26	-17.9	-11.3	-11.32

Load Case B:

	Wall "E"			Wall			Wall "E"			Wall			Roof "E"			Roof		
Zone	1E	4E	Net	1	4	Net	5E	6E	Net	5	6	Net	2E	3E	Net	2	3	Net
External Pressure Coefficients, GC_{pf}	-0.48	-0.48		-0.45	-0.45		0.61	-0.43		0.40	-0.29		-1.07	-0.53		-0.69	-0.37	
Positive Internal Pressure, psf	-12.5	-12.5	0.00	-11.7	-11.7	0.00	15.8	-11.2	26.99	10.4	-7.5	17.91	-27.8	-13.8	-13.76	-17.9	-9.6	-9.60
Negative Internal Pressure, psf	-12.5	-12.5	0.00	-11.7	-11.7	0.00	15.8	-11.2	26.99	10.4	-7.5	17.91	-27.8	-13.8	-13.76	-17.9	-9.6	-9.60
Zero Internal Pressure, psf	-12.5	-12.5	0.00	-11.7	-11.7	0.00	15.8	-11.2	26.99	10.4	-7.5	17.91	-27.8	-13.8	-13.76	-17.9	-9.6	-9.60

Wind Pressures from ASCE 7-10, Chapter 28 - Part 1: Low Rise Building (cont'd)

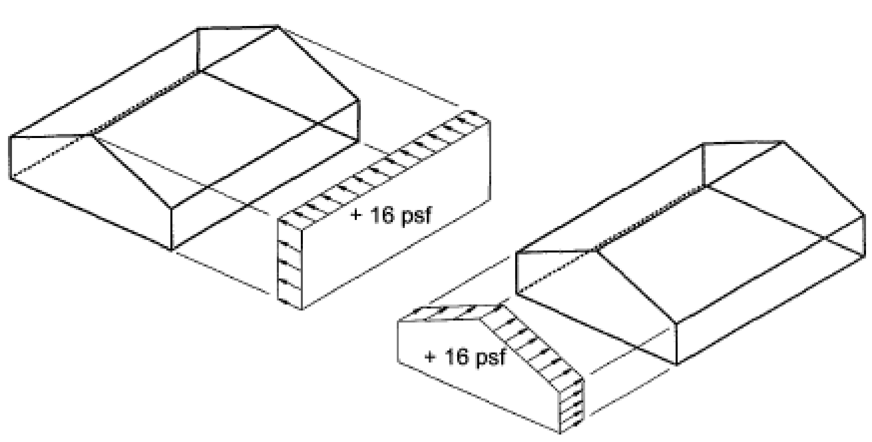


Figure C27.4-1 Application of Minimum Wind Load

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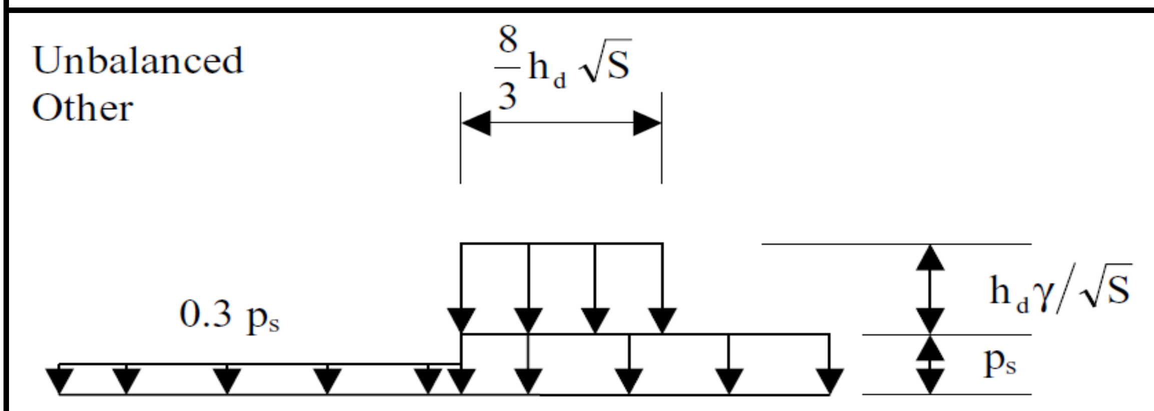
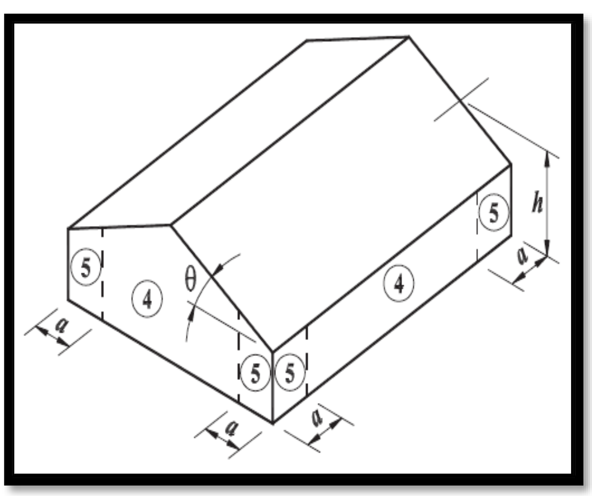
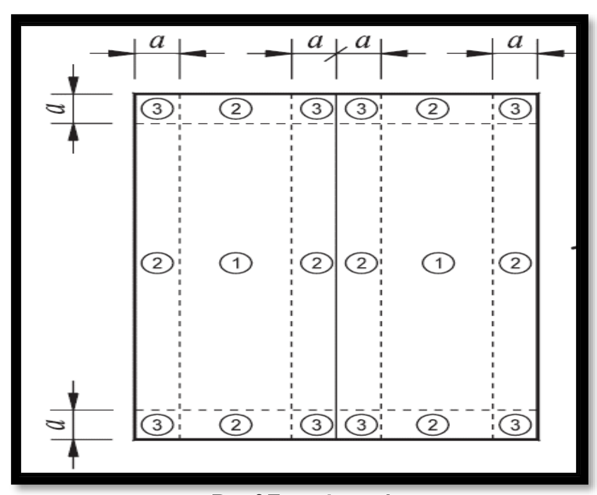
Snow Loads from ASCE 7-10		
Building Geometry:		
Roof Pitch (rise per 12 units of run)	3	/12
Horizontal Distance from Eave to Ridge, W	5.75	ft
Roof Surface	Unobstructed Slippery Surfaces	
Snow Design Parameters:		
Ground Snow Load, p_g	50	psf
Building Category	II	
Terrain Category	C	
Exposure	Partially Exposed	
Thermal Factor, C_t	1.20	
Minimum Snow Load, p_m	20	psf
Rain on Snow Surcharge Load	N/A	psf
Snow Load Used Below	50	psf
Calculated Values:		
Roof Angle, θ	14.036	deg
Importance Factor, I	1.00	
Exposure Factor, C_e	1	
Roof Slope Factor, C_s	1.00	
Drift Height, h_d	0.64	ft
Roof Slope Run for a Rise of One Unit, S	4.00	
Snow Density, γ	20.5	pcf
Flat Roof Snow Load, p_f	42.00	psf
Sloped Roof Snow Load, p_s	**42.00**	psf
Windward Unbalanced Snow Load	12.60	psf
Leeward Unbalanced Load	6.60	psf
Leeward Unbalanced + Balanced Load	**48.60**	psf
Horizontal Extent of Unbalanced load	3.43	ft



General Attachments - Components and Cladding - Part 3 Buildings with h > 60 ft		
Input Variables		
Risk Category	II	
Wind Speed, V_{ult}	115	mph
Exposure Category	C	
Building Height	20.00	ft
Roof Pitch	3	/12
Wind Directionality Factor, K_d	0.85	
Topographic Factor, K_{zt}	1.0	
Enclosure Classification	Open	
Internal Pressure Coefficient	0	
Effective Wind Area	10	ft^2
Roof Type	Flat	
Calculations		
Roof Pitch	14.036	degrees
Velocity Pressure Exposure Coefficient, K_z	0.849	
Velocity Pressure Exposure Coefficient, K_z	0.902	
Velocity Pressure Exposure Coefficient, K_z	0.902	
Velocity Pressure, q_h	26	psf
Roof External Pressure Coefficients, GC_p Figure	Fig.30.4-2B	
Wall External Pressure Coefficients, GC_p Figure	Fig.30.4-1	
Zone Dimension	3	ft
Zone Results		
Positive Internal Pressure	Positive Pressure	Negative Pressure
Zone 1	12.98	-23.36
Zone 2	12.98	-44.12
Zone 3	12.98	-67.48
Zone 4	25.95	-28.55
Zone 5	25.95	-36.34
Negative Internal Pressure	Positive Pressure	Negative Pressure
Zone 1	12.98	-23.36
Zone 2	12.98	-44.12
Zone 3	12.98	-67.48
Zone 4	25.95	-28.55
Zone 5	25.95	-36.34



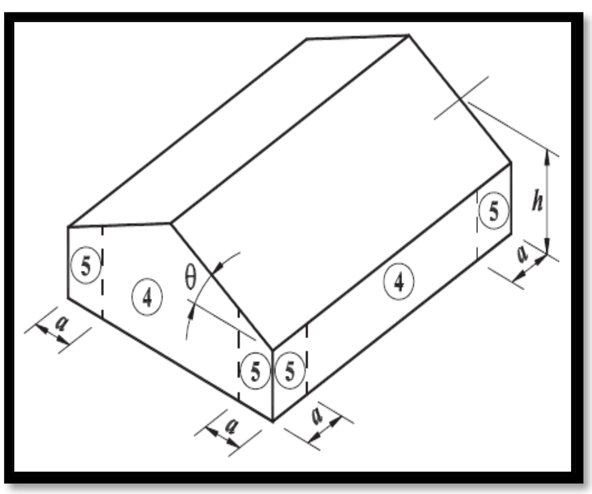
Wall Zone Locations



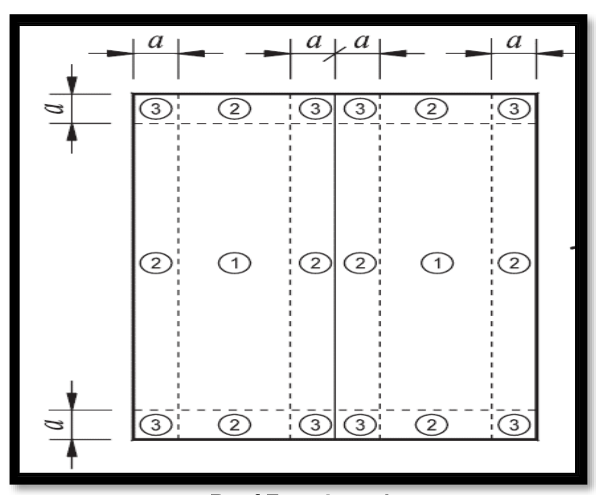
Roof Zone Locations

Max Values - ASCE 10 Loads		
	Positive Pressure	Negative Pressure
Zone 1 - Roof Field	13	-23
Zone 2 - Roof Edge	13	-44
Zone 3 - Roof Corner	13	-67
Zone 4 - Wall Field	26	-29
Zone 5 - Wall Corner	26	-36
Max Values - ASCE 5 Loads (ASCE 7 - 10 Loads Multiplied by 0.6 & Min. 10 psf)		
	Positive Pressure	Negative Pressure
Zone 1 - Roof Field	10	-14
Zone 2 - Roof Edge	10	-26
Zone 3 - Roof Corner	10	-40
Zone 4 - Wall Field	16	-17
Zone 5 - Wall Corner	16	-22

General Attachments - Components and Cladding - Part 3 Buildings with h > 60 ft		
Input Variables		
Risk Category	II	
Wind Speed, V_{ult}	115	mph
Exposure Category	C	
Building Height	20.00	ft
Roof Pitch	3	/12
Wind Directionality Factor, K_d	0.85	
Topographic Factor, K_{zt}	1.0	
Enclosure Classification	Open	
Internal Pressure Coefficient	0	
Effective Wind Area	75	ft^2
Roof Type	Flat	
Calculations		
Roof Pitch	14.036	degrees
Velocity Pressure Exposure Coefficient, K_z	0.849	
Velocity Pressure Exposure Coefficient, K_z	0.902	
Velocity Pressure Exposure Coefficient, K_z	0.902	
Velocity Pressure, q_h	26	psf
Roof External Pressure Coefficients, GC_p Figure	Fig.30.4-2B	
Wall External Pressure Coefficients, GC_p Figure	Fig.30.4-1	
Zone Dimension	3	ft
Zone Results		
Positive Internal Pressure	**Positive Pressure**	**Negative Pressure**
Zone 1	8.43	-21.09
Zone 2	8.43	-32.77
Zone 3	8.43	-53.85
Zone 4	21.94	-24.54
Zone 5	21.94	-28.32
Negative Internal Pressure	**Positive Pressure**	**Negative Pressure**
Zone 1	8.43	-21.09
Zone 2	8.43	-32.77
Zone 3	8.43	-53.85
Zone 4	21.94	-24.54
Zone 5	21.94	-28.32



Wall Zone Locations



Roof Zone Locations

Max Values - ASCE 10 Loads		
	Positive Pressure	**Negative Pressure**
Zone 1 - Roof Field	8	-21
Zone 2 - Roof Edge	8	-33
Zone 3 - Roof Corner	8	-54
Zone 4 - Wall Field	22	-25
Zone 5 - Wall Corner	22	-28
Max Values - ASCE 5 Loads (ASCE 7 - 10 Loads Multiplied by 0.6 & Min. 10 psf)		
	Positive Pressure	**Negative Pressure**
Zone 1 - Roof Field	10	-13
Zone 2 - Roof Edge	10	-20
Zone 3 - Roof Corner	10	-32
Zone 4 - Wall Field	13	-15
Zone 5 - Wall Corner	13	-17

Each Frame					Minimum Load
Area (ft^2)	Load Case	Zone	Load (psf)	Load (lbf)	Area (ft^2)
69	A	Roof	-11	-781	69
					Total = 69
ASCE 7-10 Lateral Wind =				781	1104
0.6 * Wind Load =				469	662
Max Story Load used for Design =				662	

Wind Area					Minimum Load
Area (ft^2)	Load Case	Zone	Load (psf)	Load (lbf)	Area (ft^2)
					Total = 0
ASCE 7-10 Lateral Wind =				0	0
0.6 * Wind Load =				0	0
Max Story Load used for Design =				0	

Loading Values Determined Elsewhere in this Document			
Dead Load			
Roof	15.0	psf	Cover Sheet
Floor	15.0	psf	Cover Sheet
Live Loads			
Roof	20.0	psf	Cover Sheet
Floor	100.0	psf	Cover Sheet
Snow Loads			
Snow	42.0	psf	Snow Load
Wind Loads			
Wind - Vertical C&C	16.0	psf	Snow Load
Soil			
Allowable Soil Pressure	1500.0	psf	Cover Sheet

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Roof Loading Top Plate (High Roof)

Roof Rafter				
Truss Reaction				
Span Length	15.00	ft		
Spacing	1.33	ft		
Uniform Line Loads	**Unit Values**		**Line Loads**	
Dead	15.0	psf	20	plf
Roof Live	20.0	psf	27	plf
Snow	42.0	psf	56	plf
Wind	-16.00	psf	-21	plf
Roof System - Header				
Truss Reaction				
Length	12.00	ft		
Trib	7.50	ft		
Uniform Line Loads	**Unit Values**		**Line Loads**	
Dead	15.0	psf	113	plf
Roof Live	20.0	psf	150	plf
Snow	42.0	psf	315	plf
Wind	-16.00	psf	-120	plf
Floor System				
Truss Reaction				
Span Length	15.00	ft		
Spacing	1.33	ft		
Uniform Line Loads	**Unit Values**		**Line Loads**	
Dead	15.0	psf	20	plf
Floor Live	100.0	psf	133	plf
Snow	0.0	psf	0	plf
Wind	-16.00	psf	-21	plf
Floor System - Header				
Truss Reaction				
Length	12.00	ft		
Trib	7.50	ft		
Uniform Line Loads	**Unit Values**		**Line Loads**	
Dead	15.0	psf	113	plf
Roof Live	100.0	psf	750	plf
Snow	0.0	psf	0	plf
Wind	-16.00	psf	-120	plf

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Front Posts - 2 Story				
Truss Reaction				
Length	12.00	ft		
Trib	7.50	ft		
Roof Loads			Line Loads	
Dead			1350	plf
Roof Live			1800	plf
Snow			3780	plf
Wind			-1440	plf
Floor Loads			Line Loads	
Dead			0	plf
Floor Live			0	plf
Snow			0	plf
Wind			0	plf
Total Axial			Line Loads	
Dead			1350	plf
Floor Live			1800	plf
Snow			3780	plf
Wind			-1440	plf
Wind Frame Action			Line Loads	
Shear	662.4	lb	662	plf
Moment	662.4	lb	95386	lbf-in
Front Posts - Carrying Floor				
Truss Reaction				
Length	12.00	ft		
Trib	7.50	ft		
Floor Loads			Line Loads	
Dead			1350	plf
Floor Live			9000	plf
Snow			0	plf
Wind			-1440	plf

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Roof Rafter

Column Details		
Column Details	Column Lumber Species	SOUTHERN PINE (12" wide)
	Column Lumber Grade	No.1
	Column Lumber Size	2x12
	Effective Length Factor, K_e	1.00
	Unbraced Length (in)	12
	Wet Service?	No
	Section Properties	
	Rotation Needed	No
	Width, b (in)	1.50
	Depth, d (in)	11.25
	Area, A (in^2)	16.9
	Moment of Inertia (in^4)	177.98
	Section Modulus, S (in^3)	31.6

	Design Values	Reference Design Values	C_M	C_f	C_r	R_x x C_M x C_F x C_r
Design Values	F_b	1000	1	1	1.15	1150
	F_t	650	1	1	1	650
	F_c	1600	1	1	1	1600
	E_{min}	620000	1	N/A	1	620000
	E	1700000	1	N/A	1	1700000
	F_v	175	1	N/A	1	175

		Load Case	D	D+L	D+S	D+W	D+0.75W+0.75L	D+0.75W+0.75S	0.6D+W
Loads		D.O.L	0.90	1.25	1.00	1.60	1.60	1.60	1.60
		Tension or Compression?	Compression	Compression	Compression	Compression	Compression	Compression	Compression
		Axial Load (lbs)	0	0	0	0	0	0	0
		Shear Force (lbs)	150	349	569	-10	180	344	-70
		Bending Moment (in-lbs)	6733	15711	25586	-449	8080	15486	-3142
Stability Coefficients		ℓ_e (in)	12	12	12	12	12	12	12
		ℓ_e/d	1.1	1.1	1.1	1.1	1.1	1.1	1.1
		F_c* (psi)	1440	2000	1600	2560	2560	2560	2560
		F_{cE} (psi)	447925.8	447925.8	447925.8	447925.8	447925.8	447925.8	447925.8
		α_c	311.06	223.96	279.95	174.97	174.97	174.97	174.97
		C_p	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		ℓ_e (in)	22	22	22	22	22	22	22
		R_B	10.6	10.6	10.6	10.6	10.6	10.6	10.6
		F_b* (psi)	1035	1438	1150	1840	1840	1840	1840
		F_{bE} (psi)	6631	6631	6631	6631	6631	6631	6631
		α_b	6.41	4.61	5.77	3.60	3.60	3.60	3.60
		C_L	0.99	0.99	0.99	0.98	0.98	0.98	0.98
Adjusted Design Values		F_b	1026	1418	1138	1806	1806	1806	1806
		F_t	585	813	650	1040	1040	1040	1040
		F_c	1439	1998	1599	2557	2557	2557	2557
		F_v	158	219	175	280	280	280	280
Stresses		f_a	0	0	0	0	0	0	0
		f_v	13	31	51	-1	16	31	-6
		f_b	213	497	809	-14	255	489	-99
CSI Values	Comp.	$(f_c/F_c')^2 + f_b/[F_b'[1-(f_c/F_{cE})]] < 1.0$	0.21	0.35	0.71	-0.01	0.14	0.27	-0.05
		$f_c < F_{cE}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Tens.	$f_t/F_t + f_b/F_b^* < 1.0$	0.21	0.35	0.71	-0.01	0.14	0.27	-0.05
		$(f_b - f_t)/F_b^{**} < 1.0$	0.21	0.35	0.71	-0.01	0.14	0.27	-0.05
	Shear	$f_v < F_v'$	0.08	0.14	0.29	0.00	0.06	0.11	-0.02
	Δ	Deflection (in)	0.0751	0.1752	0.3104				
	Serv.	L/Δ	2397	719	467				
	All	Result	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**

Floor System

Column Details	
Column Lumber Species	SOUTHERN PINE (12" wide)
Column Lumber Grade	No.2
Column Lumber Size	(2)-2x12
Effective Length Factor, K_e	1.00
Unbraced Length (in)	12
Wet Service?	No
Section Properties	
Rotation Needed	No
Width, b (in)	3.00
Depth, d (in)	11.25
Area, A (in^2)	33.8
Moment of Inertia (in^4)	355.96
Section Modulus, S (in^3)	63.3

Design Values	Reference Design Values	C_M	C_f	C_r	$R_x \times C_M \times C_F \times C_r$
F_b	750	1	1	1.15	863
F_t	450	1	1	1	450
F_c	1450	1	1	1	1450
E_{min}	580000	1	N/A	1	580000
E	1600000	1	N/A	1	1600000
F_v	175	1	N/A	1	175

Section	Load Case	D	D+L	D+S	D+W	D+0.75W+0.75L	D+0.75W+0.75S	0.6D+W
Loads	D.O.L	0.90	1.00	1.00	1.60	1.60	1.60	1.60
Loads	Tension or Compression?	Compression	Compression	Compression	Compression	Compression	Compression	Compression
Loads	Axial Load (lbs)	0	0	0	0	0	0	0
Loads	Shear Force (lbs)	150	1147	150	-10	778	30	-70
Loads	Bending Moment (in-lbs)	6733	51621	6733	-449	35012	1347	-3142
Stability Coefficients	ℓ_e (in)	12	12	12	12	12	12	12
Stability Coefficients	ℓ_e/d	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Stability Coefficients	F_c^* (psi)	1305	1450	1450	2320	2320	2320	2320
Stability Coefficients	F_{cE} (psi)	419027.3	419027.3	419027.3	419027.3	419027.3	419027.3	419027.3
Stability Coefficients	α_c	321.09	288.98	288.98	180.62	180.62	180.62	180.62
Stability Coefficients	C_p	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stability Coefficients	ℓ_e (in)	22	22	22	22	22	22	22
Stability Coefficients	R_B	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Stability Coefficients	F_b^* (psi)	776	863	863	1380	1380	1380	1380
Stability Coefficients	F_{bE} (psi)	24813	24813	24813	24813	24813	24813	24813
Stability Coefficients	α_b	31.97	28.77	28.77	17.98	17.98	17.98	17.98
Stability Coefficients	C_L	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adjusted Design Values	F_b	775	861	861	1376	1376	1376	1376
Adjusted Design Values	F_t	405	450	450	720	720	720	720
Adjusted Design Values	F_c	1304	1449	1449	2317	2317	2317	2317
Adjusted Design Values	F_v	158	175	175	280	280	280	280
Stresses	f_a	0	0	0	0	0	0	0
Stresses	f_v	7	51	7	0	35	1	-3
Stresses	f_b	106	816	106	-7	553	21	-50
CSI Values – Comp.	$(f_c/F_c')^2 + f_b/[F_b'[1-(f_c/F_{cE})] < 1.0$	0.14	0.95	0.12	-0.01	0.40	0.02	-0.04
CSI Values – Comp.	$f_c < F_{cE}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSI Values – Tens.	$f_t/F_t + f_b/F_b^* < 1.0$	0.14	0.95	0.12	-0.01	0.40	0.02	-0.04
CSI Values – Tens.	$(f_b - f_t)/F_b^{**} < 1.0$	0.14	0.95	0.12	-0.01	0.40	0.02	-0.04
CSI Values – Shear	$f_v < F_v'$	0.04	0.29	0.04	0.00	0.12	0.00	-0.01
CSI Values – Δ	Deflection (in)	0.0399	0.3059	0.2660				
CSI Values – Serv.	L/Δ	4511	521	588				
CSI Values – All	Result	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**

Roof System - Header

Column Details

Column Lumber Species	Gluelam
Column Lumber Grade	16F-1.3E
Column Lumber Size	3.5x11.25
Effective Length Factor, K_e	1.00
Unbraced Length (in)	12
Wet Service?	No
Section Properties	
Rotation Needed	No
Width, b (in)	3.50
Depth, d (in)	11.25
Area, A (in^2)	39.4
Moment of Inertia (in^4)	415.28
Section Modulus, S (in^3)	73.8

Design Values

Design Values	Reference Design Values	C_M	C_f	C_r	R_x x C_M x C_F x C_r
F_b	1600	1	1	1.15	1840
F_t	675	1	1	1	675
F_c	925	1	1	1	925
E_{min}	580000	1	N/A	1	580000
E	1100000	1	N/A	1	1100000
F_v	195	1	N/A	1	195

Section	Load Case	D	D+L	D+S	D+W	D+0.75W+0.75L	D+0.75W+0.75S	0.6D+W
Loads	D.O.L	0.90	1.25	1.00	1.60	1.60	1.60	1.60
	Tension or Compression?	Compression	Compression	Compression	Compression	Compression	Compression	Compression
	Axial Load (lbs)	0	0	0	0	0	0	0
	Shear Force (lbs)	675	1575	2565	-45	810	1553	-315
	Bending Moment (in-lbs)	24300	56700	92340	-1620	29160	55890	-11340
Stability Coefficients	ℓ_e (in)	12	12	12	12	12	12	12
	ℓ_e/d	1.1	1.1	1.1	1.1	1.1	1.1	1.1
	F_c^* (psi)	832.5	1156.25	925	1480	1480	1480	1480
	F_{cE} (psi)	419027.3	419027.3	419027.3	419027.3	419027.3	419027.3	419027.3
	α_c	503.34	362.40	453.00	283.13	283.13	283.13	283.13
	C_p	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	ℓ_e (in)	22	22	22	22	22	22	22
	R_B	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	F_b^* (psi)	1656	2300	1840	2944	2944	2944	2944
	F_{bE} (psi)	33773	33773	33773	33773	33773	33773	33773
	α_b	20.39	14.68	18.35	11.47	11.47	11.47	11.47
	C_L	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adjusted Design Values	F_b	1652	2292	1835	2930	2930	2930	2930
	F_t	608	844	675	1080	1080	1080	1080
	F_c	832	1156	925	1479	1479	1479	1479
	F_v	176	244	195	312	312	312	312
Stresses	f_a	0	0	0	0	0	0	0
	f_v	26	60	98	-2	31	59	-12
	f_b	329	768	1251	-22	395	757	-154
CSI Values – Comp.	$(f_c/F_c')^2 + f_b/[F_b'[1-(f_c/F_{cE})] < 1.0$	0.20	0.34	0.68	-0.01	0.13	0.26	-0.05
	$f_c < F_{cE}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSI Values – Tens.	$f_t/F_t + f_b/F_b^* < 1.0$	0.20	0.34	0.68	-0.01	0.13	0.26	-0.05
	$(f_b - f_t)/F_b^{**} < 1.0$	0.20	0.34	0.68	-0.01	0.13	0.26	-0.05
CSI Values – Shear	$f_v < F_v'$	0.15	0.25	0.50	-0.01	0.10	0.19	-0.04
CSI Values – Δ	Deflection (in)	0.1149	0.2681	0.4749				
CSI Values – Serv.	L/Δ	1253	376	244				
CSI Values – All	Result	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**

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Floor System - Header

Column Details

Column Lumber Species	Gluelam
Column Lumber Grade	24F-1.8E
Column Lumber Size	5.125x12
Effective Length Factor, K_e	1.00
Unbraced Length (in)	12
Wet Service?	No
Section Properties	
Rotation Needed	No
Width, b (in)	5.13
Depth, d (in)	12.00
Area, A (in^2)	61.5
Moment of Inertia (in^4)	738.00
Section Modulus, S (in^3)	123.0

Design Values

Design Values	Reference Design Values	C_M	C_f	C_r	R_x x C_M x C_F x C_r
F_b	2400	1	1	1.15	2760
F_t	1100	1	1	1	1100
F_c	1600	1	1	1	1600
E_{min}	850000	1	N/A	1	850000
E	1600000	1	N/A	1	1600000
F_v	265	1	N/A	1	265

Section	Load Case	D	D+L	D+S	D+W	D+0.75W+0.75L	D+0.75W+0.75S	0.6D+W
Loads	D.O.L	0.90	1.00	1.00	1.60	1.60	1.60	1.60
Loads	Tension or Compression?	Compression	Compression	Compression	Compression	Compression	Compression	Compression
Loads	Axial Load (lbs)	0	0	0	0	0	0	0
Loads	Shear Force (lbs)	675	5175	675	-45	3510	135	-315
Loads	Bending Moment (in-lbs)	24300	186300	24300	-1620	126360	4860	-11340
Stability Coefficients	ℓ_e (in)	12	12	12	12	12	12	12
Stability Coefficients	ℓ_e/d	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Stability Coefficients	F_c^* (psi)	1440	1600	1600	2560	2560	2560	2560
Stability Coefficients	F_{cE} (psi)	698700.0	698700.0	698700.0	698700.0	698700.0	698700.0	698700.0
Stability Coefficients	α_c	485.21	436.69	436.69	272.93	272.93	272.93	272.93
Stability Coefficients	C_p	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Stability Coefficients	ℓ_e (in)	22	22	22	22	22	22	22
Stability Coefficients	R_B	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Stability Coefficients	F_b^* (psi)	2484	2760	2760	4416	4416	4416	4416
Stability Coefficients	F_{bE} (psi)	99491	99491	99491	99491	99491	99491	99491
Stability Coefficients	α_b	40.05	36.05	36.05	22.53	22.53	22.53	22.53
Stability Coefficients	C_L	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adjusted Design Values	F_b	2481	2756	2756	4406	4406	4406	4406
Adjusted Design Values	F_t	990	1100	1100	1760	1760	1760	1760
Adjusted Design Values	F_c	1439	1599	1599	2558	2558	2558	2558
Adjusted Design Values	F_v	239	265	265	424	424	424	424
Stresses	f_a	0	0	0	0	0	0	0
Stresses	f_v	16	126	16	-1	86	3	-8
Stresses	f_b	198	1515	198	-13	1027	40	-92
CSI Values – Comp.	$(f_c/F_c')^2 + f_b/[F_b'[1-(f_c/F_{cE})] < 1.0$	0.08	0.55	0.07	0.00	0.23	0.01	-0.02
CSI Values – Comp.	$f_c < F_{cE}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSI Values – Tens.	$f_t/F_t + f_b/F_b^* < 1.0$	0.08	0.55	0.07	0.00	0.23	0.01	-0.02
CSI Values – Tens.	$(f_b - f_t)/F_b^{**} < 1.0$	0.08	0.55	0.07	0.00	0.23	0.01	-0.02
CSI Values – Shear	$f_v < F_v'$	0.07	0.48	0.06	0.00	0.20	0.01	-0.02
CSI Values – Δ	Deflection (in)	0.0445	0.3408	0.2963				
CSI Values – Serv.	L/Δ	3240	374	423				
CSI Values – All	Result	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**

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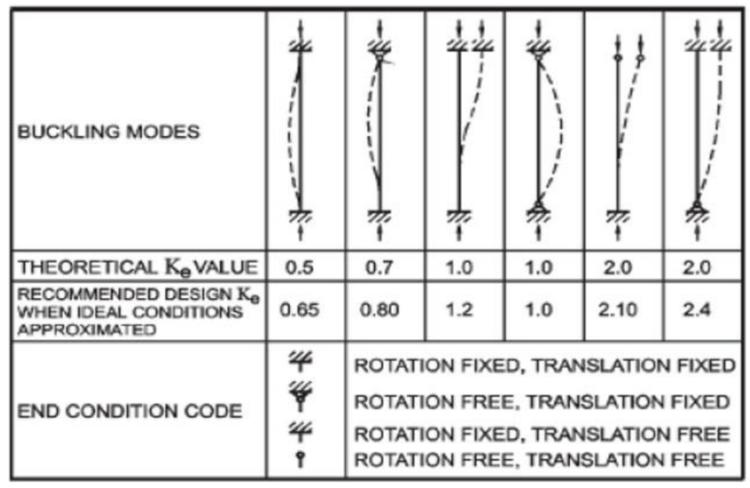
Front Posts - 2 Story

Column Details

Column Lumber Species	Southern Pine Timbers
Column Lumber Grade	No.2
Column Lumber Size	8x8
Eff. Len. Factor - Dir. 1, K_e	1.00
Unbraced Length - Dir. 1 (in)	144
Eff. Len. Factor - Dir. 2, K_e	1.00
Unbraced Length - Dir. 2 (in)	144
Length (in)	144
Wet Service?	No
Section Properties	
Rotation Needed	No
Width, b (in)	8.00
Depth, d (in)	8.00
Area, A (in^2)	64.0
Moment of Inertia (in^4)	341.33
Section Modulus, S (in^3)	85.3



Design Values

Design Values	Reference Design Values	C_M	C_v	C_r	R_x x C_M x C_F x C_r
F_b	850	1	0.80	1	680
F_t	550	1	N/A	N/A	550
F_c	525	1	N/A	N/A	525
E_{min}	440000	1	N/A	N/A	440000
E	1200000	1	N/A	N/A	1200000
F_v	165	1	N/A	N/A	165

Frame No.	

	Load Case	D	D+L	D+S	D+0.6W	D+0.75(0.6W)+0.75L	D+0.75(0.6W)+0.75S	0.6D+0.6W
Loads	D.O.L	0.90	1.25	1.15	1.60	1.60	1.60	1.60
	Tension or Compression?	Compression	Compression	Compression	Compression	Compression	Compression	Tension
	Axial Load (lbs)	1350	3150	5130	486	2052	3537	-54
	Shear Force (lbs)	0	0	0	397	298	298	397
	Bending Moment (in-lbs)	0	0	0	57231	42924	42924	57231
Stability Coefficients	ℓ_e (in) - Dir. 1	144	144	144	144	144	144	144
	ℓ_e/b - Dir 1	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	ℓ_e (in) - Dir. 2	144	144	144	144	144	144	144
	ℓ_e/d - Dir 2	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	ℓ_e/d	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	F_c* (psi)	472.5	656.25	603.75	840	840	840	840
	F_{cE} (psi)	1116.3	1116.3	1116.3	1116.3	1116.3	1116.3	1116.3
	α_c	2.36	1.70	1.85	1.33	1.33	1.33	1.33
	C_p	0.89	0.84	0.85	0.78	0.78	0.78	0.78
	ℓ_e (in)	231	231	231	231	231	231	231
	R_B	5.4	5.4	5.4	5.4	5.4	5.4	5.4
	F_b* (psi)	612	851	783	1089	1089	1089	1089
	F_{bE} (psi)	18257	18257	18257	18257	18257	18257	18257
	α_b	29.81	21.47	23.33	16.77	16.77	16.77	16.77
	C_L	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adjusted Design Values	F_b	611	848	781	1085	1085	1085	1085
	F_t	495	688	633	880	880	880	880
	F_c	421	550	515	654	654	654	654
	F_v	149	206	190	264	264	264	264
Stresses	f_a	21	49	80	8	32	55	1
	f_v	0	0	0	9	7	7	9
	f_b	0	0	0	671	503	503	671
CSI Values - Comp.	$(f_c/F_c')^2 + f_b/[F_b'[1-(f_c/F_{cE})] < 1.0$	0.00	0.01	0.02	0.62	0.48	0.49	0.62
	$f_c < F_{cE}$	0.02	0.04	0.07	0.01	0.03	0.05	0.00
CSI Values - Tens.	$f_t/F_t + f_b/F_b^* < 1.0$	0.00	0.00	0.00	0.62	0.46	0.46	0.54
	$(f_b - f_t)/F_b^{**} < 1.0$	0.00	0.00	0.00	0.62	0.46	0.46	0.62
CSI Values - Shear	$f_v < F_v'$	0.00	0.00	0.00	0.04	0.03	0.03	0.04
CSI Values - All	Result	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**

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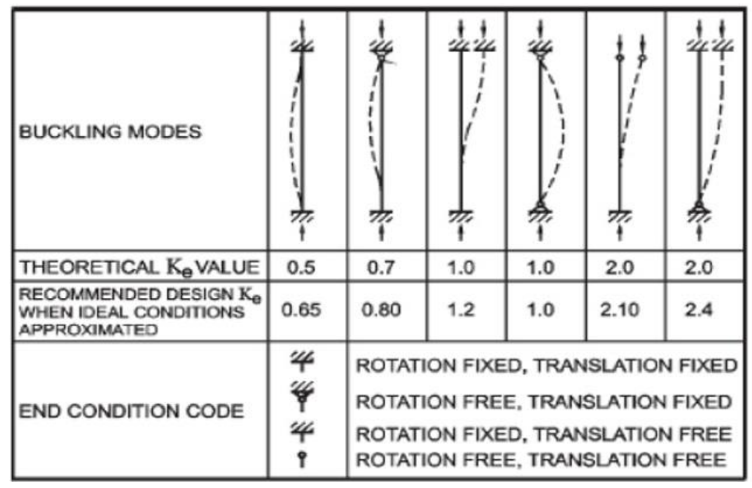
Front Posts - Carrying Floor

Column Details	
Column Lumber Species	Southern Pine Timbers
Column Lumber Grade	No.2
Column Lumber Size	6x8
Eff. Len. Factor - Dir. 1, K_e	1.00
Unbraced Length - Dir. 1 (in)	96
Eff. Len. Factor - Dir. 2, K_e	1.00
Unbraced Length - Dir. 2 (in)	96
Length (in)	96
Wet Service?	No
Section Properties	
Rotation Needed	No
Width, b (in)	5.50
Depth, d (in)	7.25
Area, A (in^2)	39.9
Moment of Inertia (in^4)	174.66
Section Modulus, S (in^3)	48.2



Design Values	Reference Design Values	C_M	C_v	C_r	R_x x C_M x C_F x C_r
F_b	850	1	0.84	1	711
F_t	550	1	N/A	N/A	550
F_c	525	1	N/A	N/A	525
E_{min}	440000	1	N/A	N/A	440000
E	1200000	1	N/A	N/A	1200000
F_v	165	1	N/A	N/A	165

Frame No.	

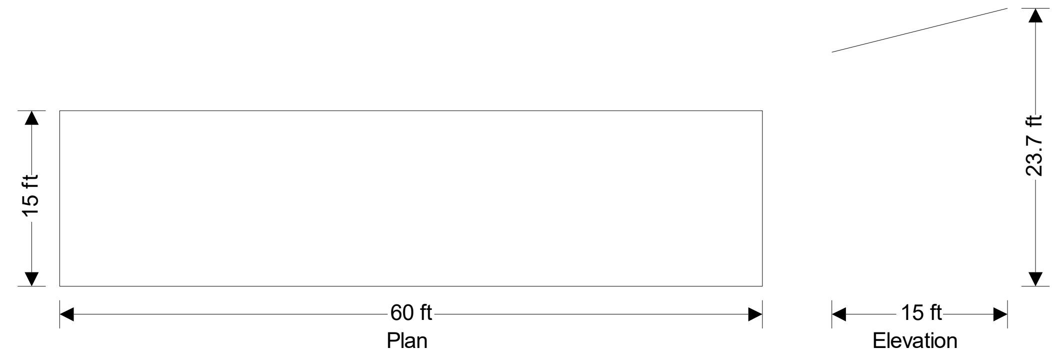
Section	Load Case	D	D+L	D+S	D+0.6W	D+0.75(0.6W)+0.75L	D+0.75(0.6W)+0.75S	0.6D+0.6W
Loads	D.O.L	0.90	1.00	1.15	1.60	1.60	1.60	1.60
	Tension or Compression?	Compression	Compression	Compression	Compression	Compression	Compression	Tension
	Axial Load (lbs)	1350	10350	1350	486	7452	702	-54
	Shear Force (lbs)	0	0	0	0	0	0	0
	Bending Moment (in-lbs)	0	0	0	0	0	0	0
Stability Coefficients	ℓ_e (in) - Dir. 1	96	96	96	96	96	96	96
	ℓ_e/b - Dir 1	17.5	17.5	17.5	17.5	17.5	17.5	17.5
	ℓ_e (in) - Dir. 2	96	96	96	96	96	96	96
	ℓ_e/d - Dir 2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
	ℓ_e/d	17.5	17.5	17.5	17.5	17.5	17.5	17.5
	F_c^* (psi)	472.5	525	603.75	840	840	840	840
	F_{cE} (psi)	2062.8	2062.8	2062.8	2062.8	2062.8	2062.8	2062.8
	α_c	4.37	3.93	3.42	2.46	2.46	2.46	2.46
	C_p	0.95	0.94	0.93	0.90	0.90	0.90	0.90
	ℓ_e (in)	160	160	160	160	160	160	160
	R_B	6.2	6.2	6.2	6.2	6.2	6.2	6.2
	F_b^* (psi)	640	711	818	1138	1138	1138	1138
	F_{bE} (psi)	13770	13770	13770	13770	13770	13770	13770
	α_b	21.52	19.37	16.84	12.10	12.10	12.10	12.10
	C_L	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adjusted Design Values	F_b	638	709	815	1133	1133	1133	1133
	F_t	495	550	633	880	880	880	880
	F_c	448	494	562	753	753	753	753
	F_v	149	165	190	264	264	264	264
Stresses	f_a	34	260	34	12	187	18	1
	f_v	0	0	0	0	0	0	0
	f_b	0	0	0	0	0	0	0
CSI Values - Comp.	$(f_c/F_c')^2 + f_b/[F_b'[1-(f_c/F_{cE})]] < 1.0$	0.01	0.28	0.00	0.00	0.06	0.00	0.00
CSI Values - Comp.	$f_c < F_{cE}$	0.02	0.13	0.02	0.01	0.09	0.01	0.00
CSI Values - Tens.	$f_t/F_t + f_b/F_b^* < 1.0$	0.00	0.00	0.00	0.00	0.00	0.00	-0.08
CSI Values - Tens.	$(f_b - f_t)/F_b^{**} < 1.0$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSI Values - Shear	$f_v < F_v'$	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CSI Values - All	Result	Pass	Pass	Pass	Pass	Pass	Pass	Pass

WIND LOADING

In accordance with ASCE7-10

Using the directional design method

Tedds calculation version 2.1.00



Building data

Type of roof	Monoslope free
Length of building	b = **60.00** ft
Width of building	d = **15.00** ft
Height to eaves	H = **20.00** ft
Pitch of roof	α_0 = **14.0** deg
Mean height	h = **21.87** ft
Wind flow	Clear

General wind load requirements

Basic wind speed	V = **115.0** mph
Risk category	II
Velocity pressure exponent coef (Table 26.6-1)	K_d = **0.85**
Exposure category (cl 26.7.3)	B
Enclosure classification (cl.26.10)	Open buildings
Internal pressure coef +ve (Table 26.11-1)	GC_{pi_p} = **0.00**
Internal pressure coef –ve (Table 26.11-1)	GC_{pi_n} = **0.00**
Gust effect factor	G_f = **0.85**

Topography

Topography factor not significant	K_{zt} = 1.0

Velocity pressure

Velocity pressure coefficient (T.27.3-1)	K_z = **0.63**
Velocity pressure	$q_h = 0.00256 \times K_z \times K_{zt} \times K_d \times V^2 \times 1\text{psf/mph}^2$ = **18.3** psf

Peak velocity pressure for internal pressure

Peak velocity pressure – internal (as roof press.)	q_i = **18.27** psf

Pressures and forces

Net pressure	$p = q_h \times G \times C_N$
Net force	$F_w = p \times A_{ref}$
Minimum design wind loading (cl.27.4.7)	p_{min_r} = **16** lb/ft^2

Roof load case 1 - Wind 0, Loadcase A

Zone	Ref. height (ft)	Ext pressure coefficient c_N	Peak velocity pressure q_h (psf)	Net pressure p (psf)	Area A_{ref} (ft^2)	Net force F_w (kips)
1 (+ve)	21.87	-0.86	18.27	-13.36	463.78	-6.19
2 (+ve)	21.87	-1.26	18.27	-19.57	463.78	-9.08

Total vertical net force $F_{w,v}$ = **-14.82** kips

Total horizontal net force $F_{w,h}$ = **3.69** kips

Minimum loading

Projected vertical area of roof $A_{vert\_r\_0} = b \times d \times \tan(\alpha_0)$ = **224.40** ft^2

Minimum overall horizontal loading $F_{w,total\_min} = p_{min\_r} \times A_{vert\_r\_0}$ = **3.59** kips

Roof load case 2 - Wind 0, Loadcase B

Zone	Ref. height (ft)	Ext pressure coefficient c_N	Peak velocity pressure q_h (psf)	Net pressure p (psf)	Area A_{ref} (ft^2)	Net force F_w (kips)
1 (+ve)	21.87	-1.83	18.27	-28.47	463.78	-13.21
2 (+ve)	21.87	0.00	18.27	0.00	463.78	0.00

Total vertical net force $F_{w,v}$ = **-12.81** kips

Total horizontal net force $F_{w,h}$ = **3.20** kips

Minimum loading

Projected vertical area of roof $A_{vert\_r\_0} = b \times d \times \tan(\alpha_0)$ = **224.40** ft^2

Minimum overall horizontal loading $F_{w,total\_min} = p_{min\_r} \times A_{vert\_r\_0}$ = **3.59** kips

Roof load case 3 - Wind 180, Loadcase A

Zone	Ref. height (ft)	Ext pressure coefficient c_N	Peak velocity pressure q_h (psf)	Net pressure p (psf)	Area A_{ref} (ft^2)	Net force F_w (kips)
1 (+ve)	21.87	1.25	18.27	19.36	463.78	8.98
2 (+ve)	21.87	1.59	18.27	24.64	463.78	11.43

Total vertical net force $F_{w,v}$ = **19.80** kips

Total horizontal net force $F_{w,h}$ = **4.94** kips

Minimum loading

Projected vertical area of roof $A_{vert\_r\_180} = b \times d \times \tan(\alpha_0)$ = **224.40** ft^2

Minimum overall horizontal loading $F_{w,total\_min} = p_{min\_r} \times A_{vert\_r\_180}$ = **3.59** kips

Roof load case 4 - Wind 180, Loadcase B

Zone	Ref. height (ft)	Ext pressure coefficient c_N	Peak velocity pressure q_h (psf)	Net pressure p (psf)	Area A_{ref} (ft^2)	Net force F_w (kips)
1 (+ve)	21.87	1.77	18.27	27.54	463.78	12.77
2 (+ve)	21.87	0.56	18.27	8.70	463.78	4.03

Total vertical net force $F_{w,v}$ = **16.31** kips

Total horizontal net force $F_{w,h}$ = **4.06** kips

Minimum loading

Projected vertical area of roof $A_{vert\_r\_180} = b \times d \times \tan(\alpha_0) =$ **224.40** ft^2

Minimum overall horizontal loading $F_{w,total\_min} = p_{min\_r} \times A_{vert\_r\_180} =$ **3.59** kips

Roof load case 5 - Wind 90, Loadcase A

Zone	Ref. height (ft)	Ext pressure coefficient c_N	Peak velocity pressure q_h (psf)	Net pressure p (psf)	Area A_{ref} (ft^2)	Net force F_w (kips)
1 (+ve)	21.87	-0.80	18.27	-12.43	338.09	-4.20
2 (+ve)	21.87	-0.60	18.27	-9.32	338.09	-3.15
3 (+ve)	21.87	-0.30	18.27	-4.66	251.37	-1.17

Total vertical net force $F_{w,v} =$ **-8.27** kips

Total horizontal net force $F_{w,h} =$ **0.00** kips

Minimum loading

Projected vertical area of roof $A_{vert\_r\_90} =$ **0.00** ft^2

Minimum overall horizontal loading $F_{w,total\_min} = p_{min\_r} \times A_{vert\_r\_90} =$ **0.00** kips

Roof load case 6 - Wind 90, Loadcase B

Zone	Ref. height (ft)	Ext pressure coefficient c_N	Peak velocity pressure q_h (psf)	Net pressure p (psf)	Area A_{ref} (ft^2)	Net force F_w (kips)
1 (+ve)	21.87	0.80	18.27	12.43	338.09	4.20
2 (+ve)	21.87	0.50	18.27	7.77	338.09	2.63
3 (+ve)	21.87	0.30	18.27	4.66	251.37	1.17

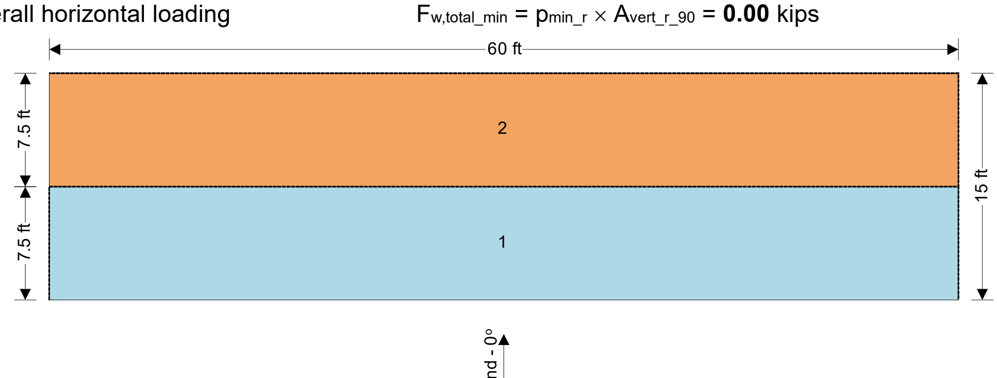
Total vertical net force $F_{w,v} =$ **7.76** kips

Total horizontal net force $F_{w,h} =$ **0.00** kips

Minimum loading

Projected vertical area of roof $A_{vert\_r\_90} =$ **0.00** ft^2

Minimum overall horizontal loading $F_{w,total\_min} = p_{min\_r} \times A_{vert\_r\_90} =$ **0.00** kips



Plan view - Monoslope roof

Tekla Tedds DrJ Engineering 6300 Enterprise Lane Madison, WI 53719	Project				Job Ref.	
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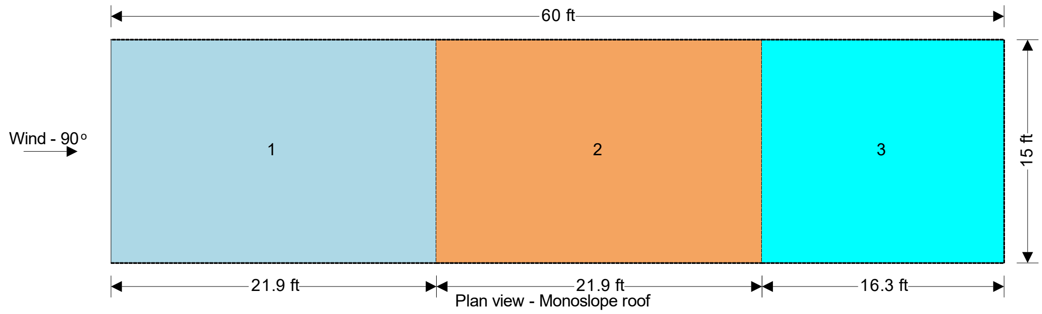
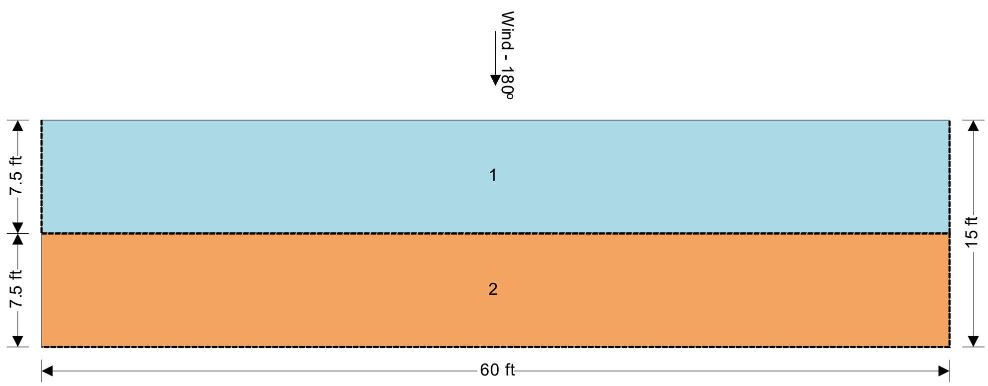
	Calc. by K	Date 06/05/2019	Chk'd by	Date	App'd by	Date



Plan view - Monoslope roof



Plan view - Monoslope roof

RETAINING WALL ANALYSIS

In accordance with International Building Code 2015

Tedds calculation version 2.9.03

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **8** ft
Stem thickness	t_{stem} = **12** in
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **150** pcf
Toe length	l_{toe} = **6** ft
Heel length	l_{heel} = **4** ft
Base thickness	t_{base} = **14** in
Key position	p_{key} = **6** ft
Key depth	d_{key} = **4** ft
Key thickness	t_{key} = **14** in
Base density	γ_{base} = **150** pcf
Height of retained soil	h_{ret} = **8** ft
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **0** ft

Retained soil properties

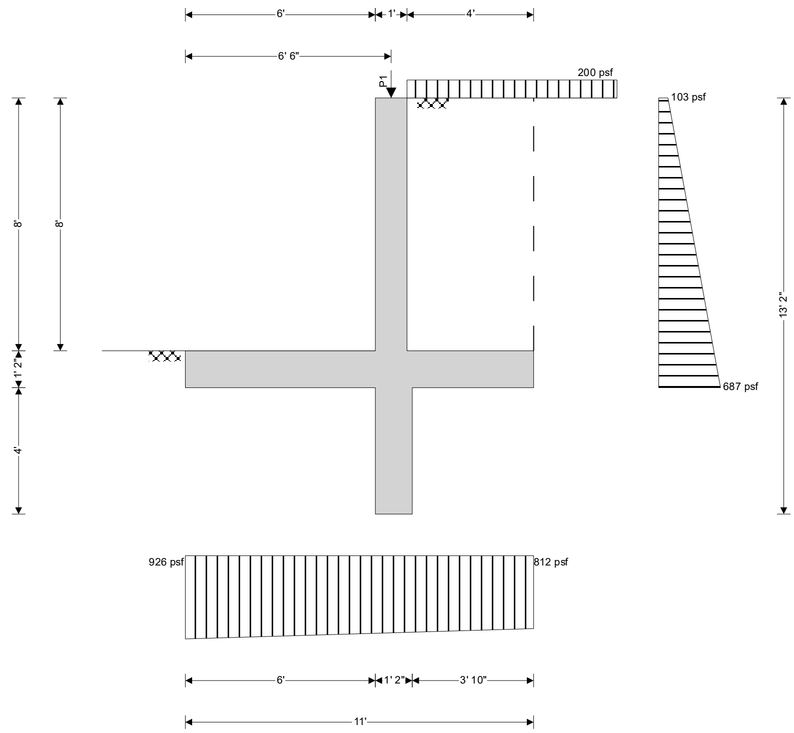
Soil type	Loose well graded sand and gravel
Moist density	γ_{mr} = **124** pcf
Saturated density	γ_{sr} = **137** pcf
Effective angle of internal resistance	ϕ_r = **28** deg
Effective wall friction angle	δ_r = **14** deg

Base soil properties

Soil type	Medium dense well graded sand and gravel
Soil density	γ_b = **128** pcf
Cohesion	c_b = **0** psf
Effective angle of internal resistance	ϕ_b = **30** deg
Effective wall friction angle	δ_b = **15** deg
Effective base friction angle	δ_{bb} = **20** deg
Allowable bearing pressure	$P_{bearing}$ = **3000** psf

Loading details

Live surcharge load	$Surcharge_L$ = **200** psf
Vertical line load at 6.5 ft	P_{D1} = **225** plf
	P_{L1} = **750** plf



General arrangement

Calculate retaining wall geometry

Base length $l_{base} = l_{toe} + t_{stem} + l_{heel} = \mathbf{11}$ ft

Base height $h_{base} = t_{base} + d_{key} = \mathbf{5.167}$ ft

Moist soil height $h_{moist} = h_{soil} = \mathbf{8}$ ft

Length of surcharge load $l_{sur} = l_{heel} = \mathbf{4}$ ft

- Distance to vertical component $x_{sur\_v} = l_{base} - l_{heel} / 2 = \mathbf{9}$ ft

Effective height of wall $h_{eff} = h_{base} + d_{cover} + h_{ret} = \mathbf{13.167}$ ft

- Distance to horizontal component $x_{sur\_h} = h_{eff} / 2 - d_{key} = \mathbf{2.583}$ ft

- Distance to horizontal component above key $x_{sur\_h\_a} = (h_{eff} - d_{key}) / 2 = \mathbf{4.583}$ ft

Area of wall stem $A_{stem} = h_{stem} \times t_{stem} = \mathbf{8}$ ft^2

- Distance to vertical component $x_{stem} = l_{toe} + t_{stem} / 2 = \mathbf{6.5}$ ft

Area of wall base $A_{base} = l_{base} \times t_{base} + d_{key} \times t_{key} = \mathbf{17.5}$ ft^2

- Distance to vertical component $x_{base} = (l_{base}^2 \times t_{base} / 2 + d_{key} \times t_{key} \times (p_{key} + t_{key} / 2)) / A_{base} = \mathbf{5.789}$ ft

Area of moist soil $A_{moist} = h_{moist} \times l_{heel} = \mathbf{32}$ ft^2

- Distance to vertical component $x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} = \mathbf{9}$ ft

- Distance to horizontal component $x_{moist\_h} = h_{eff} / 3 - d_{key} = \mathbf{0.389}$ ft

- Distance to horizontal component above key $x_{moist\_h\_a} = (h_{eff} - d_{key}) / 3 = \mathbf{3.056}$ ft

Using Coulomb theory

At rest pressure coefficient $K_0 = 1 - \sin(\phi_r) = \mathbf{0.531}$

Passive pressure coefficient — $K_P = \sin(90 - \phi_b)^2 / (\sin(90 + \delta_b) \times [1 - \sqrt{[\sin(\phi_b + \delta_b) \times \sin(\phi_b) / (\sin(90 + \delta_b))]}]^2) =$ **4.977**

From IBC 2015 cl.1807.2.3 Safety factor

Load combination 1 — 1.0 × Dead + 1.0 × Live + 1.0 × Lateral earth

Sliding check

Vertical forces on wall

Wall stem — $F_{stem} = A_{stem} \times \gamma_{stem} =$ **1200** plf

Wall base — $F_{base} = A_{base} \times \gamma_{base} =$ **2625** plf

Line loads — $F_{P\_v} = P_{D1} + 0 \times P_{L1} =$ **225** plf

Moist retained soil — $F_{moist\_v} = A_{moist} \times \gamma_{mr} =$ **3960** plf

Total — $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} =$ **8010** plf

Horizontal forces on wall

Surcharge load — $F_{sur\_h} = K_0 \times \cos(\delta_r) \times Surcharge_L \times h_{eff} =$ **1356** plf

Moist retained soil — $F_{moist\_h} = K_0 \times \cos(\delta_r) \times \gamma_{mr} \times h_{eff}^2 / 2 =$ **5522** plf

Total — $F_{total\_h} = F_{sur\_h} + F_{moist\_h} =$ **6877** plf

Check stability against sliding

Base soil resistance — $F_{exc\_h} = K_P \times \cos(\delta_b) \times \gamma_b \times (h_{pass} + h_{base})^2 / 2 =$ **8180** plf

Base friction — $F_{friction} = F_{total\_v} \times \tan(\delta_{bb}) =$ **2915** plf

Resistance to sliding — $F_{rest} = F_{exc\_h} + F_{friction} =$ **11096** plf

Factor of safety — $FoS_{sl} = F_{rest} / F_{total\_h} =$ **1.613** > 1.5

PASS - Factor of safety against sliding is adequate

Overturning check

Vertical forces on wall

Wall stem — $F_{stem} = A_{stem} \times \gamma_{stem} =$ **1200** plf

Wall base — $F_{base} = A_{base} \times \gamma_{base} =$ **2625** plf

Line loads — $F_{P\_v} = P_{D1} + 0 \times P_{L1} =$ **225** plf

Moist retained soil — $F_{moist\_v} = A_{moist} \times \gamma_{mr} =$ **3960** plf

Total — $F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{moist\_v} =$ **8010** plf

Horizontal forces on wall

Surcharge load — $F_{sur\_h} = K_0 \times \cos(\delta_r) \times Surcharge_L \times (h_{eff} - d_{key}) =$ **944** plf

Moist retained soil — $F_{moist\_h} = K_0 \times \cos(\delta_r) \times \gamma_{mr} \times (h_{eff} - d_{key})^2 / 2 =$ **2676** plf

Base soil — $F_{exc\_h} = \max(-K_P \times \cos(\delta_b) \times \gamma_b \times (h_{pass} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h})) =$ **-3620** plf

Total — $F_{total\_h} = F_{sur\_h} + F_{moist\_h} + F_{exc\_h} =$ **0** plf

Overturning moments on wall

Surcharge load — $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h\_a} =$ **4325** lb_ft/ft

Moist retained soil — $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h\_a} =$ **8178** lb_ft/ft

Base soil — $M_{exc\_OT} = F_{exc\_h} \times x_{exc\_h} =$ **8246** lb_ft/ft

Total — $M_{total\_OT} = M_{sur\_OT} + M_{moist\_OT} + M_{exc\_OT} =$ **20750** lb_ft/ft

Restoring moments on wall

Wall stem — $M_{stem\_R} = F_{stem} \times x_{stem} =$ **7800** lb_ft/ft

Wall base $M_{base\_R} = F_{base} \times x_{base}$ = **15196** lb_ft/ft

Line loads $M_{P\_R} = (abs(P_{D1} + 0 \times P_{L1})) \times p_1$ = **1462** lb_ft/ft

Moist retained soil $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **35641** lb_ft/ft

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{P\_R} + M_{moist\_R}$ = **60099** lb_ft/ft

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **2.896** > 1.5

PASS - Factor of safety against overturning is adequate

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = A_{stem} \times \gamma_{stem}$ = **1200** plf

Wall base $F_{base} = A_{base} \times \gamma_{base}$ = **2625** plf

Surcharge load $F_{sur\_v} = Surcharge_L \times l_{heel}$ = **800** plf

Line loads $F_{P\_v} = P_{D1} + P_{L1}$ = **975** plf

Moist retained soil $F_{moist\_v} = A_{moist} \times \gamma_{mr}$ = **3960** plf

Total $F_{total\_v} = F_{stem} + F_{base} + F_{sur\_v} + F_{P\_v} + F_{moist\_v}$ = **9560** plf

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_0 \times \cos(\delta_r) \times Surcharge_L \times (h_{eff} - d_{key})$ = **944** plf

Moist retained soil $F_{moist\_h} = K_0 \times \cos(\delta_r) \times \gamma_{mr} \times (h_{eff} - d_{key})^2 / 2$ = **2676** plf

Base soil $F_{pass\_h} = \max(-K_P \times \cos(\delta_b) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2, -(F_{moist\_h} + F_{sur\_h}))$ = **-3620** plf

Total $F_{total\_h} = \max(F_{sur\_h} + F_{moist\_h} + F_{pass\_h} - F_{total\_v} \times \tan(\delta_{bb}), 0 \text{ plf})$ = **0** plf

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem}$ = **7800** lb_ft/ft

Wall base $M_{base} = F_{base} \times x_{base}$ = **15196** lb_ft/ft

Surcharge load $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h\_a}$ = **2875** lb_ft/ft

Line loads $M_P = ((P_{D1} + P_{L1})) \times p_1$ = **6337** lb_ft/ft

Moist retained soil $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h\_a}$ = **27463** lb_ft/ft

Base soil $M_{pass} = -F_{pass\_h} \times x_{pass\_h}$ = **-8246** lb_ft/ft

Total $M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{moist} + M_{pass}$ = **51425** lb_ft/ft

Check bearing pressure

Distance to reaction $\bar{x} = M_{total} / F_{total\_v}$ = **5.379** ft

Eccentricity of reaction $e = \bar{x} - l_{base} / 2$ = **-0.121** ft

Loaded length of base $l_{load} = l_{base}$ = **11** ft

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base})$ = **926** psf

Bearing pressure at heel $q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base})$ = **812** psf

Factor of safety $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel})$ = **3.238**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

<u>RETAINING WALL DESIGN</u>

In accordance with ACI 318-14

Tedds calculation version 2.9.03

Concrete details

Compressive strength of concrete — f'_c = **3500** psi

Concrete type — Normal weight

Reinforcement details

Yield strength of reinforcement — f_y = **60000** psi

Modulus of elasticity or reinforcement — E_s = **29000000** psi

Cover to reinforcement

Front face of stem — c_{sf} = **1.5** in

Rear face of stem — c_{sr} = **1.5** in

Top face of base — c_{bt} = **2** in

Bottom face of base — c_{bb} = **3** in

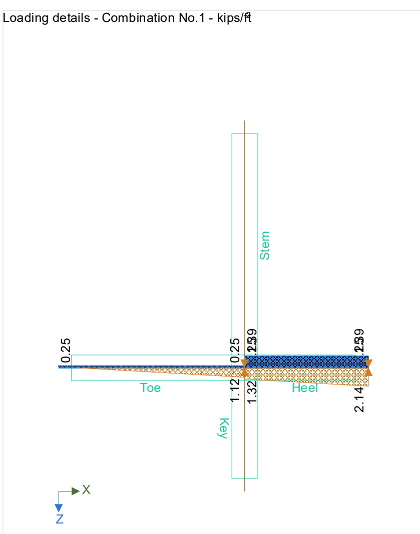
From IBC 2015 cl.1605.2.1 Basic load combinations

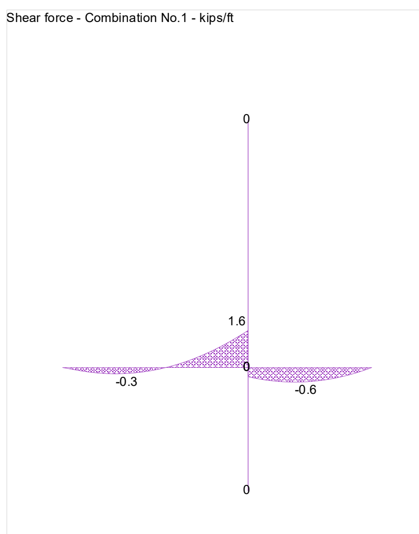
Load combination no.1 — 1.4 × Dead

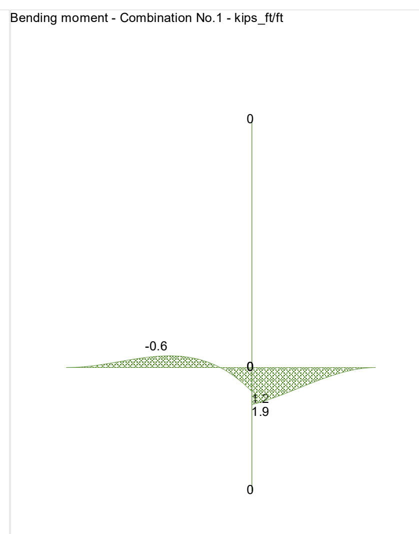
Load combination no.2 — 1.2 × Dead + 1.6 × Live + 1.6 × Lateral earth

Load combination no.3 — 1.2 × Dead + 1.0 × Earthquake + 1.0 × Live + 1.6 × Lateral earth

Load combination no.4 — 0.9 × Dead + 1.0 × Earthquake + 1.6 × Lateral earth







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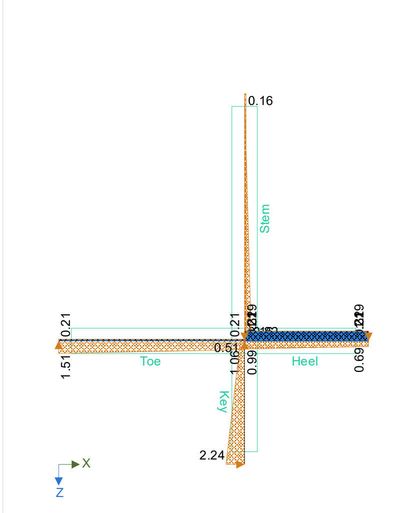
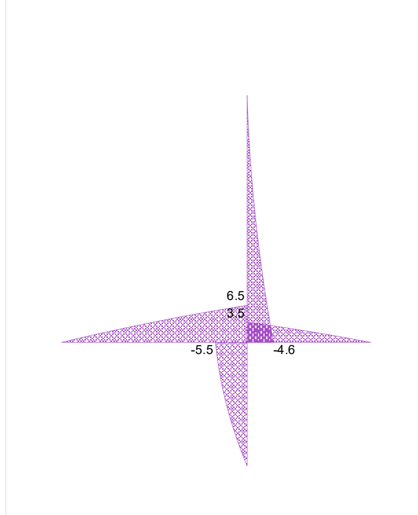
Loading details - Combination No.2 - kips/ft

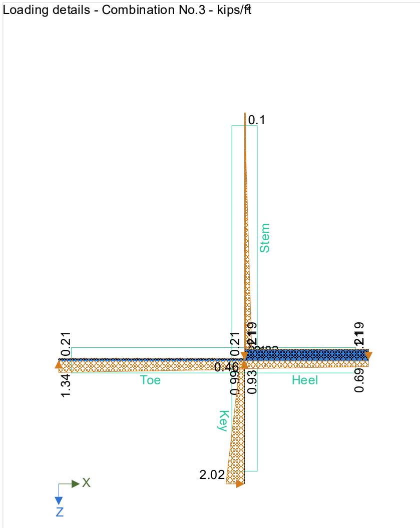


Shear force - Combination No.2 - kips/ft

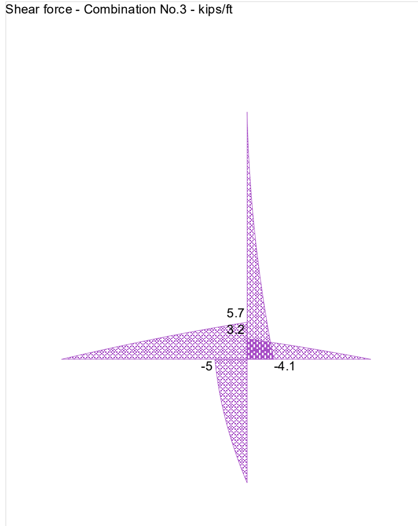


Bending moment - Combination No.2 - kips_ft/ft

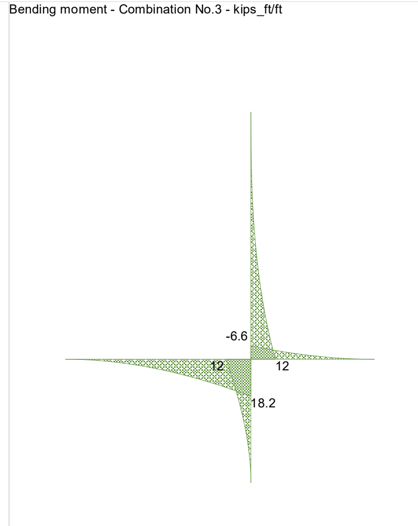
Loading details - Combination No.3 - kips/ft



Shear force - Combination No.3 - kips/ft



Bending moment - Combination No.3 - kips_ft/ft



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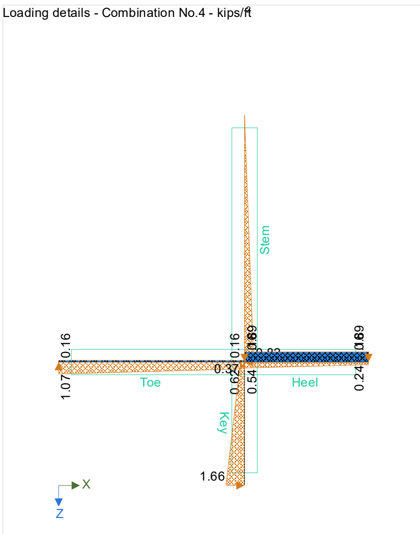
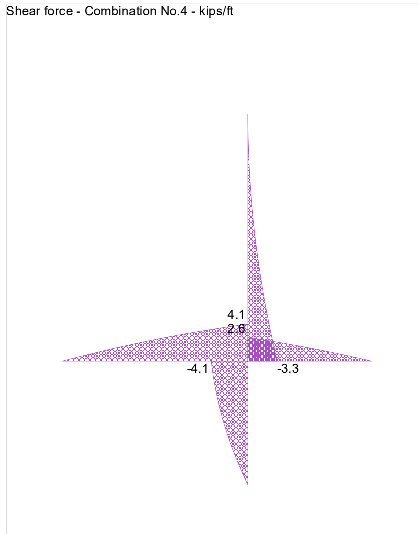
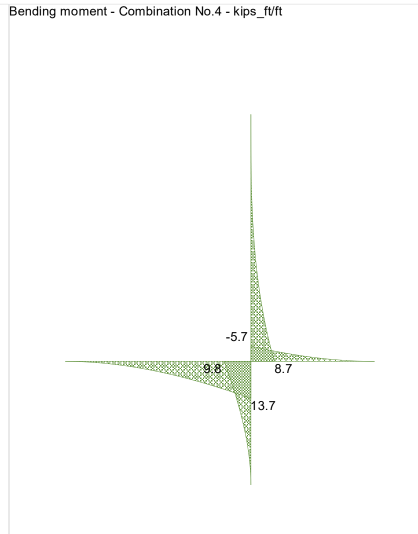






Check stem design at base of stem

Depth of section — $h = \mathbf{12}$ in

Rectangular section in flexure - Section 22.3

Design bending moment combination 2 — $M = \mathbf{13969}$ lb_ft/ft

Depth of tension reinforcement — $d = h - c_{sr} - \phi_{sr} / 2 = \mathbf{10.187}$ in

Compression reinforcement provided — No.4 bars @ 16" c/c

Area of compression reinforcement provided — $A_{sf.prov} = \pi \times \phi_{sf}^2 / (4 \times s_{sf}) = \mathbf{0.147}$ in^2/ft

Tension reinforcement provided — No.5 bars @ 8" c/c

Area of tension reinforcement provided — $A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr}) = \mathbf{0.46}$ in^2/ft

Maximum reinforcement spacing - cl.11.7.2 — $s_{max} = \min(18 \text{ in}, 3 \times h) = \mathbf{18}$ in

PASS - Reinforcement is adequately spaced

Depth of compression block — $a = A_{sr.prov} \times f_y / (0.85 \times f'_c) = \mathbf{0.773}$ in

Neutral axis factor - cl.22.2.2.4.3 — $\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = \mathbf{0.85}$

Depth to neutral axis — $c = a / \beta_1 = \mathbf{0.91}$ in

Strain in reinforcement — $\varepsilon_t = 0.003 \times (d - c) / c = \mathbf{0.030588}$

Section is in the tension controlled zone

Strength reduction factor — $\phi_f = \min(\max(0.65 + (\varepsilon_t - 0.002) \times (250 / 3), 0.65), 0.9) = \mathbf{0.9}$

Nominal flexural strength — $M_n = A_{sr.prov} \times f_y \times (d - a / 2) = \mathbf{22551}$ lb_ft/ft

Design flexural strength — $\phi M_n = \phi_f \times M_n = \mathbf{20296}$ lb_ft/ft

$M / \phi M_n = \mathbf{0.688}$

PASS - Design flexural strength exceeds factored bending moment

By iteration, reinforcement required by analysis — $A_{sr.des} = \mathbf{0.313}$ in^2/ft

Minimum area of reinforcement - cl.9.6.1.2 — $A_{sr.min} = \max(3 \times \sqrt{(f'_c \times 1 \text{ psi})}, 200 \text{ psi}) \times d / f_y = \mathbf{0.408}$ in^2/ft

PASS - Area of reinforcement provided is greater than minimum area of reinforcement required

Rectangular section in shear - Section 22.5

Design shear force — $V = \mathbf{4579}$ lb/ft

Concrete modification factor - cl.19.2.4 — $\lambda = \mathbf{1}$

Nominal concrete shear strength - eqn.22.5.5.1 $V_c = 2 \times \lambda \times \sqrt{(f'_c \times 1 \text{ psi})} \times d$ = **14465** lb/ft

Strength reduction factor ϕ_s = **0.75**

Design concrete shear strength - cl.11.5.1.1 $\phi V_c = \phi_s \times V_c$ = **10849** lb/ft

$V / \phi V_c$ = **0.422**

PASS - No shear reinforcement is required

Horizontal reinforcement parallel to face of stem

Minimum area of reinforcement - cl.11.6.1 $A_{sx.req} = 0.002 \times t_{stem}$ = **0.288** in^2/ft

Transverse reinforcement provided No.4 bars @ 16" c/c each face

Area of transverse reinforcement provided $A_{sx.prov} = 2 \times \pi \times \phi_{sx}^2 / (4 \times s_{sx})$ = **0.295** in^2/ft

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section h = **14** in

Rectangular section in flexure - Section 22.3

Design bending moment combination 2 M = **20703** lb_ft/ft

Depth of tension reinforcement $d = h - c_{bb} - \phi_{bb} / 2$ = **10.688** in

Compression reinforcement provided No.5 bars @ 8" c/c

Area of compression reinforcement provided $A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt})$ = **0.46** in^2/ft

Tension reinforcement provided No.5 bars @ 8" c/c

Area of tension reinforcement provided $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **0.46** in^2/ft

Maximum reinforcement spacing - cl.7.7.2.3 s_{max} = min(18 in, 3 × h) = **18** in

PASS - Reinforcement is adequately spaced

Depth of compression block $a = A_{bb.prov} \times f_y / (0.85 \times f'_c)$ = **0.773** in

Neutral axis factor - cl.22.2.2.4.3 β_1 = min(max(0.85 - 0.05 × (f'_c - 4 ksi) / 1 ksi, 0.65), 0.85) = **0.85**

Depth to neutral axis $c = a / \beta_1$ = **0.91** in

Strain in reinforcement $\varepsilon_t = 0.003 \times (d - c) / c$ = **0.032236**

Section is in the tension controlled zone

Strength reduction factor ϕ_f = min(max(0.65 + (ε_t - 0.002) × (250 / 3), 0.65), 0.9) = **0.9**

Nominal flexural strength $M_n = A_{bb.prov} \times f_y \times (d - a / 2)$ = **23702** lb_ft/ft

Design flexural strength $\phi M_n = \phi_f \times M_n$ = **21332** lb_ft/ft

$M / \phi M_n$ = **0.971**

PASS - Design flexural strength exceeds factored bending moment

By iteration, reinforcement required by analysis $A_{bb.des}$ = **0.446** in^2/ft

Minimum area of reinforcement - cl.7.6.1.1 $A_{bb.min} = 0.0018 \times h$ = **0.302** in^2/ft

PASS - Area of reinforcement provided is greater than minimum area of reinforcement required

Rectangular section in shear - Section 22.5

Design shear force V = **6454** lb/ft

Concrete modification factor - cl.19.2.4 λ = **1**

Nominal concrete shear strength - eqn.22.5.5.1 $V_c = 2 \times \lambda \times \sqrt{(f'_c \times 1 \text{ psi})} \times d$ = **15175** lb/ft

Strength reduction factor ϕ_s = **0.75**

Design concrete shear strength - cl.7.6.3.1 $\phi V_c = \phi_s \times V_c$ = **11381** lb/ft

$V / \phi V_c$ = **0.567**

PASS - No shear reinforcement is required

Check base design at heel

Depth of section — h = **14** in

Rectangular section in flexure - Section 22.3

Design bending moment combination 2 — M = **7434** lb_ft/ft

Depth of tension reinforcement — $d = h - c_{bt} - \phi_{bt} / 2$ = **11.688** in

Compression reinforcement provided — No.5 bars @ 8" c/c

Area of compression reinforcement provided — $A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **0.46** in²/ft

Tension reinforcement provided — No.5 bars @ 8" c/c

Area of tension reinforcement provided — $A_{bt.prov} = \pi \times \phi_{bt}^2 / (4 \times s_{bt})$ = **0.46** in²/ft

Maximum reinforcement spacing - cl.7.7.2.3 — s_{max} = min(18 in, 3 × h) = **18** in

PASS - Reinforcement is adequately spaced

Depth of compression block — $a = A_{bt.prov} \times f_y / (0.85 \times f'_c)$ = **0.773** in

Neutral axis factor - cl.22.2.2.4.3 — β_1 = min(max(0.85 - 0.05 × (f'c - 4 ksi) / 1 ksi, 0.65), 0.85) = **0.85**

Depth to neutral axis — $c = a / \beta_1$ = **0.91** in

Strain in reinforcement — $\varepsilon_t = 0.003 \times (d - c) / c$ = **0.035533**

Section is in the tension controlled zone

Strength reduction factor — ϕ_f = min(max(0.65 + (ε_t - 0.002) × (250 / 3), 0.65), 0.9) = **0.9**

Nominal flexural strength — $M_n = A_{bt.prov} \times f_y \times (d - a / 2)$ = **26003** lb_ft/ft

Design flexural strength — $\phi M_n = \phi_f \times M_n$ = **23402** lb_ft/ft

$M / \phi M_n$ = **0.318**

PASS - Design flexural strength exceeds factored bending moment

By iteration, reinforcement required by analysis — $A_{bt.des}$ = **0.143** in²/ft

Minimum area of reinforcement - cl.7.6.1.1 — $A_{bt.min} = 0.0018 \times h$ = **0.302** in²/ft

PASS - Area of reinforcement provided is greater than minimum area of reinforcement required

Rectangular section in shear - Section 22.5

Design shear force — V = **3518** lb/ft

Concrete modification factor - cl.19.2.4 — λ = **1**

Nominal concrete shear strength - eqn.22.5.5.1 — $V_c = 2 \times \lambda \times \sqrt{(f'_c \times 1 \text{ psi})} \times d$ = **16595** lb/ft

Strength reduction factor — ϕ_s = **0.75**

Design concrete shear strength - cl.7.6.3.1 — $\phi V_c = \phi_s \times V_c$ = **12446** lb/ft

$V / \phi V_c$ = **0.283**

PASS - No shear reinforcement is required

Check key design

Depth of section — h = **14** in

Rectangular section in flexure - Section 22.3

Design bending moment combination 2 — M = **13308** lb_ft/ft

Depth of tension reinforcement — $d = h - c_{bb} - \phi_k / 2$ = **10.688** in

Compression reinforcement provided — No.5 bars @ 8" c/c

Area of compression reinforcement provided — $A_{k.prov} = \pi \times \phi_k^2 / (4 \times s_k)$ = **0.46** in²/ft

Tension reinforcement provided — No.5 bars @ 8" c/c

Area of tension reinforcement provided — $A_{k.prov} = \pi \times \phi_k^2 / (4 \times s_k)$ = **0.46** in²/ft

Maximum reinforcement spacing - cl.7.7.2.3 — s_{max} = min(18 in, 3 × h) = **18** in

PASS - Reinforcement is adequately spaced

Depth of compression block: $a = A_{k.prov} \times f_y / (0.85 \times f'_c)$ = **0.773** in

Neutral axis factor - cl.22.2.2.4.3: β_1 = min(max(0.85 - 0.05 × (f'_c - 4 ksi) / 1 ksi, 0.65), 0.85) = **0.85**

Depth to neutral axis: $c = a / \beta_1$ = **0.91** in

Strain in reinforcement: $\varepsilon_t = 0.003 \times (d - c) / c$ = **0.032236**

Section is in the tension controlled zone

Strength reduction factor: ϕ_f = min(max(0.65 + (ε_t - 0.002) × (250 / 3), 0.65), 0.9) = **0.9**

Nominal flexural strength: $M_n = A_{k.prov} \times f_y \times (d - a / 2)$ = **23702** lb_ft/ft

Design flexural strength: $\phi M_n = \phi_f \times M_n$ = **21332** lb_ft/ft

$M / \phi M_n$ = **0.624**

PASS - Design flexural strength exceeds factored bending moment

By iteration, reinforcement required by analysis: $A_{k.des}$ = **0.283** in^2/ft

Minimum area of reinforcement - cl.7.6.1.1: $A_{k.min} = 0.0018 \times h$ = **0.302** in^2/ft

PASS - Area of reinforcement provided is greater than minimum area of reinforcement required

Rectangular section in shear - Section 22.5

Design shear force: V = **5497** lb/ft

Concrete modification factor - cl.19.2.4: λ = **1**

Nominal concrete shear strength - eqn.22.5.5.1: $V_c = 2 \times \lambda \times \sqrt{(f'_c \times 1\ psi)} \times d$ = **15175** lb/ft

Strength reduction factor: ϕ_s = **0.75**

Design concrete shear strength - cl.7.6.3.1: $\phi V_c = \phi_s \times V_c$ = **11381** lb/ft

$V / \phi V_c$ = **0.483**

PASS - No shear reinforcement is required

Transverse reinforcement parallel to base

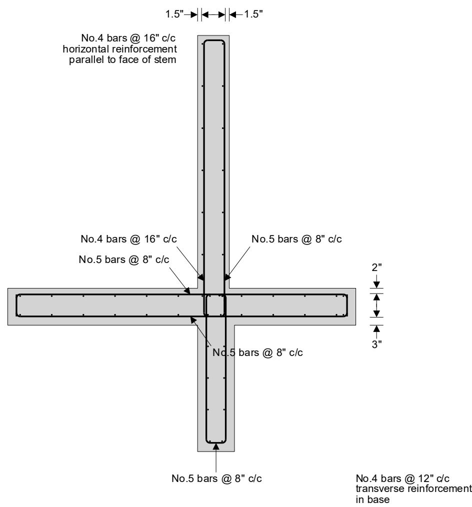
Minimum area of reinforcement - cl.76.1.1: $A_{bx.req} = 0.0018 \times t_{base}$ = **0.302** in^2/ft

Transverse reinforcement provided: No.4 bars @ 12" c/c each face

Area of transverse reinforcement provided: $A_{bx.prov} = 2 \times \pi \times \phi_{bx}^2 / (4 \times s_{bx})$ = **0.393** in^2/ft

PASS - Area of reinforcement provided is greater than area of reinforcement required

Tekla Tedds DrJ Engineering 6300 Enterprise Lane Madison, WI 53719	Project				Job Ref.	
	Section				Sheet no./rev. 11	
	Calc. by K	Date 5/2/2019	Chk'd by	Date	App'd by	Date



Reinforcement details