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C.R. Laurence Co., Inc.
2503 E. Vernon Ave
Los Angeles, CA 90058

Date: 06/09/2026

RE: CRL TurboFlex® Glass Balustrade/Base Shoe System Structural Performance

To whom it may concern,

Rice Engineering Inc. (REI), located in Luxemburg, WI, has analyzed the structural integrity of the CRL TurboFlex® glass balustrade system. The following report outlines the engineering process and provides relevant tables, charts, and figures to aid in determining the structural capacity or maximum design loading of the TurboFlex® system.

The system has been analyzed for current code requirements. This includes but is not limited to ASTM E1300, ASTM E2358, 2024 International Building Code, 2024 International Residential Building Code, ASCE 7-22, ACI 318-19, AISC 360-22. Non-code standards include NGA FM05 modulus of rupture reference, GANA stress tables, and AAMA TIR A9. Some criteria may need to be verified by the fabricator or manufacturer that is outside the scope of this report. Examples include meeting the requirements for ASTM E2353, ASTM C1048, ASTM E894, or meeting ANSI Z97.1 safety glazing standards.

Note that these calculations are for reference only and are not to be used in site specific instances without the approval of a registered engineer. Rice Engineering Inc. takes no liability for use of calculations. REI is licensed in all 50 states and has a team of engineers who regularly design these system so please reach out if there are any questions.

Warmest regards,

Tonya Free, P.E.*
Glass Engineering Manager
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* (AL, AR, AZ, CO, IN, KY, MD, MS, TN, WI)

RICE ENGINEERING
Structural Design ⟫ Beyond the Structure

1.0 Note from the Engineer:

The following report meets or exceeds the requirements of the 2015, 2018, 2021, and 2024 International Commercial/Residential Building Code Editions. (* shown on previous sheet are the current engineering licenses I hold as of the date of this report, not the only states this report is analyzed to). This report is the structural analysis only; not design.

Design loadings include:
Commercial: 200 LB at any point up to 42” A.F.F. / 50 PLF at 42” A.F.F. / ASD Windload
Residential: 50 PLF at 42” A.F.F. / ASD Windload – 200 LB Loading is not required per code

The concentrated and uniform live loading (also referred to as guard loading) has been applied at the top of the glass regardless of height or relationship to the finished floor. While this may be conservative for certain circumstances, it provides a worst-case scenario and is what the tables and analysis in this report assume.

Differential deflection of the glass lites may occur if there is no top rail. 9/16” or ½” glass will require a top rail to prevent this pinch hazard. Thicker glazing generally will not require a cap structurally if interior and using SGP/ionoplast. Exterior locations may still have deflection concerns at the joints, even with the thicker glazing, if no cap is used. If you are not using a top cap or attached handrail and are using glass ¾” thick or greater, consult with engineering if a pinch hazard is present.

Alternative anchor spacings, interlayer types, glass spans, etc. may be used with the approval of a registered professional engineer. All equations and inputs used in the provided tables are shown within the report unless FEA has been performed. Always check all relevant tables; each component has been analyzed separately and values shown are independent of each other.

2.0: Glazing Design

Design of the glazing differs based on whether the project is interior or exterior, type of heat treatment and interlayer, size of panels, and nominal panel thickness. Exterior panels perform worse than interior when laminated, non-structural interlayers perform worse than structural interlayers (ionoplast), wider panels perform better than skinny panels, and thicker glass performs better than thinner glass in a typical instance.

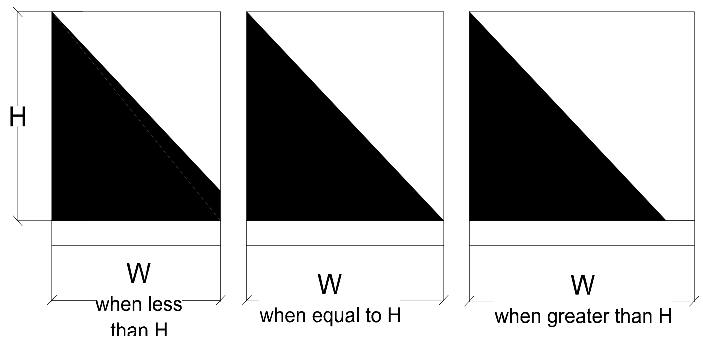
All current codes require the use of laminated glass unless there is no risk of glass falling onto people below. Annealed cannot be used under any circumstances; heat strengthened or fully tempered only. This report focuses on tempered glass only due to it having on average twice the strength of heat strengthened.

Top cap:

The 2024 IBC notes that a top cap should be used to span a minimum of 3 glass lites and shall remain in place in the event that one lite break. There is an exclusion to remove the cap but even if you meet this exclusion, a cap may be required for structural purposes. A cap helps prevent a pinch point at the glass butt joint and may also help transfer loading to adjacent glass panels. When in doubt, use a cap. The exclusion states that an attached top cap or handrail is not required where the glass baluster panels are laminated glass with two or more glass plies of equal thickness and of the the same glass type. These balusters shall be tested to remain in place as a barrier following impact or glass breakage in accordance with ASTM E2353. Design of top caps are outside of the scope of this report.

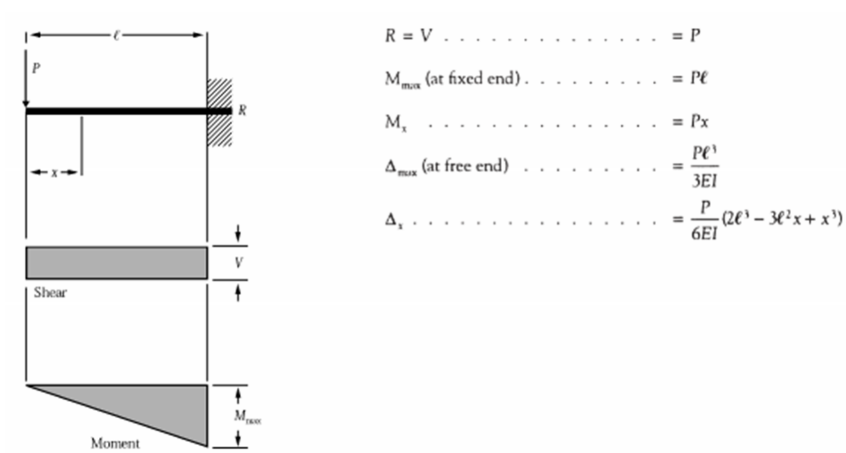
Load Distribution and Design:

Design of the glass and anchorage comes down to two beam equations with the width of the glass playing a role for the concentrated loading (200 LB up to 42" above finished floor). Figure 1 indicates the load path of a concentrated loading at the top corner of the panel. See how the skinnier panel (left) doesn't break out the black triangle (the load/stress) as well as the wider panels? The design is optimized for the glazing when width = height. Since the live load (50 PLF up to 42" above finished floor) and windload are in a "per-unit" basis, figure 1 is not applicable for these load cases.



<u>Figure 1: Stress breakout for concentrated loading at corner of cantilever beam</u>

Figures 2 and 3 show the beam equation for the glass based on load type. These are used in the glass design example. Figure 2 is used for the concentrated loading while Figure 3 is used for the live load and windload.



<u>Figure 2: Beam Equation Cantilever with Concentrated Loading at top</u>

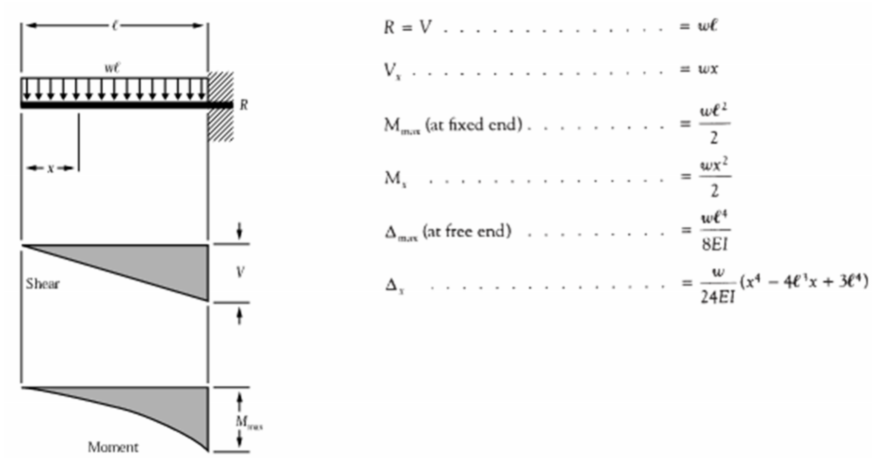


Figure 3: Beam Equation Cantilever with Uniform Loading

Glazing design requires the use of a minimum design thickness per ASTM E1300. If monolithic (single ply), use Table 1; if laminated, use Tables 2 and 3 to determine the equivalent thickness (Figure 4). It is industry standard to use 1 hour for live loading and 3 second for the winldoad and concentrated loading.

TABLE 4 Nominal and Minimum Glass Thicknesses

Nominal Thickness or Designation, mm (in.)	Minimum Thickness, mm (in.)
2.0 (picture)	1.80 (0.071)
2.5 (3⁄32)	2.16 (0.085)
2.7 (lami)	2.59 (0.102)
3.0 (1⁄8)	2.92 (0.115)
4.0 (5⁄32)	3.78 (0.149)
5.0 (3⁄16)	4.57 (0.180)
6.0 (1⁄4)	5.56 (0.219)
8.0 (5⁄16)	7.42 (0.292)
10.0 (3⁄8)	9.02 (0.355)
12.0 (1⁄2)	11.91 (0.469)
16.0 (5⁄8)	15.09 (0.595)
19.0 (3⁄4)	18.26 (0.719)
22.0 (7⁄8)	21.44 (0.844)
25.0 (1)	24.61 (0.969)

Table 1: ASTM E1300 Minimum Glass Thicknesses (Monolithic)

PVB Interlayer								
	Load Duration							
	3 Second				1 Hour			
	Shear Modulus		Elastic Modulus (E)		Shear Modulus		Elastic Modulus (E)	
Temp (°C)	MPa	psi	MPa	psi	MPa	psi	MPa	psi
30 (86°F)	0.97	140.69	2.91	422.06	0.44	63.82	1.32	191.45
50 (122°F)	0.44	63.82	1.32	191.45	0.05	7.25	0.16	23.21

<u>Table 2: PVB E and G for Equivalent Thickness</u>

SentryGlas® Interlayer								
	Load Duration							
	3 Second				1 Hour			
	Shear Modulus (G)		Elastic Modulus (E)		Shear Modulus (G)		Elastic Modulus (E)	
Temp (°C)	MPa	psi	MPa	psi	MPa	psi	MPa	psi
30 (86°F)	141.0	20450.3	413.0	59900.6	60.0	8702.3	178.0	25816.7
50 (122°F)	26.4	3829.0	78.0	11312.9	4.2	609.2	12.6	1827.5

<u>Table 3: SGP E and G for Equivalent Thickness</u>

Figure 4 indicates how to calculate the equivalent laminated thickness per ASTM E1300. A different design thickness is used for stress and deflection. “L” is the bending length, not the width of the panel. Per figure 2 and 3, “L” should be the height of the glass in a cantilever application. Width only plays a role for the 200 lb concentrated force. Figure 5 indicates a design example for the glazing and the equations used to determine both the minimum width of the panel and maximum windload on the panel as shown in Tables 4/5/6. The software used for these figures automatically converts units.

Inputs: PerASTM E1300 X9

$L := 48\ in$	Bending length of the glass
$t_1 := 0.219\ in$	ASTM E1300 Minimum Thickness : Ply 1
$t_2 := 0.219\ in$	ASTM E1300 Minimum Thickness : Ply 2
$t_{Int} := 0.06\ in$	Interlayer Thickness
$E_{glass} := 10400000\ psi$	Modulus of Elasticity of Soda Lime Flat Glass
$E_{Int} := 23\ psi$	Modulus of Elasticity of Interlayer
$G_{Int} := 8\ psi$	Shear Modulus of interlayer

Note: The input name shown may not match ASTM E1300 Appendix X9. The basis is the same. Please also watch units. The software being used for this example automatically converts units.

It is standard to use the lesser equivalent thickness (for unequal ply thicknesses)

Calculations: *All Calculations Below This Line Are Automatic*

$$h_s := 0.5 \cdot (t_1 + t_2) + t_{Int} \rightarrow 0.28\ in$$

$$h_{s\_1} := \frac{h_s \cdot t_1}{t_1 + t_2} \rightarrow 0.14\ in$$

$$h_{s\_2} := \frac{h_s \cdot t_2}{t_1 + t_2} \rightarrow 0.14\ in$$

$$I_s := t_1 \cdot h_{s\_2}{}^2 + t_2 \cdot h_{s\_1}{}^2 \rightarrow 0.01\ in^3$$

$$\Gamma := \frac{1}{1 + \frac{9.6 \cdot E_{glass} \cdot I_s \cdot t_{Int}}{G_{Int} \cdot h_s{}^2 \cdot L^2}} \rightarrow 0.03$$

Results:

$$t_{deflection} := \sqrt[3]{t_1{}^3 + t_2{}^3 + 12 \cdot \Gamma \cdot I_s} \rightarrow 0.29\ in$$ Equivalent thickness for deflection

$$t_{stress1} := \sqrt{\frac{t_{deflection}{}^3}{t_1 + 2 \cdot \Gamma \cdot h_{s\_2}}} \rightarrow 0.32\ in$$ Equivalent thickness for ply 1

$$t_{stress2} := \sqrt{\frac{t_{deflection}{}^3}{t_1 + 2 \cdot \Gamma \cdot h_{s\_1}}} \rightarrow 0.32\ in$$ Equivalent thickness for ply 2

Figure 4: ASTM E1300 X9 Equivalent Laminated Thickness Equations

Inputs:

$WL := 25\ \text{psf}$

$LL := 50\ \text{plf}$

$PL := 200\ \text{lbf}$

$H := 32\ \text{in}$

$W := H$

$Trib := 1\ \text{in}$

$t_{WL\_Stress} := 0.469\ \text{in}$

$t_{WL\_Deflection} := 0.469\ \text{in}$

$t_{LL\_Stress} := 0.469\ \text{in}$

$t_{LL\_Deflection} := 0.469\ \text{in}$

$E_{glass} = 10400000\ \text{psi}$

$F_{glass} := 24000\ \text{psi}$ For Fully Tempered Glazing

$\Omega := 4$

Calculations:

All Calculations Below This Line Are Automatic

$L_{eff\_WL} := Trib = 1\ \text{in}$

$L_{eff\_LL} := Trib = 1\ \text{in}$

$L_{eff\_PL} := \text{Min}(H, W) = 32\ \text{in}$

$$S_{WL} := \frac{t_{WL\_Stress}^{2} \cdot L_{eff\_WL}}{6} = 0.04\ \text{in}^3 \qquad I_{WL} := \frac{t_{WL\_Deflection}^{3} \cdot L_{eff\_WL}}{12} = 0.009\ \text{in}^4$$

$$S_{LL} := \frac{t_{LL\_Stress}^{2} \cdot L_{eff\_LL}}{6} = 0.04\ \text{in}^3 \qquad I_{LL} := \frac{t_{LL\_Deflection}^{3} \cdot L_{eff\_LL}}{12} = 0.009\ \text{in}^4$$

$$S_{PL} := \frac{t_{WL\_Stress}^{2} \cdot L_{eff\_PL}}{6} = 1.17\ \text{in}^3 \qquad I_{PL} := \frac{t_{WL\_Deflection}^{3} \cdot L_{eff\_PL}}{12} = 0.275\ \text{in}^4$$

t_{WL_Stress}

$$\sigma_{WL} := \frac{WL \cdot Trib \cdot H^2}{S_{WL}} = 4849\ \text{psi} \qquad \Delta_{WL} := \frac{WL \cdot Trib \cdot H^4}{8\ E_{glass} \cdot I_{WL}} = 0.25\ \text{in}$$

$$\sigma_{LL} := \frac{LL \cdot Trib \cdot H}{S_{LL}} = 3637\ \text{psi} \qquad \Delta_{LL} := \frac{LL \cdot Trib \cdot H^3}{3\ E_{glass} \cdot I_{LL}} = 0.51\ \text{in}$$

$$\sigma_{PL} := \frac{PL \cdot H}{S_{PL}} = 5456\ \text{psi} \qquad \Delta_{PL} := \frac{PL \cdot H^3}{3\ E_{glass} \cdot I_{PL}} = 0.76\ \text{in}$$

Results:

$$\Delta_{max} := \text{Max}\left(\Delta_{WL}, \Delta_{LL}, \Delta_{PL}\right) = 0.76\ \text{in}$$

$$\Delta_{allow} := \frac{H}{24} + \frac{W}{96} = 1.67\ \text{in}$$

$$\sigma_{FS4} := \text{Max}\left(\sigma_{LL}, \sigma_{PL}\right) = 5456\ \text{psi}$$

$$\sigma_{POB} := \sigma_{WL} = 4849\ \text{psi}$$

$$\sigma_{all\_FS4} := \frac{F_{glass}}{\Omega} = 6000\ \text{psi}$$ FT glass to a FS = 4

$$\sigma_{all\_POB} := 9600\ \text{psi}$$ FT glass to a FS = 2.5

$$I_{deflection} := \frac{\Delta_{max}}{\Delta_{allow}} = 0.46$$

Interaction is less than 1.0 so design is valid

$$I_{stress} := \text{Max}\left(\frac{\sigma_{FS4}}{\sigma_{all\_FS4}}, \frac{\sigma_{POB}}{\sigma_{all\_POB}}\right) = 0.91$$

Figure 5: Design Equations and Example for Cantilever Guardrail Glazing

Minimum Width of Interior Cantilevered Guardrail (Fully Tempered)																
Composition (nominal thickness in inches)	Interlayer Thickness (in)	Interlayer	H (in) Top of Guard to Top of Shoe													
			36		38		40		42		44		46		48	
			Width (in)	Max Δ (in)	Width (in)	Max Δ (in)	Width (in)	Max Δ (in)	Width (in)	Max Δ (in)	Width (in)	Max Δ (in)	Width (in)	Max Δ (in)	Width (in)	Max Δ (in)
1/4 over 1/4	0.06	PVB	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.06	SGP	30	0.99	31	1.12	33	1.23	35	1.34	36	1.51	38	1.61	39	1.79
5/16 over 5/16	0.06	PVB	30	1.37	31	1.5	32	1.63	32	1.82	33	1.96	34	2.09	35	2.24
	0.06	SGP	18	0.77	19	0.85	20	0.94	21	1.04	22	1.14	23	1.24	24	1.35
	0.09	PVB	31	1.43	32	1.57	32	1.76	33	1.91	34	2.06	35	2.2	36	2.35
	0.09	SGP	17	0.72	18	0.84	18	0.93	19	1.01	20	1.1	21	1.2	22	1.3
3/8 over 3/8	0.06	PVB	21	1.19	22	1.3	23	1.39	23	1.56	24	1.66	25	1.76	25	1.94
	0.06	SGP	13	0.62	13	0.73	14	0.79	15	0.85	15	0.98	16	1.05	17	1.12
	0.09	PVB	22	1.23	23	1.34	24	1.45	24	1.62	25	1.73	26	1.85	26	2.03
	0.09	SGP	12	0.6	13	0.66	13	0.77	14	0.83	14	0.95	15	1	16	1.07

Minimum Width of Exterior Cantilevered Guardrail (Fully Tempered)																
Composition (nominal thickness in inches)	Interlayer Thickness (in)	Interlayer	H (in) Top of Guard to Top of Shoe													
			36		38		40		42		44		46		48	
			Min. Width (in)	Max Δ (in)	Min. Width (in)	Max Δ (in)	Min. Width (in)	Max Δ (in)	Min. Width (in)	Max Δ (in)	Min. Width (in)	Max Δ (in)	Min. Width (in)	Max Δ (in)	Min. Width (in)	Max Δ (in)
1/4 over 1/4	0.06	PVB	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.06	SGP	31	1.04	32	1.17	34	1.28	35	1.43	37	1.57	38	1.76	40	1.96
5/16 over 5/16	0.06	PVB	36	1.46	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.06	SGP	19	0.8	20	0.89	21	0.98	21	1.12	22	1.22	23	1.31	24	1.43
	0.09	PVB	36	1.53	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.09	SGP	18	0.79	19	0.87	20	0.94	20	1.08	21	1.17	22	1.26	23	1.36
3/8 over 3/8	0.06	PVB	24	1.29	25	1.42	26	1.56	27	1.7	28	1.83	29	1.97	30	2.11
	0.06	SGP	13	0.7	14	0.76	15	0.82	15	0.93	16	1	17	1.07	17	1.2
	0.09	PVB	25	1.3	26	1.44	27	1.65	28	1.74	29	1.89	30	2.03	31	2.2
	0.09	SGP	13	0.68	13	0.78	14	0.89	14	0.95	15	1	16	1.06	16	1.19

Table 4: Minimum Width of Glass required for 200 LB Loading

Maximum windload can be determined by re-writing the beam equations shown in Figure 3 with the allowable stress of 9600 psi for tempered and 4800 psi for heat strengthened.

Calculate the elastic section modulus (S) and moment of intertia (I) in the weak axis orientation using either the design thickness per ASTM E1300 for monolithic glazing or the equivalent stress thickness for laminated glass. Calculate the maximum windload for stress and maximum windload for the deflection criteria required (H/24+W/96 is a maximum per code) though 1 ½” is recommended in the industry, and use the lesser of the two outcomes.

$$t_{deflection} := \sqrt[3]{t_1{}^3 + t_2{}^3 + 12 \cdot \Gamma \cdot I_s} = 0.28 \text{ in}$$ Equivalent thickness for deflection

$$t_{stress1} := \sqrt{\frac{t_{deflection}{}^3}{t_1 + 2 \cdot \Gamma \cdot h_{s\_2}}} = 0.32 \text{ in}$$ Equivalent thickness for ply 1

$$t_{stress2} := \sqrt{\frac{t_{deflection}{}^3}{t_1 + 2 \cdot \Gamma \cdot h_{s\_1}}} = 0.32 \text{ in}$$ Equivalent thickness for ply 2

$$t_{stress} := \text{Min}\left(t_{stress1}, t_{stress2}\right) = 0.32 \text{ in}$$

Back-Solving for Maximum Windload:

$F := 9600 \text{ psi}$ $\quad Trib := 1 \text{ in}$

$H := 36 \text{ in}$ $\quad L_{eff\_WL} := Trib$

Trib and Leff are equal here since they are place holders. Windload has been views as a per-inch basis.

$W := H$

$$S_{WL} := \frac{t_{stress}{}^2 \cdot L_{eff\_WL}}{6} = 0.02 \text{ in}^3$$

$$\Delta_{allow} := \frac{H}{24} + \frac{W}{96} = 1.88 \text{ in}$$

$$I_{WL} := \frac{t_{deflection}{}^3 \cdot L_{eff\_WL}}{12} = 0.002 \text{ in}^4$$

$$Max\_WL\_Stress := \frac{F \cdot S_{WL}}{Trib \cdot H^2} = 18 \text{ psf}$$

$$Max\_WL\_Deflection := \frac{\Delta_{allow} \cdot 8 \cdot E_{glass} \cdot I_{WL}}{Trib \cdot H^4} = 25.2 \text{ psf}$$

Figure 6: Example to back-solve for maximum Windload in glazing

Using the back-solving approach and assuming the width is always at least the height, the following are the maximum ASD windloads (Tables5/6) . NA means the glazing did not work for guard loadings and are excluded from this table. To get the maximum LRFD windload, divide the value in the table by 0.6. Example: 39.1 PSF ASD = 65.17 PSF LRFD

Do not use PVB with an exposed interlayer in exterior conditions as it may cause delamination. If using an alternative interlayer, always confirm its exterior capabilities.

Maximum ASD Windload of Exterior Cantilevered Guardrail (Fully Tempered)														
Nominal Glass Thickness (in)	H (in) Top of Guard to Top of Shoe													
	36		38		40		42		44		46		48	
	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)
1/2"	39.1	1.88	35.1	1.98	31.7	2.08	28.7	2.19	26.2	2.29	24	2.4	22	2.5
5/8"	62.9	1.88	56.5	1.98	51	2.08	46.2	2.19	42.1	2.29	38.5	2.4	35.4	2.5
3/4"	91.9	1.88	82.5	1.98	74.4	2.08	67.5	2.19	61.5	2.29	56.3	2.4	51.7	2.5

Table 5: Maximum ASD Windload – Exterior - Monolithic

Maximum ASD Windload of Exterior Cantilevered Guardrail (Fully Tempered)																	
Composition (nominal thickness in inches)	Interlayer Thickness (in)	Interlayer	H (in) Top of Guard to Top of Shoe														
			36		38		40		42		44		46		48	
			Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)	Max WL (psf)	Max Δ (in)
1/4 over 1/4	0.06	PVB	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.06	SGP	42.5	1.88	38.3	1.98	34.7	2.08	31.5	2.19	28.8	2.29	26.4	2.4	24.3	2.5
5/16 over 5/16	0.06	PVB	37.8	1.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.06	SGP	70.6	1.88	63.5	1.98	57.5	2.08	52.3	2.19	47.8	2.29	43.9	2.4	40.4	2.5
	0.09	PVB	36.6	1.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	0.09	SGP	75.3	1.88	68	1.98	61.8	2.08	56.4	2.19	51.5	2.29	47.3	2.4	43.6	2.5
3/8 over 3/8	0.06	PVB	53.6	1.88	48.8	1.98	44.7	2.08	41.3	2.19	38.1	2.29	35.5	2.4	33.1	2.5
	0.06	SGP	100	1.88	90.2	1.98	81.6	2.08	74.5	2.19	68	2.29	62.4	2.4	57.5	2.5
	0.09	PVB	52	1.88	47.4	1.98	43.2	2.08	39.8	2.19	36.8	2.29	34.1	2.4	31.8	2.5
	0.09	SGP	105.1	1.88	94.8	1.98	86.3	2.08	78.7	2.19	72	2.29	66.2	2.4	61	2.5

Table 6: Maximum ASD Windload – Exterior – Laminated

3.0: Shoe Design

The TurboFlex® channel shoe is made of 6063-T6 aluminum. The open web shaped channel legs provide a strong and coder compliant support while reducing costs due to lesser material being required.

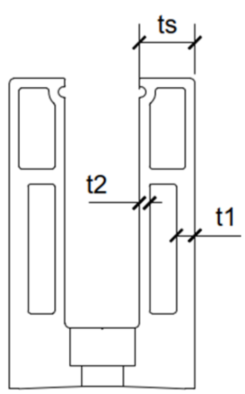


Figure 7: Shoe design Example

Maximum ASD Windload for Base Shoe	
Glass Height (in)	Windload (PSF)
36	97
38	88
40	80
42	72
44	66
46	60
48	56

Table 7: Baseshoe Maximum Loading

Check Shoe:

$$P_{wall} := \frac{\text{Max}\left(M_{PL} \cdot n_{PL}^{-1}, M_U\right)}{0.67 \cdot t_s} = 5043 \text{ lbf}$$

$$f_{comp} := \frac{P_{wall}}{t_1 \cdot space} = 9339 \text{ psi} \qquad F_{comp} := 13700 \cdot \text{psi}$$

$$f_{ten} := \frac{P_{wall}}{t_2 \cdot space} = 4743 \text{ psi} \qquad F_{ten} := 15200 \cdot \text{psi}$$

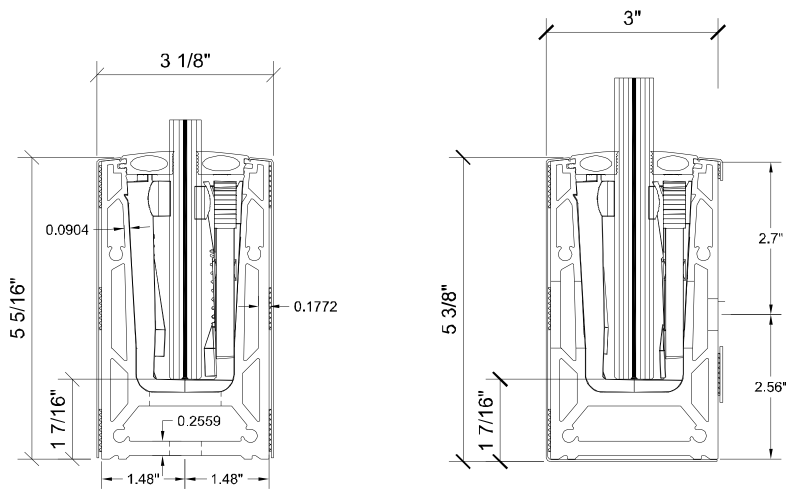
$$I_{shoe} := \text{Max}\left(\frac{f_{comp}}{F_{comp}}, \frac{f_{ten}}{F_{ten}}\right) = 0.68$$

Mp = Moment from 200 LB
Mu = Moment from 50 PLF
MWL = Moment from Windload
N = number of fasteners effective for 200 LB
S = fastener spacing

4.0: Anchor Design

The TurboFlex® balustrade may be mounted on the top or side into steel, concrete, or wood. Alternative substrates are not included in this report and need to be confirmed by a registered design engineer. Regardless of glass thickness, the shoe size and information in the anchorage tables below does not change. Adequate anchorage of the balustrade is critical to the safety and structural integrity of the system as a whole. If the anchorage fails, the guard fails. The shoe itself along with the attachment into the structure are the critical components for the scope of the balustrade. The engineer of record or building engineer will need to confirm the structural integrity of the component being attached to.

Turboflex® standard anchor bolt spacings are 6” and 12”. Alternative fasteners spacings may be used with engineering approval. Do not use 400 series stainless steel with aluminum. All exterior conditions require stainless steel, hot dipped galvanized, or coated fasteners. The anchor design is independent of the glass design which is independent of the shoe design. Review glazing, shoe, and anchorage tables. Design approach and calculations to follow tables.



Top Mount **Fascia (Side) Mount**

Figure 9: Top and Side Mounted Shoe

Anchorage into Steel:

Steel = 3/8” thick minimum with Fy = 36 KSI or better
1/2”-13, Cond A, S.S. Bolt with 3/8” Min. A36 Steel Thread Engagement
Assumes use of top cap or 6 effective for 6” spacing and 3 effective for 12” spacing
Includes windload, live load, concentrated load

Top Mounted Anchorage - 3/8" Steel Maximum Windload (ASD in PSF)		
Glass Height (in)	6" O.C.	12" O.C.
36	114	57
38	103	51
40	94	47
42	86	43
44	79	39
46	73	36
48	68	33

Side Mounted Anchorage - 3/8" Steel Maximum Windload (ASD in PSF)		
Glass Height (in)	6" O.C.	12" O.C.
36	120	98
38	120	89
40	120	81
42	120	75
44	120	69
46	120	63
48	118	58

Table 8: Maximum ASD Windload for steel substrate

Anchorage into Concrete:

Assumptions as shown per table. All concrete assumed cracked due to the potential for micro-factures. 1st edge distance is the center of bolt to closest edge of concrete. The KWIK HUS-EZ may also be referred to as KH-EZ and the designations are interchangeable.

<u>Includes 200 LB, 50 PLF, and Windload</u>
Assumptions into Concrete:
Concrete Strength = 4000 psi Cracked
6" Slab thickness typical
4 ¾" Min. 1st Edge Distance
6" Min. 2nd Edge Distance Typical
6" Min. End Distance Typical
6 Fasteners for PL
<u>Spacing 6"</u>

Top Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ (OR S.S.) INTO F'C = 4000 PSI CRACKED CONCRETE 6"	
Glass Height (in)	2 1/2" Embedment
36	70
38	63
40	57
42	52
44	47
46	43
48	39

Side Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ (OR S.S.) INTO F'C = 4000 PSI CRACKED CONCRETE 6"	
Glass Height (in)	2 1/2" Embedment
36	108
38	97
40	87
42	76
44	71
46	66
48	60

(Assumes 4 Fasteners for PL @ 12" O.C. – 3 does not work for PL so a top cap to aid in load transfer is required for these edge distances)
<u>Spacing = 12"</u>

Top Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ (OR S.S.) INTO F'C = 4000 PSI CRACKED CONCRETE 12"	
Glass Height (in)	2 1/2" Embedment
36	41
38	36
40	NA
42	NA
44	NA
46	NA
48	NA

Side Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ (OR S.S.) INTO F'C = 4000 PSI CRACKED CONCRETE 12"	
Glass Height (in)	2 1/2" Embedment
36	63
38	56
40	51
42	47
44	42
46	39
48	35

<u>Table 9: Maximum ASD Windload for Concrete Anchors</u>

Includes Windload Only
Assumptions into Concrete:
Concrete Strength = 4000 psi Cracked
6" Slab thickness
4 ¾" Min. 1st Edge Distance
6" Min. 2nd Edge Distance Typical
6" Min. End Distance Typical
Spacing = 6" and 12"

Top Mounted Anchorage - Concrete Maximum Windload (ASD) M8 GALVANIZED HSL 4 INTO F'C = 4000 PSI CRACKED CONCRETE		
Glass Height (in)	6" SPACING	12" SPACING
36	67	35
38	60	31
40	54	28
42	49	25
44	45	23
46	41	21
48	38	19

Side Mounted Anchorage - Concrete Maximum Windload (ASD) M8 GALVANIZED HSL 4 INTO F'C = 4000 PSI CRACKED CONCRETE		
Glass Height (in)	6" SPACING	12" SPACING
36	104	51
38	93	46
40	84	42
42	76	38
44	69	34
46	63	31
48	58	29

Includes 200 LB, 50 PLF, and Windload
Assumptions into Concrete:
Concrete Strength = 4000 psi Cracked
6" Slab thickness typical
4 3/8" Min. 1st Edge Distance
6" Min. 2nd Edge Distance Typical
6" Min. End Distance Typical
6 Fasteners effective for PL @ 6" O.C. and 3 for 12" O.C.

Side Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KIWK HUS-EZ (OR S.S.) INTO F'C = 4000 PSI CRACKED CONCRETE WITH 2 1/2" EMBEDMENT		
Glass Height (in)	6" SPACING	12" SPACING
36	108	64
38	97	58
40	88	52
42	79	47
44	72	43
46	66	39
48	61	36

Side Mounted Anchorage - Concrete Maximum Windload (ASD) M8 GALVANIZED HSL 4 INTO F'C = 4000 PSI CRACKED CONCRETE M8 d12*97		
Glass Height (in)	6" SPACING	12" SPACING
36	103	52
38	92	47
40	83	42
42	75	38
44	69	35
46	63	32
48	58	29

Table 10: Maximum ASD Windload for Concrete Anchors Continued

<u>Includes 200 LB, 50 PLF, and Windload</u>
Assumptions into Concrete:
Concrete Strength = As Shown
3 ¼" Min. Nominal Embedment
6" Min. Slab thickness
6" Min. 2nd Edge Distance Typical6" Min. End Distance Typical
6 Fasteners Effective for PL – 6" Spacing
(*Indicates spans that are <u>not</u> ok for guard loadings but are acceptable for windload)

Top Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ CRC INTO F'C = 3000 PSI CRACKED CONCRETE WITH 3 3/4" EDGE DISTANCE	
Glass Height (in)	3 1/4" Embedment
36	60
38	54
40	48
42	44
44*	40
46*	36
48*	33

Top Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ CRC INTO F'C = 4000 PSI CRACKED CONCRETE WITH 3" EDGE DISTANCE	
Glass Height (in)	3 1/4" Embedment
36	59
38	53
40	47
42	43
44*	39
46*	36
48*	33

Side Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ CRC INTO F'C = 3000 PSI CRACKED CONCRETE WITH 3 3/4" TOP EDGE DISTANCE	
Glass Height (in)	3 1/4" Embedment
36	92
38	83
40	75
42	68
44	62
46	56
48	52

Side Mounted Anchorage - Concrete Maximum Windload (ASD) 3/8" HILTI KWIK HUS-EZ CRC INTO F'C = 4000 PSI CRACKED CONCRETE WITH 3" TOP EDGE DISTANCE	
Glass Height (in)	3 1/4" Embedment
36	90
38	81
40	74
42	67
44	61
46	56
48	51

<u>Table 11: Maximum ASD Windload for Concrete Anchors Continued</u>

Anchorage into Wood Blocking:

Wood = SG = 0.5 or better (Douglas Fir Larch) with moisture content at service (MC) as noted with 3/8" headed lag bolt. No reductions for spacing, edge distance, end distance, temperature, or end grain factor have been used for these tables. Load duration factors include the use of 1.6 for windload and point load, 1.25 for live load, and 0.9 for deadload. Do not use zinc coating in exterior conditions; galvanized or 300 series stainless steel should be used. All loadings have been rounded down to the nearest whole number. Minimum requirements per the NDS wood code include: 7*diameter minimum edge distance, 4*diameter minimum spacing, and 4*diameter minimum edge distance.

Includes 200 LB, 50 PLF, and Windload
Assumptions into Wood Blocking:
SG = 0.5 Wood Blocking with 3/8" Lag Bolt (Fyb= 45 KSI Min.)
6 Fasteners effective for PL @ 6" O.C. and 3 for 12" O.C.

Spacing = 6"

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 6" O.C. MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	56	67	80
38	50	60	70
40	45	54	64
42	40	49	58
44	NA	45	52
46	NA	41	48
48	NA	36	44

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	NA	NA	NA
38	NA	NA	NA
40	NA	NA	NA
42	NA	NA	NA
44	NA	NA	NA
46	NA	NA	NA
48	NA	NA	NA

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 6" O.C. MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	86	103	120
38	77	93	109
40	70	84	98
42	64	77	90
44	58	70	82
46	53	64	75
48	49	59	69

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	NA	50	58
38	NA	NA	52
40	NA	NA	48
42	NA	NA	43
44	NA	NA	40
46	NA	NA	NA
48	NA	NA	NA

Table 12A: Maximum ASD Windload for Wood Anchors @ 6" O.C

Includes 200 LB, 50 PLF, and Windload Continued
Assumptions into Wood Blocking:
SG = 0.5 Wood Blocking with 3/8" Lag Bolt (Fyb= 45 KSI Min.)
6 Fasteners effective for PL @ 6" O.C. and 3 for 12" O.C.

Spacing = 12"

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	NA	NA	NA
38	NA	NA	NA
40	NA	NA	NA
42	NA	NA	NA
44	NA	NA	NA
46	NA	NA	NA
48	NA	NA	NA

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. MC >19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	NA	NA	NA
38	NA	NA	NA
40	NA	NA	NA
42	NA	NA	NA
44	NA	NA	NA
46	NA	NA	NA
48	NA	NA	NA

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	NA	50	58
38	NA	NA	52
40	NA	NA	48
42	NA	NA	43
44	NA	NA	40
46	NA	NA	NA
48	NA	NA	NA

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. MC >19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	NA	NA	NA
38	NA	NA	NA
40	NA	NA	NA
42	NA	NA	NA
44	NA	NA	NA
46	NA	NA	NA
48	NA	NA	NA

Table 12B: Maximum ASD Windload for Wood Anchors @ 12" O.C.

Includes Windload Only
Assumptions into Wood Blocking:
SG = 0.5 Wood Blocking with 3/8" Lag Bolt (Fyb= 45 KSI Min.)

Spacing = 6"

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 6" O.C. NO RAIL LOADINGS MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	56	67	80
38	50	60	70
40	45	54	64
42	40	49	58
44	36	45	52
46	33	41	48
48	30	36	44

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 6" O.C. NO RAIL LOADINGS MC >19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	39	46	54
38	35	42	48
40	32	37	44
42	29	34	40
44	26	31	36
46	24	28	33
48	22	26	30

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 6" O.C. NO RAIL LOADINGS MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	86	103	120
38	77	93	109
40	70	84	98
42	64	77	90
44	58	70	82
46	53	64	75
48	49	59	69

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 6" O.C. NO RAIL LOADINGS MC >19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	60	72	84
38	54	65	76
40	51	59	68
42	44	53	62
44	40	49	57
46	37	45	52
48	34	41	48

Table 13A: Maximum ASD Windload for Wood Anchors continued @ 6" O.C.

Includes Windload Only
Assumptions into Wood Blocking:
SG = 0.5 Wood Blocking with 3/8" Lag Bolt (Fyb= 45 KSI Min.)

Spacing = 12"

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. NO RAIL LOADINGS MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	27	33	38
38	24	29	34
40	22	27	31
42	20	24	28
44	18	22	25
46	16	20	23
48	15	18	21

Top Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. NO RAIL LOADINGS MC >19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	19	23	27
38	17	21	24
40	16	19	22
42	14	17	20
44	13	15	18
46	12	14	16
48	11	13	15

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. NO RAIL LOADINGS MC ≤19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	40	50	58
38	36	45	52
40	33	41	48
42	30	37	43
44	27	34	40
46	25	31	36
48	23	28	33

Side Mounted Anchorage - Wood Maximum Windload (ASD) - 12" O.C. NO RAIL LOADINGS MC >19%			
Glass Height (in)	4" Penetration	5" Penetration	6" Penetration
36	28	34	40
38	25	31	37
40	23	28	33
42	21	25	30
44	19	23	27
46	17	21	25
48	16	19	23

Table 13B: Maximum ASD Windload for Wood Anchors continued @ 12" O.C.

Anchorage into Wood Blocking – Alternative Angle at top mounted shoe:

When the balustrade shoe is too close to the edge of the wood blocking or a straight attachment just isn't possible, an edge angle approach may be used. The idea is to mount a steel angle to the edge of the curb and tap into the angle with the steel bolts noted above. As pullout of 5/16" steel and 3/8" steel are not the governing failure mode of the ½" cap screw, the maximum windloads noted under the "Anchorage into Steel" section are still valid.

The standard angle size is 5" x 5" x 5/16" thick x 4" long. These angles are to be placed at an on center spacing consistent with the bolt in the baseshoe (ie 6" or 12" o.c. standard). Each angle is attached into wood blocking with (4) #14 flat head woodscrews with a minimum of 2" wood penetration. This angle must sit fully on the curb, at no time should any part of it be free-floating or unsupported.

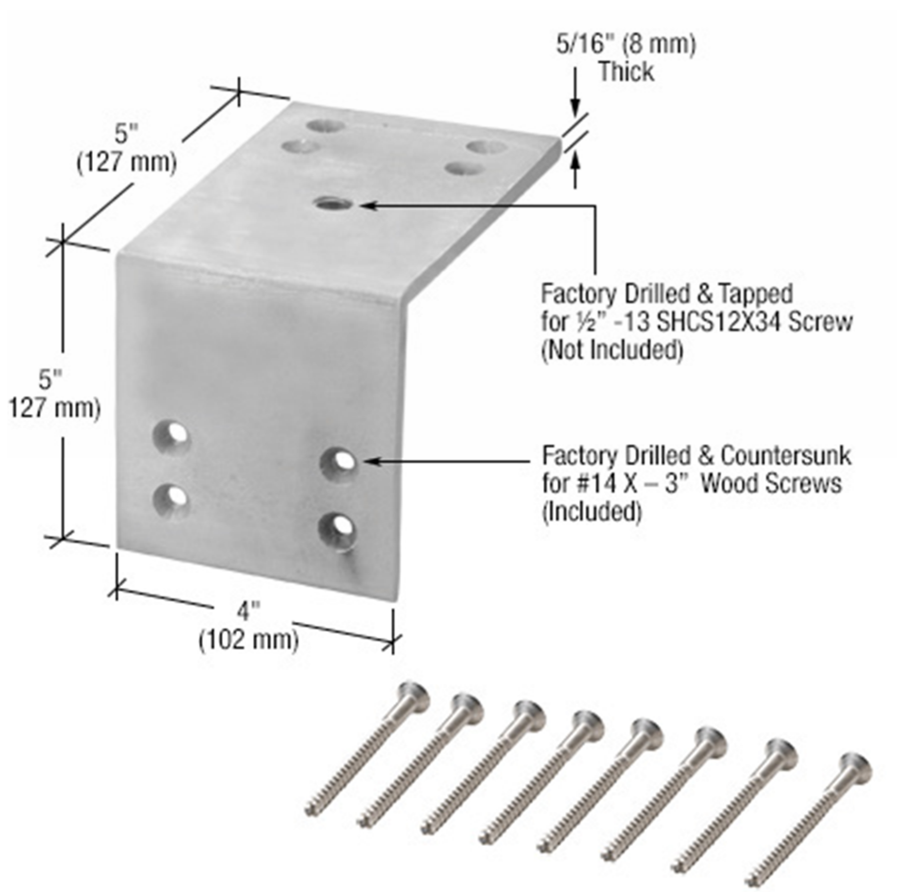


Figure 10: Alternative Side Mounted Angle at Wood Blocking

Anchorage into Wood Blocking – Alternative Angle continued:

#14 Flat Head Woodscrews with a 2" penetration can withstand 299lbs of shear and 410lbs of tension with a Cd = 1.6 withouth interaction assuming an SG = 0.5 wood blocking. The maximum force the angle and woodscrews can handle, per connection point, is an Rz of 250lbs and a coupled force of 2100lbs.

The coupled force is determined by taking the moment from the beam equation, at the top of the shoe, divided by 1.375in (the distance from the shoe bearing to the ½" cap screw). These forces have been confirmed through finite element plate modeling in the positive and negative directions to determine worst case. The ASD allowable stress in A36 steel is 36,000 psi/1.67 = 21556psi. Concentrated load, live load, and windload have been accounted for. Always check the other relevant tables as all tables are independent.

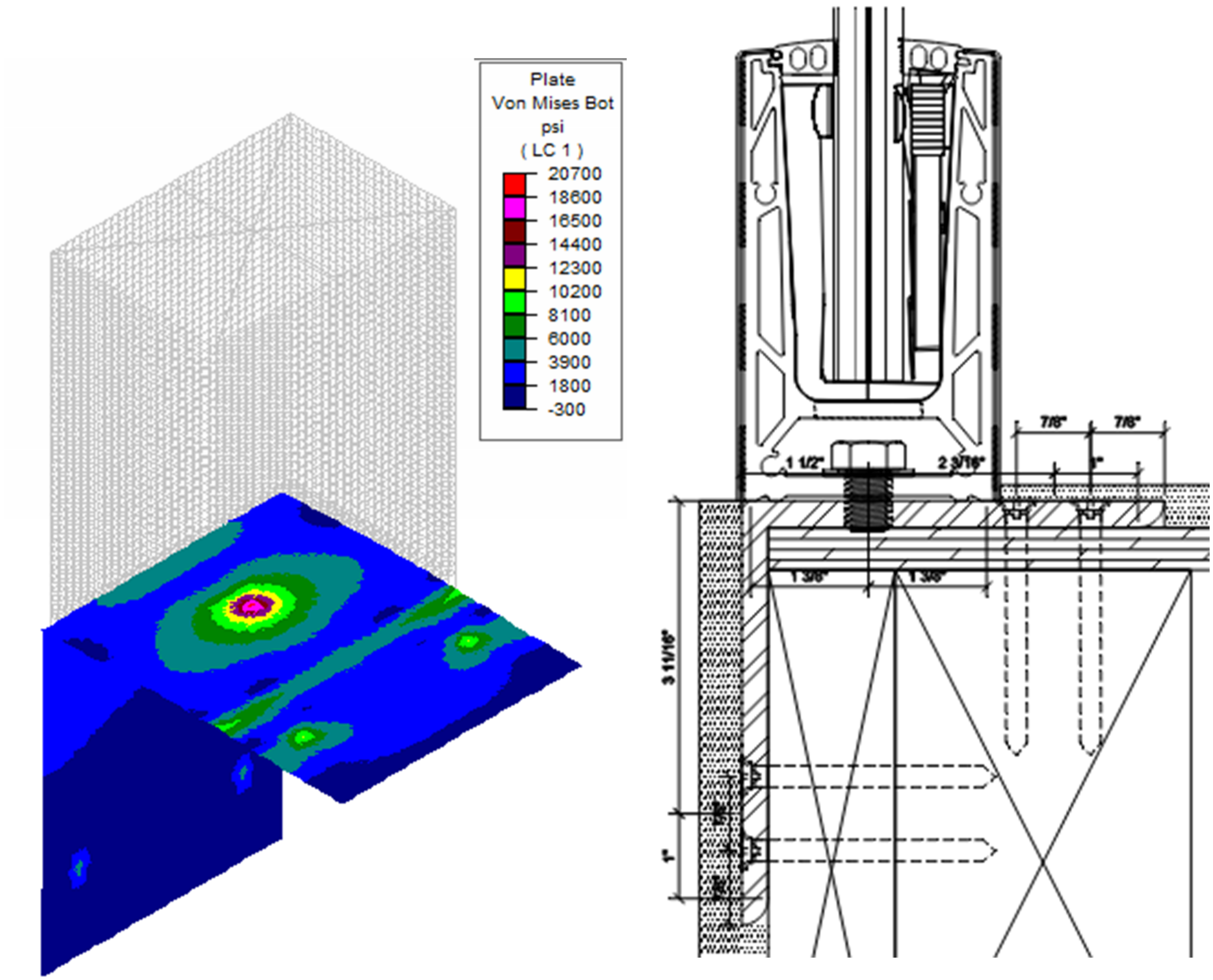


Figure 11: Alternative Side Mounted Angle at Wood Blocking

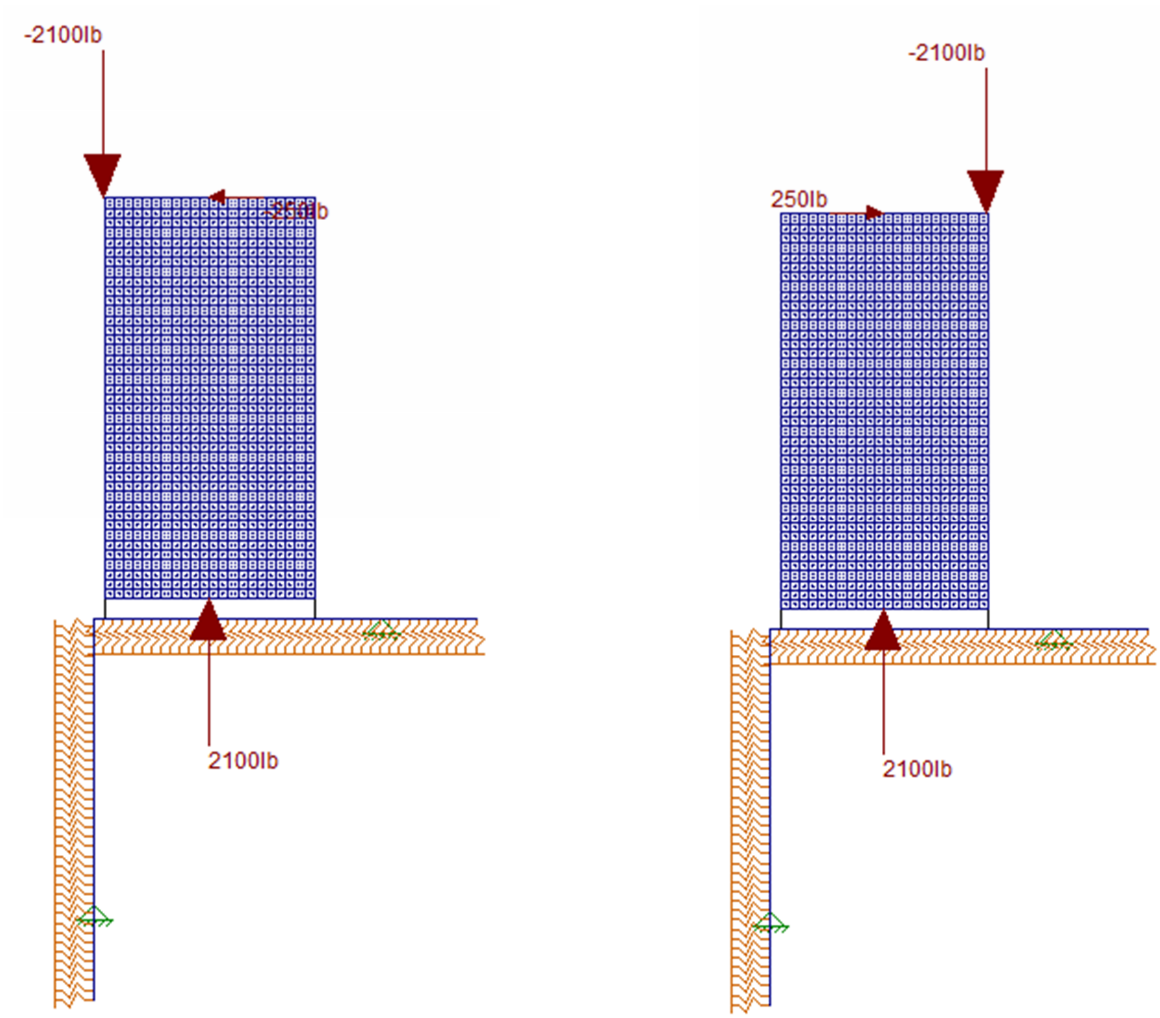


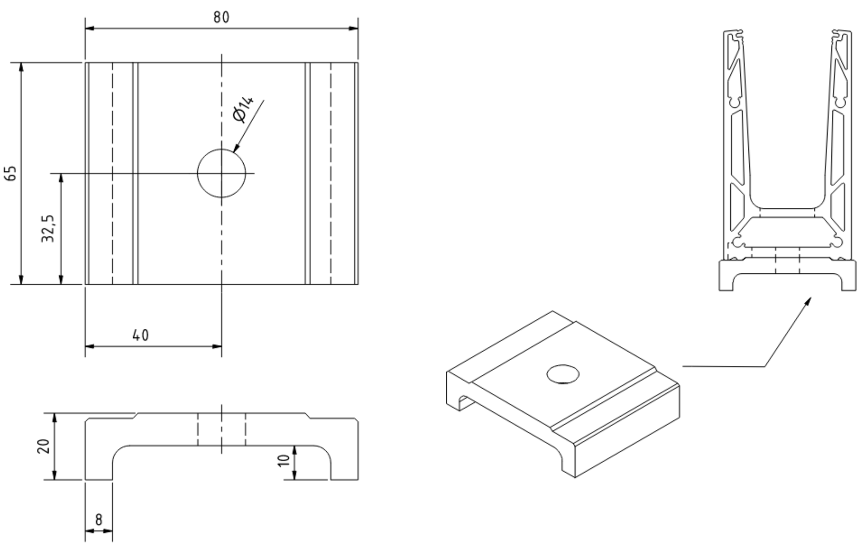
Figure 12: Negative (Left) and Positive (Right) Loading of Curb Mounted Angle

Curb Mounted Angle - Maximum Windload (ASD in PSF) for Steel Angle and #14 Woodscrews		
Glass Height (in)	6" O.C.	12" O.C.
36	106	53
38	95	48
40	86	43
42	78	39
44	71	NA
46	65	NA
48	60	NA

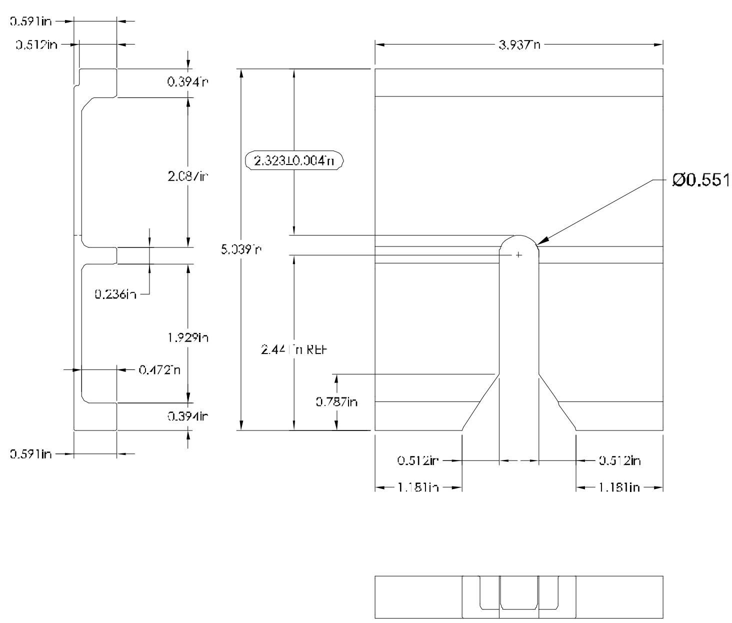
Table 14: Maximum ASD Windload for Curb Mounted Angle and Attachment

Alternative Drain Blocks:

Aluminum drain blocks may be used on the top mounted or side mounted shoe spaced per anchor bolt. These blocks, shown below, are an optional shim to keep the shoe pushed off of the substrate. The drain blocks, also referred to as spacer shims, are non-structural and are acceptable up to 20mm (25/32") thick on the top mounted locations and up to 15mm (9/16") thick on side mounted locations. Since tension is the controlling loading on the anchor bolts, bending of the fasteners through these thicknesses from shear is ok by inspection.



Top Mount Drain Block



Fascia/Side Mount Drain Block

Figure 13: Alternative Drain Blocks

Anchorage Design:

Top Mounted

Inputs:

Reactions:

$WL := 33\ psf$

$LL := 50\ plf$

$PL := 200\ lbf$

$H := 48\ in$

$W := H$

$Trib := 1\ in$

$t_{LL\_1Hr} := 0.469\ in$

$LL_v := 0\ plf$ Simultaneous Vertical live load

Shoe:

$H_s := 135\ mm$

$t_1 := 0.09\ in$

$t_2 := 0.1772\ in$

$t_s := 0.608\ in$

$t := 0.25\ in$

Anchor Bolts:

$space := 12\ in$

$n_{PL} := 3$

$L_{resist} := 75\ mm \cdot 0.5 = 37.5\ mm$

$Crush := 0.85$

$d := 0.5\ in$

$\Omega_{bear} := 1.95$

$\Omega_{pullout} := 3$

$F_{TU} := 30000\ psi$

$F_U := 58000\ psi$

Steel:

$N := \frac{13}{in}$

$FT_U := 75000\ psi$

$\Omega_{steel} := 2.5$

$t_{eng} := 0.375\ in$

$A_{TSI} := 0.086\ in^2$

Concrete:

$\phi := 0.6$

$N_{model} := 3$

Wood:

$CD_{3sec} := 1.6$

$CD_{1hr} := 1.25$

Calculations:

All Calculations Below This Line Are Automatic

$R_P := PL = 200\ lbf$

$M_P := PL \cdot H = 9600\ lbf \cdot in$

$I_{LL} := \frac{space \cdot t_{LL\_1Hr}^{3}}{12} = 0.1\ in^4$

$\Delta_{LL} := \frac{LL \cdot space \cdot H^3}{3\ E_{glass} \cdot I_{LL}} = 1.72\ in$

$M_{LL} := LL \cdot space \cdot H + LL_v \cdot space \cdot \Delta_{LL} = 2400\ lbf \cdot in$

$R_{LL} := \frac{M_{LL}}{H} = 50\ lbf$

$R_{WL} := WL \cdot space \cdot H = 132\ lbf$

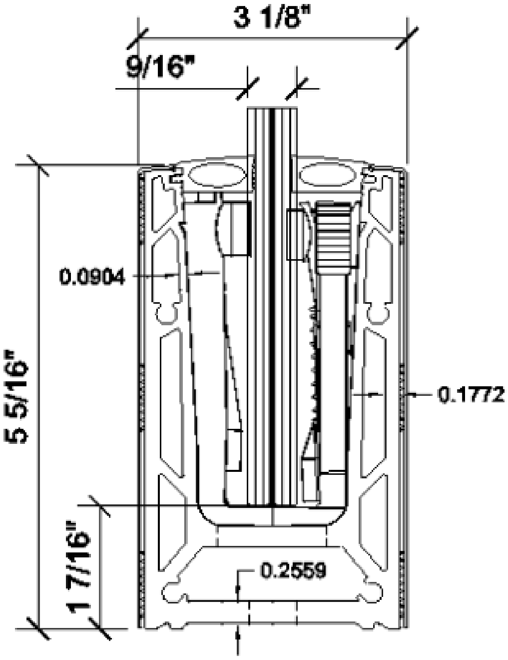
$M_{WL} := \frac{WL \cdot space \cdot H^2}{2} = 3168\ lbf \cdot in$

$R_{PL} := R_P = 200\ lbf$

$M_{PL} := M_P + R_{PL} \cdot H_s = 10662.99\ lbf \cdot in$

$R_U := \text{Max}\left(R_{LL}, R_{WL}\right) = 132\ lbf$

$M_U := \text{Max}\left(M_{LL}, M_{WL}\right) + R_U \cdot H_s = 3869.57\ lbf \cdot in$



Check Shoe:

$$P_{wall} := \frac{\text{Max}\left(M_{PL} \cdot n_{PL}^{-1}, M_U\right)}{0.67 \cdot t_s} = 9499\ lbf$$

$$f_{comp} := \frac{P_{wall}}{t_1 \cdot space} = 8796\ psi \qquad F_{comp} := 13700 \cdot psi$$

$$f_{ten} := \frac{P_{wall}}{t_2 \cdot space} = 4467\ psi \qquad F_{ten} := 15200 \cdot psi$$

$$I_{shoe} := \text{Max}\left(\frac{f_{comp}}{F_{comp}}, \frac{f_{ten}}{F_{ten}}\right) = 0.64$$

Check Anchor Bolts:

Steel:

$$V_{PL} := \frac{R_{PL}}{n_{PL}} = 66.67\ \text{lbf}$$

$$T_{PL} := \frac{M_{PL}}{n_{PL} \cdot L_{resist} \cdot Crush} = 2832\ \text{lbf}$$

$$V_U := R_U = 132\ \text{lbf}$$

$$T_U := \frac{M_U}{L_{resist} \cdot Crush} = 3084\ \text{lbf}$$

$$V := \text{Max}\left(V_{PL}, V_U\right) = 132\ \text{lbf}$$

$$T := \text{Max}\left(T_{PL}, T_U\right) = 3084\ \text{lbf}$$

$$A_R := \frac{\pi \cdot \left(\left(d - \frac{1.2269}{N}\right)^2\right)}{4} = 0.13\ \text{in}^2$$

$$A_S := \frac{\pi \cdot \left(\left(d - \frac{0.9743}{N}\right)^2\right)}{4} = 0.14\ \text{in}^2$$

$$Pullout := \frac{t_{eng} \cdot N \cdot A_{TSI} \cdot F_U}{\Omega_{pullout}} = 8106\ \text{lbf}$$

$$Tension := \frac{0.75 \cdot FT_U \cdot A_S}{\Omega_{steel}} = 3193\ \text{lbf}$$

$$Shear := \frac{0.75 \cdot FT_U \cdot A_R}{\Omega_{steel} \cdot \sqrt{3}} = 1679\ \text{lbf}$$

$$F_{bear} := \frac{2 \cdot d \cdot t \cdot F_{TU}}{\Omega_{bear}} = 3846\ \text{lbf}$$

$$V_{steel} := \text{Min}\left(F_{bear}, Shear\right) = 1679\ \text{lbf}$$

$$T_{steel} := \text{Min}\left(Pullout, Tension\right) = 3193\ \text{lbf}$$

$$I_s := \left(\frac{V}{V_{steel}}\right)^2 + \left(\frac{T}{T_{steel}}\right)^2 = 0.94$$

Concrete:

$$V_{PL\_C} := \frac{R_{PL}}{n_{PL} \cdot \phi} \cdot N_{model} = 333.33\ \text{lbf}$$

$$M_{PL\_C} := \frac{M_{PL}}{n_{PL} \cdot \phi} \cdot N_{model} = 17771.65\ \text{lbf} \cdot \text{in}$$

$$V_{LL\_C} := \frac{R_{LL}}{\phi} \cdot N_{model} = 250\ \text{lbf}$$

$$M_{LL\_C} := \frac{M_{LL}}{\phi} \cdot N_{model} + V_{LL\_C} \cdot H_s = 13329\ \text{lbf} \cdot \text{in}$$

$$V_{WL\_C} := \frac{R_{WL}}{\phi} \cdot N_{model} = 660\ \text{lbf}$$

$$M_{WL\_C} := \frac{M_{WL}}{\phi} \cdot N_{model} = 15840\ \text{lbf} \cdot \text{in}$$

$$V_{conc\_Model} := \text{Max}\left(V_{PL\_C}, V_{LL\_C}, V_{WL\_C}\right) = 660\ \text{lbf}$$

$$M_{conc\_Model} := \text{Max}\left(M_{PL\_C}, M_{LL\_C}, M_{WL\_C}\right) = 17772\ \text{lbf} \cdot \text{in}$$

Model at least 3 fasteners to account for spacing reduction

Fasteners at concrete need to be modeled through design software or must go through an ACI 318 analysis - the phi factor of 0.6 is used to convert the loading to LRFD

Wood:

$$V_{PL\_W} := \frac{R_{PL}}{n_{PL} \cdot CD_{3sec}} = 42\ \text{lbf}$$

$$T_{PL\_W} := \frac{M_{PL}}{n_{PL} \cdot CD_{3sec} \cdot L_{resist} \cdot Crush} = 1770\ \text{lbf}$$

$$V_{LL\_W} := \frac{R_{LL}}{CD_{1hr}} = 40\ \text{lbf}$$

$$T_{LL\_W} := \frac{M_{LL}}{CD_{1hr} \cdot L_{resist} \cdot Crush} = 1530\ \text{lbf}$$

$$V_{WL\_W} := \frac{R_{WL}}{CD_{3sec}} = 82\ \text{lbf}$$

$$T_{WL\_W} := \frac{M_{WL}}{CD_{3sec} \cdot L_{resist} \cdot Crush} = 1578\ \text{lbf}$$

$$V_w := \text{Max}\left(V_{PL\_W}, V_{LL\_W}, V_{WL\_W}\right) = 82\ \text{lbf}$$

$$T_w := \text{Max}\left(T_{PL\_W}, T_{LL\_W}, T_{WL\_W}\right) = 1770\ \text{lbf}$$

Use a CD = 1 for the analysis of the lag bolts as CD has already been accounted for.

Side Mounted :

Inputs:

Reactions:

$WL := 40\ psf$

$LL := 50\ plf$

$PL := 200\ lbf$

$H := 48\ in$

$W := H$

$Trib := 1\ in$

$t_{LL\_1Hr} := 0.469\ in$

Shoe:

$H_s := 135\ mm$

$t_1 := 0.09\ in$

$t_2 := 0.1772\ in$

$t_s := 0.608\ in$

$t := 0.25\ in$

$t_g := 0.75\ in$

Anchor Bolts:

$space := 6\ in$

$n_{PL} := 6$

$L_{resist} := 65\ mm = 2.56\ in$

$Crush := 0.85$

$d := 0.5\ in$

$\Omega_{bear} := 1.95$

$\Omega_{pullout} := 3$

$F_{TU} := 30000\ psi$

$F_U := 58000\ psi$

Steel:

$N := \frac{13}{in}$

$FT_U := 75000\ psi$

$\Omega_{steel} := 2.5$

$t_{eng} := 0.375\ in$

$A_{TSI} := 0.086\ in^2$

Concrete:

$\phi := 0.6$

$N_{model} := 3$

Wood:

$CD_{3sec} := 1.6$

$CD_{1hr} := 1.25$

$CD_{DL} := 0.9$

$LL_v := 0\ plf$ Simultaneous Vertical live load

Calculations:

All Calculations Below This Line Are Automatic

$R_P := PL = 200\ lbf$

$M_P := PL \cdot H = 9600\ lbf \cdot in$

$I_{LL} := \frac{space \cdot t_{LL\_1Hr}^{\ 3}}{12} = 0.05\ in^4$

$\Delta_{LL} := \frac{LL \cdot space \cdot H^3}{3\ E_{glass} \cdot I_{LL}} = 1.72\ in$

$M_{LL} := LL \cdot space \cdot H + LL_v \cdot space \cdot \Delta_{LL} = 1200\ lbf \cdot in$

$R_{LL} := \frac{M_{LL}}{H} = 25\ lbf$

$R_y := t_g \cdot 158 \cdot pcf \cdot (H + 0.5 \cdot H_s) \cdot space = 20.84\ lbf$ Per anchor bolt

$R_{WL} := WL \cdot space \cdot H = 80\ lbf$

$M_{WL} := \frac{WL \cdot space \cdot H^2}{2} = 1920\ lbf \cdot in$

$R_{PL} := R_P = 200\ lbf$

$M_{PL} := M_P + R_{PL} \cdot 0.5 \cdot H_s = 10131.5\ lbf \cdot in$

$R_U := \mathrm{Max}(R_{LL}, R_{WL}) = 80\ lbf$

$M_U := \mathrm{Max}(M_{LL}, M_{WL}) + R_U \cdot 0.5 \cdot H_s = 2132.6\ lbf \cdot in$

Check Shoe:

$$P_{wall} := \frac{\mathrm{Max}\left(M_{PL} \cdot n_{PL}^{\ -1}, M_U\right)}{0.67 \cdot t_s} = 5235\ lbf$$

$$f_{comp} := \frac{P_{wall}}{t_1 \cdot space} = 9695\ psi \qquad F_{comp} := 13700 \cdot psi$$

$$f_{ten} := \frac{P_{wall}}{t_2 \cdot space} = 4924\ psi \qquad F_{ten} := 15200 \cdot psi$$

$$I_{shoe} := \mathrm{Max}\left(\frac{f_{comp}}{F_{comp}}, \frac{f_{ten}}{F_{ten}}\right) = 0.71$$

Check Anchor Bolts:

$$M_{DL} := \left(R_y + LL_v \cdot space\right) \cdot 1.5\ in = 31.27\ lbf \cdot in$$

Steel:

$$V_{PL} := R_y = 20.84\ lbf$$

$$T_{PL} := \frac{M_{PL} + M_{DL}}{n_{PL} \cdot L_{resist} \cdot Crush} + R_{PL} = 979\ lbf$$

$$V_U := R_U + R_y = 100.84\ lbf$$

$$T_U := \frac{M_U + M_{DL}}{L_{resist} \cdot Crush} + R_U = 1075\ lbf$$

$$V := \mathrm{Max}\left(V_{PL}, V_U\right) = 101\ lbf$$

$$T := \mathrm{Max}\left(T_{PL}, T_U\right) = 1075\ lbf$$

$$A_R := \frac{\pi \cdot \left(\left(d - \frac{1.2269}{N}\right)^2\right)}{4} = 0.13\ in^2$$

$$A_S := \frac{\pi \cdot \left(\left(d - \frac{0.9743}{N}\right)^2\right)}{4} = 0.14\ in^2$$

$$Pullout := \frac{t_{eng} \cdot N \cdot A_{TSI} \cdot F_U}{\Omega_{pullout}} = 8106\ lbf$$

$$Tension := \frac{0.75 \cdot FT_U \cdot A_S}{\Omega_{steel}} = 3193\ lbf$$

$$Shear := \frac{0.75 \cdot FT_U \cdot A_R}{\Omega_{steel} \cdot \sqrt{3}} = 1679\ lbf$$

$$F_{bear} := \frac{2 \cdot d \cdot t \cdot F_{TU}}{\Omega_{bear}} = 3846\ lbf$$

$$V_{steel} := \mathrm{Min}\left(F_{bear}, Shear\right) = 1679\ lbf$$

$$T_{steel} := \mathrm{Min}\left(Pullout, Tension\right) = 3193\ lbf$$

$$I_{steel} := \left(\frac{V}{V_{steel}}\right)^2 + \left(\frac{T}{T_{steel}}\right)^2 = 0.12$$

Concrete:

$$V_{PL\_C} := \left(R_y \cdot 1.2\right) \cdot N_{model} = 75.04\ lbf$$

$$M_{PL\_C} := \left(\frac{M_{PL}}{n_{PL} \cdot \phi} + M_{DL} \cdot 1.2\right) \cdot N_{model} = 8555.47\ lbf \cdot in$$

$$T_{PL\_C} := \frac{R_{PL}}{n_{PL} \cdot \phi} \cdot N_{model} = 166.67\ lbf$$

$$V_{LL\_C} := \left(R_y \cdot 1.2\right) \cdot N_{model} = 75\ lbf$$

$$M_{LL\_C} := \left(\frac{M_{LL}}{\phi} + M_{DL} \cdot 1.2\right) \cdot N_{model} + V_{LL\_C} \cdot H_s = 6511\ lbf \cdot in$$

$$T_{LL\_C} := \frac{R_{LL}}{\phi} \cdot N_{model} = 125\ lbf$$

$$V_{WL\_C} := \left(R_y \cdot 1.2\right) \cdot N_{model} = 75\ lbf$$

$$M_{WL\_C} := \left(\frac{M_{WL}}{\phi} + M_{DL} \cdot 1.2\right) \cdot N_{model} = 9713\ lbf \cdot in$$

$$T_{WL\_C} := \frac{R_{WL}}{\phi} \cdot N_{model} = 400\ lbf$$

$$V_{conc\_Model} := \mathrm{Max}\left(V_{PL\_C}, V_{LL\_C}, V_{WL\_C}\right) = 75\ lbf$$

$$M_{conc\_Model} := \mathrm{Max}\left(M_{PL\_C}, M_{LL\_C}, M_{WL\_C}\right) = 9713\ lbf \cdot in$$

$$T_{conc\_Model} := \mathrm{Max}\left(T_{PL\_C}, T_{LL\_C}, T_{WL\_C}\right) = 400\ lbf$$

Model at least 3 fasteners to account for spacing reduction

Fasteners at concrete need to be modeled through design software or must go through an ACI 318 analysis - the phi factor of 0.6 is used to convert the loading to LRFD

Wood:

$$V_{PL\_W} := \frac{R_y}{CD_{DL}} = 23\ lbf$$

$$T_{PL\_W} := \frac{\frac{M_{PL}}{CD_{3sec}} + \frac{M_{DL}}{CD_{DL}}}{n_{PL} \cdot L_{resist} \cdot Crush} + \frac{R_{PL}}{CD_{3sec}} = 613\ lbf$$

$$V_{LL\_W} := \frac{R_y}{CD_{DL}} = 23.16\ lbf$$

$$T_{LL\_W} := \frac{\frac{M_{LL}}{CD_{1hr}} + \frac{M_{DL}}{CD_{DL}}}{L_{resist} \cdot Crush} + \frac{R_{LL}}{CD_{1hr}} = 477\ lbf$$

$$V_{WL\_W} := \frac{R_y}{CD_{DL}} = 23\ lbf$$

$$T_{WL\_W} := \frac{\frac{M_{WL}}{CD_{3sec}} + \frac{M_{DL}}{CD_{DL}}}{L_{resist} \cdot Crush} + \frac{R_{WL}}{CD_{3sec}} = 618\ lbf$$

$$V_w := \mathrm{Max}\left(V_{PL\_W}, V_{LL\_W}, V_{WL\_W}\right) = 23\ lbf$$

$$T_w := \mathrm{Max}\left(T_{PL\_W}, T_{LL\_W}, T_{WL\_W}\right) = 618\ lbf$$

Use a CD = 1 for the analysis of the lag bolts as the CD has already been accounted for.