8 November 2021

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SUBJ: TAPER-LOC® SYSTEM DRY-GLAZE
TEMPERED LAMINATED GLASS RAIL SYSTEM WITH SGP INTERLAYER
9/16" LAMINATED GLASS - L56S AND 9BL56 BASE SHOES

The GRS Glass Railing Dry Glaze Taper-Loc™ System utilizing 9/16" laminated tempered glass with Sentry Glas+™ interlayer balustrade lights in a properly anchored, aluminum extruded base shoe and appropriate cap rail to construct guards for fall protection. The system is intended for interior and exterior weather exposed applications and is suitable for use in most natural environments. The system may be used for residential, commercial and industrial applications where not subject to vehicle impacts. This is an engineered system designed for the following criteria:

The design loading conditions are:
Conc. load = 200 lbs any direction, any location along top or 42" above walking surface*
Uniform load = 50 plf perpendicular to glass at top or 42" above walking surface*
Load of 50 lbs on one square foot at any location on glass.
Wind load = As stated for the application and components, 10 psf minimum - ASD level.

*Refer to 2021 IBC Section 1607.9, applicable when fall protection is required.
Installations without a top rail shall comply with the recommendations herein and IBC 2407.1.2.

Glass stresses are designed for a safety factor of 4.0 (IBC 2407.1.1) for live loads.

The system will meet the applicable requirements of the 2015, 2018 and 2021 International Building Codes, 2016 and 2020 California Building Codes, 2017 and 2020 Florida Building Code (as wind loading permits) and other state codes adopting the IBC when properly designed by a qualified professional and correctly installed. This report is intended to provide design guidance to said design professional and isn't intended to demonstrate code compliance of any specific installation. Aluminum components are designed in accordance with the 2015 and 2020 Aluminum Design Manuals (ADM). Stainless steel components are designed in accordance with SEI/ASCE 8-02 *Specification for the Design of Cold-Formed Stainless Steel Structural Members* or AISC *Design Guide 27 Structural Stainless Steel* as appropriate.

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Typical Installations:
Surface or fascia mounted to:
1/2” cap screw to steel @ 12” o.c.:
3/8” Hilti HUS EZ to concrete @ 12” o.c. or @ 6” O.C.
1/2” x 6” socket head lag screws to wood (moisture content maintained ≤ 19%) @ 12” o.c. or @ 6” O.C. as required for loading.
Refer to Table 5 on page 20 for surface mounted anchor strength and allowable wind loads or Table 6 on page 22 for fascia mounted anchor strength and allowable wind loads.

Embedded base shoe:
Glass strength controls for all cases

ALLOWABLE LOADS ON GLASS
The allowable load on the glass is dependent on the glass makeup and light width. Refer to table 2 for allowable moment for wind loading.
Calculate glass moment based on wind load-
$M_w = w*h^2*0.55*12”$: in-lb/ft
where:
w = wind load pressure in psf
h = effective cantilever height:
h = from top of base shoe to top edge of cap rail or glass if no cap rail installed when wet glazed. When installed with Taper-Locs® add 0.042 feet (1/2 in) to allow for Taper-Locs® are set below top of base shoe.

FOR INSTALLATION WITH A TOP RAIL: Maximum glass cantilever height for fall protection is limited to that height at which the glass bending moment does not exceed the allowable glass moments as shown in Table 2 (page 7 of 24) for 50 plf live load or 200 lb concentrated live load being applied at top of glass or at 42 inches above the finish floor, whichever is less, for compliance with the International Building Code (all versions) and International Residential Code (all versions).

FOR INSTALLATION WITHOUT A TOP RAIL: The glass balustrade may be installed without a top rail when permitted by IBC 2407.1.2 Exception and approval by the *building official*. Maximum glass cantilever height for fall protection is limited to the glass height as shown in Table 4 (page 10 of 24) for compliance with the International Building Code (all versions) and International Residential Code (all versions).

REFER TO GRS TOP RAILS AND HANDRAILS ENGINEERING REPORT FOR CAP RAILS (REQUIRED FOR FALL PROTECTION) AND HANDRAILS (REQUIRED ALONG STAIRS AND RAMPS.)

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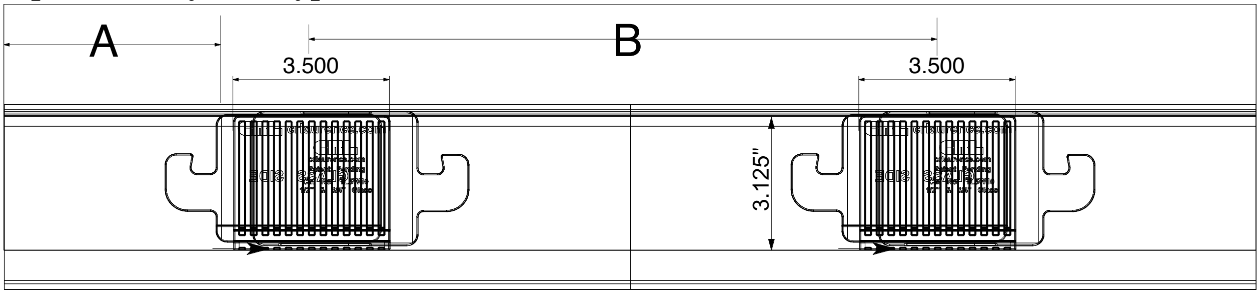
Taper-Loc® System Typical Installation



For two ply laminated glass with 1/4" Fully Tempered Glass and 1/16" interlayer maximum glass light height is 42":
Edge Distance: 2" ≤ A ≤ 4"; 51mm ≤ A ≤ 102mm
Center to center spacing: 5" ≤ B ≤ 8": 127 mm ≤ B ≤ 203 mm

Panel Width/Required quantity of Taper-Loc Plates:

6" to <10" (127 to 254 mm)	1 TL Plate
10" to <16" (254 to 406 mm)	2 TL Plates
16" to <24" (406 to 610 mm)	3 TL Plates
24" to <32" (610 to 813 mm)	4 TL Plates
32" to <40" (813 to 1,016 mm)	5 TL Plates
40" to <48" (1,016 to 1,219 mm)	6 TL Plates
48" to <56" (1,219 to 1,422 mm)	7 TL Plates
56" to <64" (1,422 to 1,626 mm)	8 TL Plates
64" to <72" (1,626 to 1,829 mm)	9 TL Plates
72" to <84" (1,067 to 1,422 mm)	10 TL Plates
80" to ≤84" (2,032 - 2,134 mm)	11 TL Plates

Minimum Glass Lite Width = 6" when top rail/guardrail is continuous, welded corners or attached to additional supports at rail ends.

NOTES:

1. For glass light heights over 42" A_{max} and B_{max} shall be reduced proportionally.
   $A_{max} = 4*(42/h)$
   $B_{max} = 8*(42/h)$

2. For glass light heights under 42" A_{max} and B_{max} shall not be increased.

3. A_{min} and B_{min} are for ease of installation and can be further reduced as long as proper installation is achieved.

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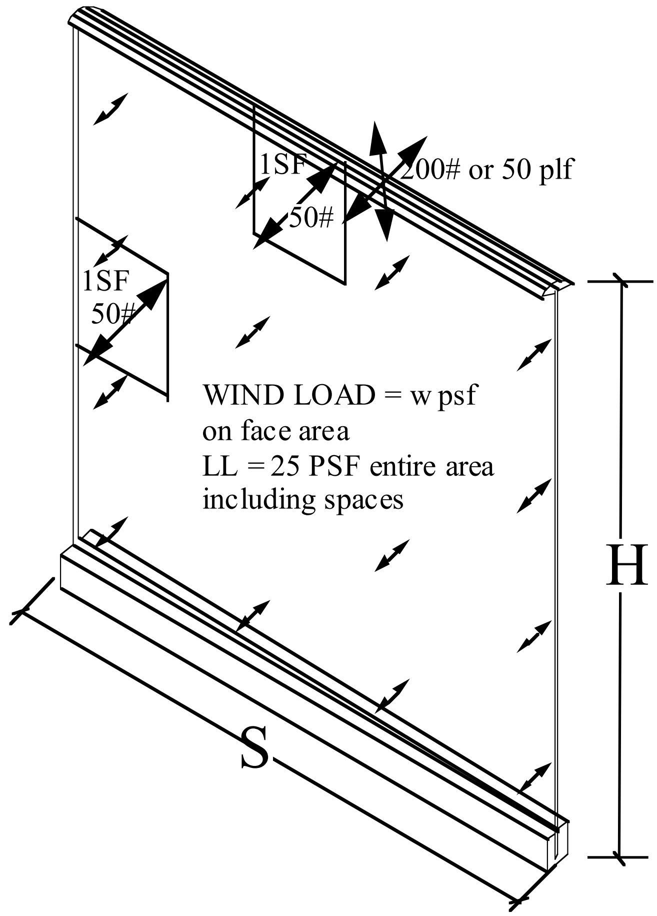
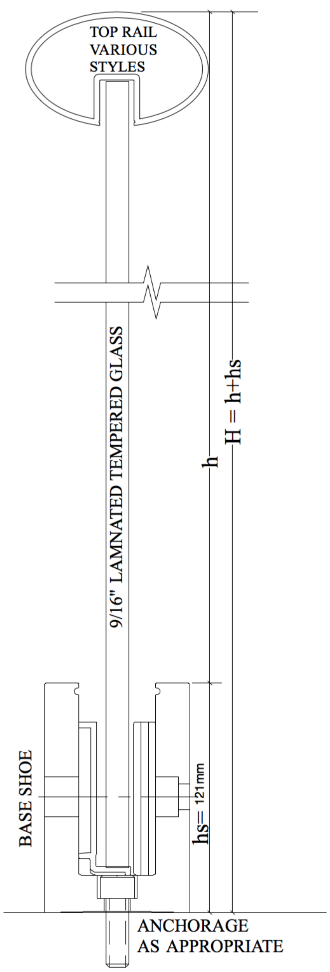
LOAD CASES:

Dead load = 6.9 psf for glass
1.8 plf top rail
3.0 plf for base shoe

Loading:
Horizontal load to base shoe
25 psf*H or W*H
Balustrade moments
M_i = 25 psf*H^2/2 or
M_w = w psf* H^2/2

For top rail loads:
M_c = 200#*H
M_u = 50plf*H





FOR WIND
SCREEN OR DIVIDER APPLICATIONS WHERE FALL PROTECTION IS NOT REQUIRED THE CAP RAIL MAY BE OMITTED.
THE 200# LOAD, 50 PLF LOAD AND 25 PSF LOAD CASES ARE APPLICABLE TO GUARD APPLICATIONS.
MINIMUM WIND LOAD IS 10 PSF.
WIND LOADS ARE ALLOWABLE STRESS DESIGN LOADS.
WIND LOADS CALCULATED AT STRENGTH LEVEL PER ASCE/SEI 7-16 SHALL BE ADJUSTED TO ASD LEVEL BY MULTIPLYING THE STRENGTH LEVEL LOADS BY 0.6.

WHEN INSTALLED WITHOUT A CAP RAIL DIFFERENTIAL DEFLECTION OF THE GLASS LIGHTS MUST BE CHECKED AND LIMITED TO UNDER 1/2”

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<u>WIND LOADING ON FENCES OR GUARDS</u>

Calculated in accordance with ASCE/SEI 7-16 Section 29.3.1 *Design Wind Loads on Solid Freestanding Walls and Solid Signs*. This section is applicable for free standing building guardrails, wind walls and balcony railings that return to building walls. Section 30.8 *Parapets* may be applicable when the rail is along a roof perimeter. **Wind loads must be determined by a qualified individual for a specific installation.**

$F = q_h(GC_f)A_s$ (ASCE 7-16 eq. 29.3-1)

G = 0.85 from (section 26.11.)

$C_f = 2.5*0.8*0.6 = 1.2$ (Figure 29.3-1) with reduction for solid and end returns, will vary.

$q_h = 0.00256K_zK_{zt}K_dV^2$ Where:

- K_z from (Table 26.10-1) at the height z of the railing centroid and exposure.
- $K_d = 0.85$ from (Table 26.6-1).
- K_{zt} From ASCE 26.8 for the site topography, typically 1.0.
- V = Wind speed (mph) 3 second gust, (Figure 26.5-1B) or per local authority.

Simplifying - Assuming $1.3 \le C_f \le 2.6$ (Typical limits for fence or guard with returns.)

Adjustment for full height solid: f = 1.8-1 = 0.8

Adjustment to Allowable Stress Design: $w_{asd} = 0.6w_{strength}$

- For $C_f = 1.3$: $F = q_h*0.85*1.3*0.8*0.6 = 0.53\ q_h$
- For $C_f = 2.6$: $F = q_h*0.85*2.6*0.8*0.6 = 1.06\ q_h$

Wind Load will vary along length of fence in accordance with ASCE 7-16 Figure 29.3-1.

Typical exposure factors for K_z with height 0 to 15’ above grade:

Exposure	B	C	D
K_z =	0.70	0.85	1.03

Centroid of wind load acts at 0.55h on the fence.

$w_{asd} = 0.53*0.00256*K_z*V^2$ or $w_{asd} = 1.06*0.00256*K_z*V^2$

Table 1	W_{ASD} in psf for $C_f = 1.3$			W_{ASD} in psf for $C_f = 2.6$		
Wind speed	Exp B K_z =0.7	Exp C K_z =0.85	Exp D K_z=1.03	Exp B K_z =0.7	Exp C K_z =0.85	Exp D K_z=1.03
100	9.5	11.5	14.0	19.0	23.1	28.0
110	11.5	14.0	16.9	23.0	27.9	33.8
120	13.7	16.6	20.1	27.4	33.2	40.2
130	16.1	19.5	23.6	32.1	39.0	47.2
140	18.6	22.6	27.4	37.2	45.2	54.8
150	21.4	25.9	31.4	42.7	51.9	62.9
160	24.3	29.5	35.8	48.6	59.0	71.6

For other values of C_f multiply wind load for $C_f = 1.3$ value by $C_f/1.3$

Where guard ends without a return the wind forces may be as much as 1.667 times C_f=2.6 value.

MINIMUM WIND LOAD TO BE USED IS 10 PSF.

GLASS STRENGTH

All glass is fully tempered laminated glass conforming to the specifications of ANSI Z97.1, ASTM C 1048-18 and CPSC 16 CFR 1201. For the two ply 9/16" glass the average Modulus of Rupture F_r is 24,000 psi.

Allowable glass bending stress for live loads: 24,000/4 = 6,000 psi. – Tension stress calculated.
For wind loads the allowable stress in ASTM E1300-16 may be used - Maximum edge stress of 10,600 psi; however, recommend limiting to 9,600 psi because of support conditions.
Determine effective thickness of the laminated glass for stresses and deflections based on ASTM E1300-16 appendix X9.
For PVB interlayer G = 140 psi
For SGP interlayer G = 15,600 psi (SentryGlas Plus product data published by Kuraray)
The values of G are selected as most appropriate for service conditions and load durations.
$h_1 = h_2 = 0.219"$
$h_v = 0.06"$
a = least width - typically total glass height including portion in base shoe: 41" for 42" overall height including base shoe.
$h_s = 0.5(h_1+h_2)+h_v = 0.5(0.219*2)+0.06 = 0.279"$
$h_{s;1} = h_{s;2} = (h_s h_1)/(h_1+h_2) = (0.279*0.219)/(2*0.219) = 0.1395"$
$I_s = h_1 h^2_{s;2} + h_2 h^2_{s;1} = 2*(0.219*0.1395"^2) = 0.00852$
$\Gamma = 1/[1+9.6(EI_s h_v)/(Gh^2_s a^2)]$
effective thickness for deflection:
$h_{ef;w} = (h_1^3 + h^3_2 + 12\Gamma I_s)^{1/3}$
effective thickness for glass stress:
$h_{1;ef;\sigma} = [h_{ef;w}^3/(h+2\Gamma h_s)]^{1/2}$
M_{aL} = 6,000psi*2* $h_{1;ef;\sigma}^2$ = 12,000 $h_{1;ef;\sigma}^2$ "#/ft = 1,000 $h_{1;ef;\sigma}^2$ '#/ft For Live Loads
M_{aW} = 9,600psi*2* $h_{1;ef;\sigma}^2$ For Wind Loads

Exterior installations assumed.
For heat and size PVB interlayer shear modulus. G = 70 psi (T ≤ 122 F˚)

For SentryGlas interlayer use G = 1,640 psi (11.3 MPa)
(from Kuraray SentryGlas *Effective Laminate Thickness for the Design of Laminated Glass* based on 122˚F, (50˚C) and short term load duration)

For cantilevered elements basic beam theory for cantilevered beams is used.
$M_w = W*L^2/2$ for uniform load W and span L or
$M_p = P*L$ for concentrated load P and span L,
$\Delta = (1-0.22^2)*w/12*h^4/(10{,}400{,}000* h_{ef;w}^3)$ for wind load
$\Delta = (1-0.22^2)*50*h^3/(3*10{,}400{,}000* h_{ef;w}^3)$ for 50 plf live load load

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Table 2	h_1, h_2	h_v		$h_{s;1}$ $h_{s;2}$		I_s	h_s	
6mm	0.219	0.06		0.1395		0.0085	0.279	
6mm	0.219	0.06		0.1395		0.0085	0.279	
Shortest Dimension	Γ PVB	Γ SGP	$h_{ef;w}$ PVB	$h_{ef;w}$ SGP	$h_{1;ef;\sigma}$ PVB	$h_{1;ef;\sigma}$ SGP	All. wind mom. lb-in/ft PVB	All. wind mom. lb-in/ft SGP
12	0.0236	0.2646	0.2861	0.3636	0.3222	0.4052	2201	3480
24	0.0881	0.5900	0.3108	0.4333	0.3510	0.4605	2613	4496
36	0.1785	0.7640	0.3399	0.4628	0.3822	0.4790	3097	4864
41	0.2199	0.8077	0.3517	0.4697	0.3939	0.4829	3289	4944
48	0.2787	0.8520	0.3672	0.4764	0.4085	0.4866	3537	5020
60	0.3764	0.8999	0.3904	0.4835	0.4286	0.4904	3894	5099
72	0.4651	0.9283	0.4093	0.4876	0.4434	0.4925	4169	5143

Minimum glass thickness from ASTM C1036. If thicker glass is used in fabricating the laminated glass greater effective thicknesses may be calculated based on actual glass thickness.

GLASS PANELS LOADS:

From 2021 IBC 1607.9

At top – 200lb concentrated or 50 plf Any direction

Or On panel – 50 lbs on one square foot

Or Wind load on entire area; 10 psf minimum

DETERMINE MAXIMUM PANEL HEIGHT:

For 50 plf distributed load:

$h = (M_{aL}/u) = M_{aL}/50plf$

For 200# load, not top rail:

$h = M_{aL}*S/200\#$ where S = light length in feet when installed with cap rail

For installation without a cap rail and load at corner of glass:

$h = M_{aL}*(2/3*S)/200\#$ where $S \leq h$

For wind load

$h = (M_{aw}/(0.55W))^{1/2}$

maximum wind load for given light height:

$W = M_{aw}/(0.55h^2)$

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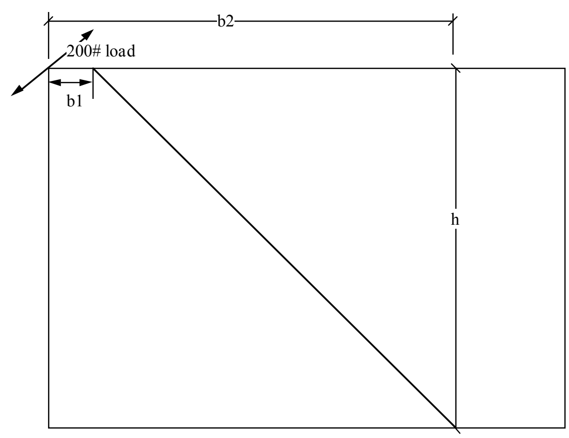
Determine height at which wind load will control over 50 plf top load:
M_{aL} = 50plf*h = (W*0.55h^2)/1.6
Solve for h:
h = 145.5/W
or solve for W:
W = 145.45/h
or
W*h = 145.45
Relationship of wind to height where wind load controls over 50 plf top load (See graph)
Below line 50 plf top load will control design.

Glass thickness and light width must be adequate to support the imposed load.

For 200 lb concentrated load
Worst case is load at end of light top corner with no top rail:



The load will be initially resisted by a strip = 8t
For 9/16” glass = 4.48”
The shear will transfer along the glass at a 45˚ angle to spread across the panel. - Deflection continuity of the glass requires that load be transferred across the full width with decreasing load as it gets farther from the corner.
$b_2 = b_1+h$

M_{ave} = 200*h/(b_2) average moment.
Peak moment at free edge will be greater based on triangular loading along strip considered and glass beyond assumed width carries no loading.
$M_{min} = (1/2)M_{max}$
$M_{ave} = (M_{max} + M_{min})/2 = (M_{max} + (1/2)M_{max})/2 = (3/2)M_{max}/2= (3/4)M_{max}$
$M_{max} = 4/3M_{ave}$ = 1.3333*200*h/(b_2) $\leq 1000t^2$ (live load allowable stress)
Rearranging and simplifying:
$h \leq 3.75*b_2t^2$

LOAD TESTS

CR Laurence performed in-house tests to verify the glass strength. Tests were performed on 5 glass lights 48” long x 41” tall set into the L56S base shoe with 6 sets of the LTL96X Taper-Loc® ‘X’ Tapers.

The laminated glass fabricated with 0.06” Sentry Glas+

Glass test loads: - 38” effective glass cantilever height.
Effective thickness for deflection calculated from maximum deflection measured:
$t = [(P*38^3)/(\Delta*3*4*10.4x10^6)]^{1/3}$
P = load at deflection, Δ
TABLE 3

Test	Max Load	Defl in	Moment/ft	Defl at 800# load	Eff. thickness Defl - Inches	Glass stress at failure	Comment
1	851	4.5	8403.625	4.250	0.4358	22125	at failure
2	928	4.38	9164	3.750	0.4544	22195	at failure
3	886	4.5	8749.25	4.125	0.4401	22581	No failure
4	898	4.625	8867.75	4.375	0.4316	23802	at failure
5	886	4.875	8749.25	4.125	0.4401	22581	No failure
Ave	889.8	4.576	8786.775	4.125	0.4404	22657	

The tests confirm that the glass will meet the safety factor of 4 for live loads based on the 200 lb concentrated load and 50 plf uniform load (equivalent loads for the 4’ long lights tested.)

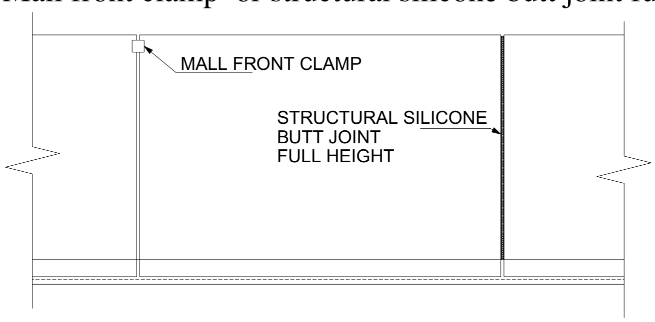
Note on strength - The average modulus of rupture of the lights that failed (3) is 22,707 psi.
The other two lights didn’t fail so modulus of rupture can’t be determined but would exceed this.
Average modulus of rupture versus 24,000 psi based on direct testing for tempered soda glass:
%MR = 22,707/24,000 = 0.946: 5.4% under. This is within the expected range of ≥ 20,000 psi.

FOR INSTALLATION WITHOUT A TOP RAIL

Maximum glass cantilever height based on light width for 200lb live load and no top rail:
Also verify for 50 plf live load- $h \leq 3000*2*t^2/50 = 120t^2$ (allowable stress reduced for residual condition)

Table 4 Light width inches	Effective thickness PVB	Maximum height inches 200# PVB	50 PLF Max height inches PVB	Effective thickness SGP	Maximum height inches 200# load SGP	50 PLF Max height inches SGP
12	0.318	N/A	N/A	0.405	7.4	19.7
24	0.338	N/A	N/A	0.461	19.1	25.4
36	0.364	N/A	N/A	0.479	31.0	27.5
41	0.374	N/A	N/A	0.483	35.9	28.0
45	0.382	N/A	N/A	0.485	39.7	28.25
66	0.382	N/A	N/A	0.485	39.7	28.25
73	0.382	N/A	N/A	0.485	39.7	28.25

Limit effective thickness to value for 45" width.
For 42" guard height - required glass cantilever height:
For height inclusive of base shoe h_g = 38.5"
For height above base shoe h_g = 42.5" (42" clear glass height above top of base shoe).
PVB interlayer should not be used without a top rail.
For installations without a top rail the differential deflection of glass lights must be checked based on 200 lb concentrated load on one light. Where deflection exceeds 11/16" the lights must be connected together at the joints to limit differential deflection. Recommend using mall front clamps, H clip or similar within 12 inches of the top of the glass.
Mall front clamp or structural silicone butt joint full height.



POOL FENCE

When installed as a pool fence the live loads are assumed as acting at 42" above finish floor.

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FOR INSTALLATIONS WITH A TOP RAIL:

Top rail is assumed to have adequate stiffness to distribute load across length of light

Determine Minimum light length: S (ft) for height h (ft) :

$M_{aL} = S_{yt}$*6,000psi = B*2t^2*6,000psi ≥ 200h

B_{min} = 200h/(12,000*t^2) = h/(60t^2)

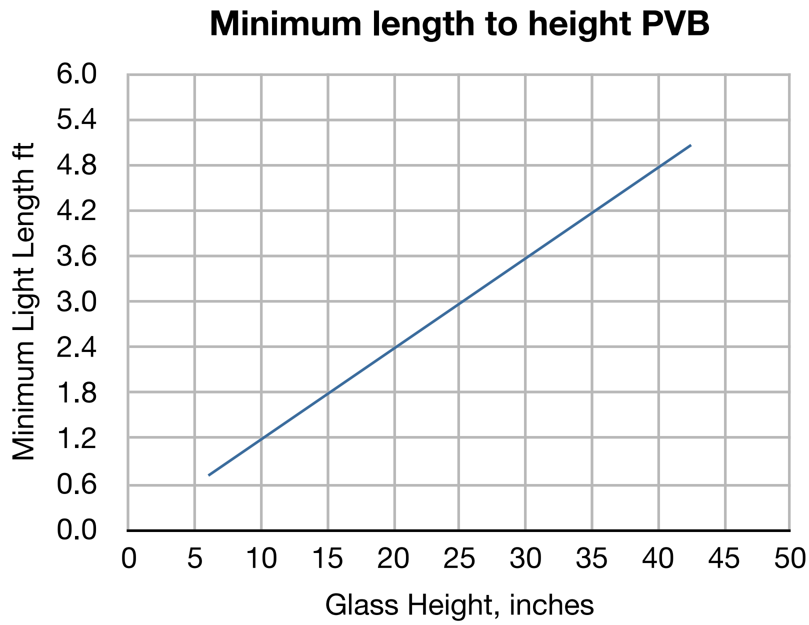
B_{min} is minimum length in feet

h is cantilever height in inches

For PVB interlayer

B_{min} = h/(60*0.374^2) = h/8.393

For lights smaller than the minimum required top rail must be continuous to additional supports such as wall, post or larger glass lights on each side.



For SGP Interlayer

Maximum allowable ht for SGP interlayer

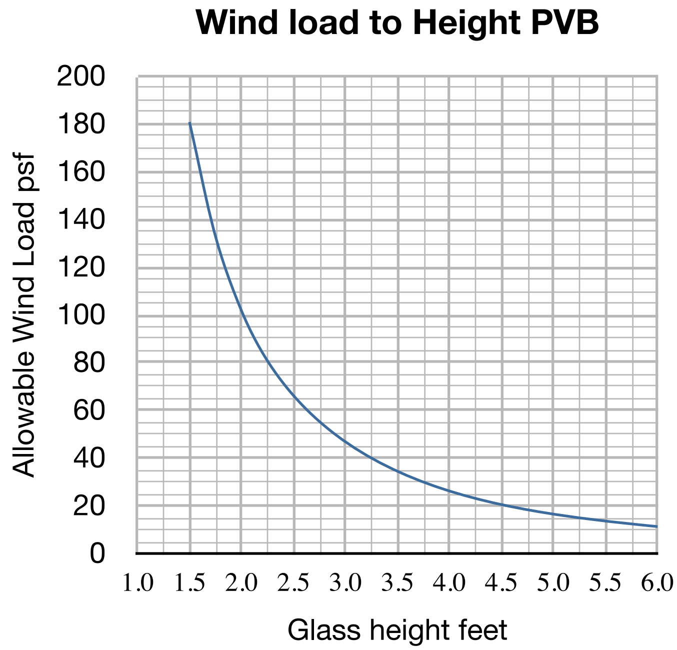
h≤ 2,952”#/f/50plf = 59” (glass cantilever height in inches)

Minimum light length:

For SGP interlayer

B_{min} = h/(60*0.483^2) = h/14.0

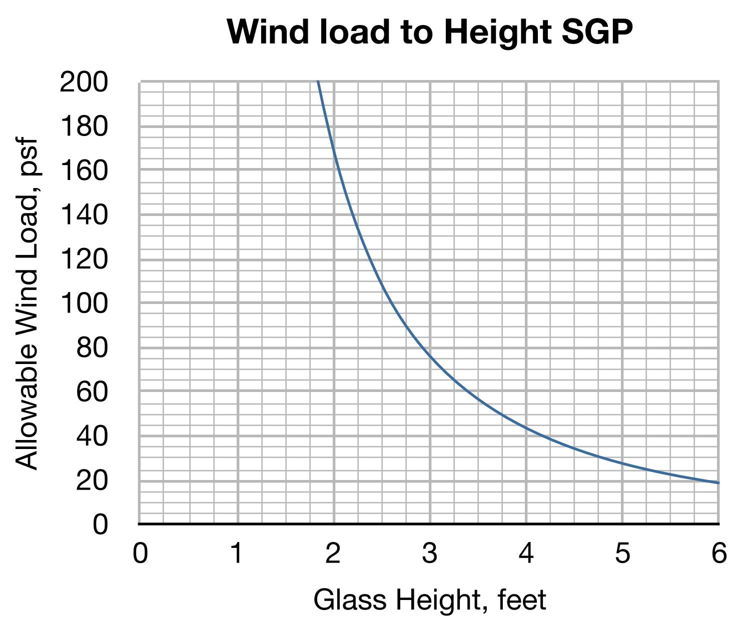
FOR 9/16” LAM. GLASS:
Determine relationship between allowable wind load ASD and wind screen height:



For PVB interlayer
$h_{ef;\sigma}$ = 0.374” typical
M_{wa} = 2*0.374^2*9,600 = 2,686”# = 223.8’#
h = (223.8’#/ft/(0.55*W))$^{1/2}$
W = 406.9/H^2
H = glass height in feet

NOTES:
Base Shoe anchorage may limit wind loads to less than that allowed by the glass strength.
Specifier shall be responsible to determine applicable load cases and wind load.

For SGP interlayer
$h_{ef;\sigma}$ = 0.483” typical
M_{wa} = 2*0.483^2*9,600 = 4,479”# = 373.26’#
h = (373.26’#/ft/(0.55*W))$^{1/2}$
W = 678.66/H^2
H = glass height in feet



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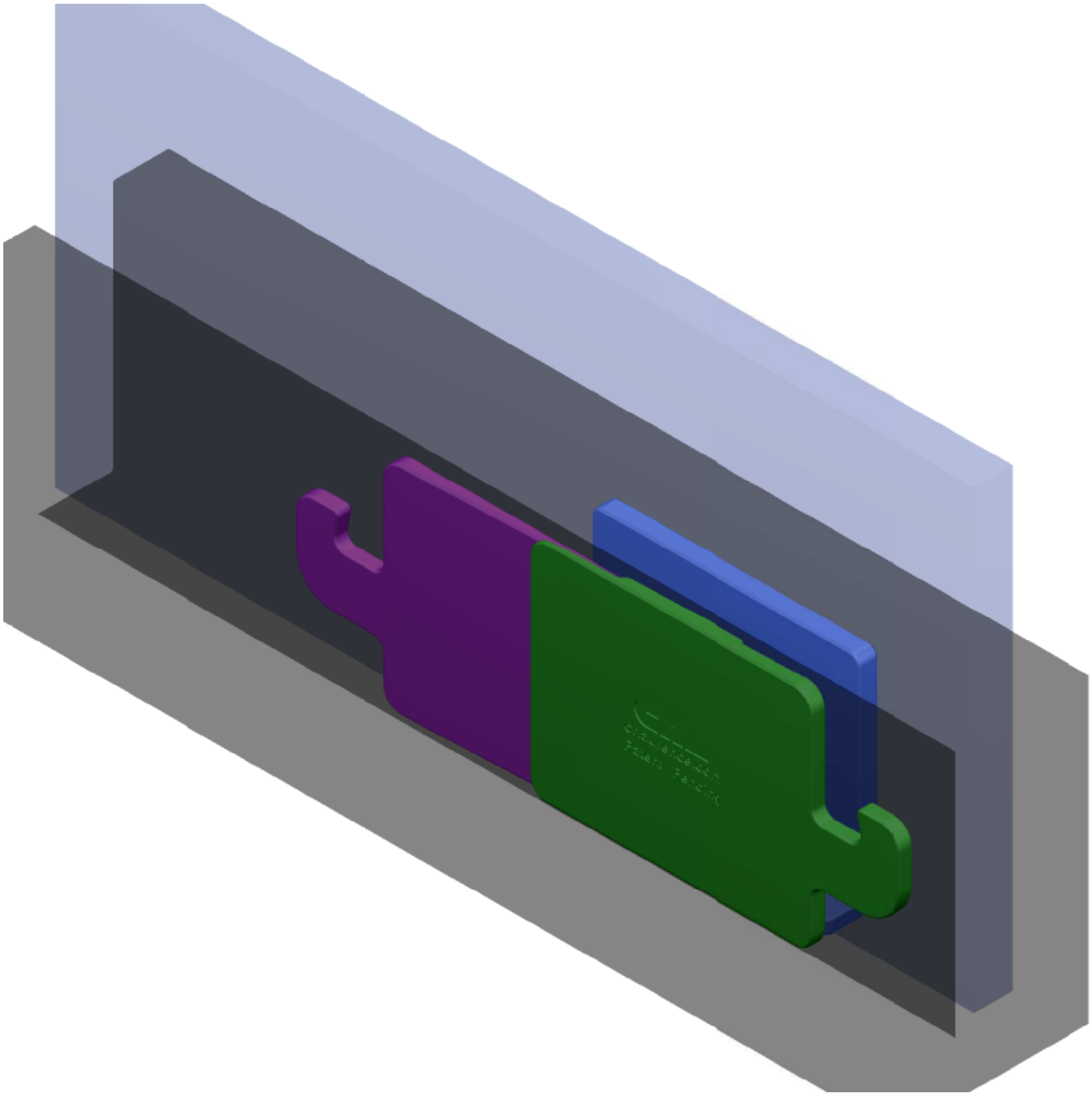
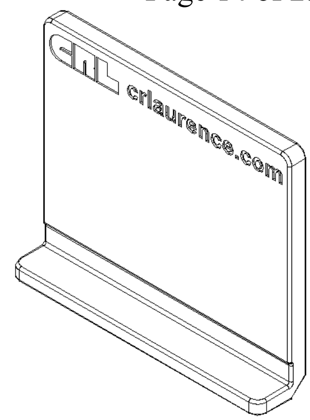
DRY-GLAZE TAPER-LOC SYSTEM



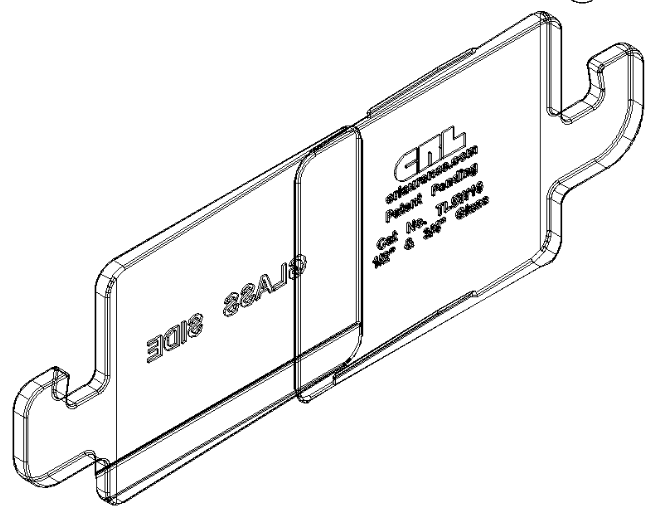
Glass is clamped inside the aluminum base shoe by the Taper-Loc Shoe Setting Plate (L shaped piece on the back side) and two Taper-Loc Shim Plates (front side). The glass is locked in place by the compressive forces created by the Taper-Loc shim plates being compressed together by the installation tool. Use of the calibrated installation tool assures that the proper compressive forces are developed. Until the shim plates are fully installed the glass may be moved within the base shoe for adjustment.

Glass may be extracted by reversing the installation tool to extract tapers.

The Taper-Loc setting plate is bonded to the glass by adhesive tape to hold it in place during installation and to improve glass retention in the base shoe.



Surface area of the setting plate adhered to the glass:
$A = 2\text{”}*2.5\text{”} = 5\ in^2$
adhesive shear strength ≥ 80 psi
3M™ VHB Tape
$Z = (2/3)*5\ in^2*80 = 267\#$ minimum
setting plate locks into place in the base shoe by friction created by the compression generated when the shim plates
are locked into place.



Installation force:
T_{des} = 250#” design installation torque
T_{max} = 300#” maximum installation torque
Compressive force generated by the installation torque:
C = (0.2*250#”/1.0”)/ sin(1.76˚)
C = 1,628#

Frictional force of shims and setting plate against aluminum base shoe:
coefficient of friction, μ= 0.65
f = 2*(1,628#0.65) = 2,117#

Frictional force of shims against glass:
μ = 0.20
f = 1,628*0.20 = 326#

Resistance to glass pull out:
U = 267#+326# = 593#

Safety factor for 200# pullout resistance = 2*593/200 = 5.93
Based on two taper sets
Minimum recommended installation torque:
4/5.93*250 = 169#”

Extraction force required to remove tapers after installation at design torque:
T = 250*(0.7/0.2) = 875#”

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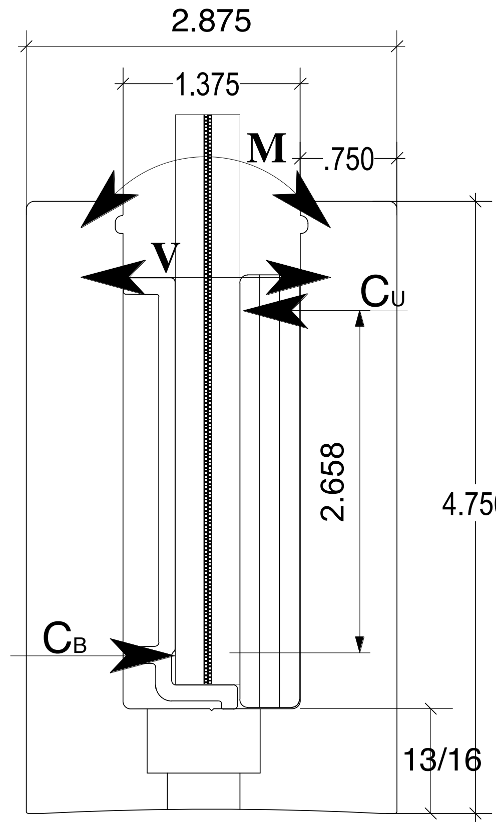
Glass anchorage against overturning:
Determine reactions of Taper-Loc plates on the glass:
Assuming elastic bearing on the wedges the reactions will have centroids at approximately 1/6*3.188" from the upper and lower edges of the bearing surfaces:



R_{CU} @ 1/6*3.188 = 0.53"
e = 3.188-0.53 = 2.658"
From ∑M about R_{CU} = 0
0 = M+V*(0.53"/2) - R_{CB} *(2.658-0.53/2)
Let M = V*42.5" (42" exposed glass height)
M_a = 233.3#' for 9/16" SGP laminated glass
V = 233.3/3.33' = 65.9#
substitute and simplify:
0 = V*(42.5"+0.265") - R_{CB}*2.393"
Solving for - R_{CB}
R_{CB} = 65.9*42.765/2.393 = 1,178#
For C_B = 3,000 psi:
R_{CB} = 3.5"*(3.188"/2)*3,000psi/2 = 8,369# > 1,178#

Bearing strength is okay
M_a = 8,369*(1/2*3.188") = 13,340#"

At maximum allowable moment determine bending in base shoe legs:
Bending at bottom of base shoe leg based on maximum allowable Taper-Loc reaction
M_i = R_C*[0.188+(3.188*2/3]
M_i = 8,369*(2.313) = 19,360#"

Strength of leg 12" length = 18,668#" See base shoe calculations later in this report.

Allowable load for Taper-Locs exceeds base shoe strength which exceeds glass strength.

Allowable moment on system is limited to allowable glass moment for 9/16" laminated glass based on minimum glass dimension and interlayer.

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GLASS STRESS ADJUSTMENTS FOR THE TAPER-LOC SYSTEM

The Taper-Loc System provides is a concentrated support:
Stress concentration factor on glass based on maximum 8" glass width to each Taper-Loc set.

Moment concentration factor
Full scale tests and numerous FEA models indicate that there is no appreciable bending stress concentration associated with the concentrated point supports that the Taper-loc system employs. This is because of the purely elastic behavior of the glass for short duration loads up to failure combined with the ratio of the glass height to clear spacing between supports being greater than 2. The glass curvature must be nearly constant across the width of the glass so bending stress must be nearly constant. Thus bending stress will be accurately modeled as constant across the glass width.
F_b = 6,000 psi Allowable bending stress based on an SF = 4.0

Shear concentration factor:
Accounts for effect of point support
C_V = 8"/3.5"*(2-3.5/8) = 3.57
F_{Va} = 3,000 psi maximum allowable shear stress

Allowable Glass Loads:
M_a = S*6,000 psi
V_a = t*b/3.57

For 9/16" laminated glass, 12" width:
$M_a = 2*h_{ef;\sigma}^2*6{,}000$ for live load
V_a = 0.438*12*3,000/3.57 = 4,415# for live load

Since shear load in all scenarios is under 10% of allowable it can be ignored in determining allowable bending since it has less than 1% impact on allowable bending loads or rail heights.

Maximum edge distance for edge of glass to centerline of Taper-Loc plates:
e_{des} = 8/2 = 4" for design conditions (no reduction in allowable loads)

For single < 10" wide light can increase e to 5".

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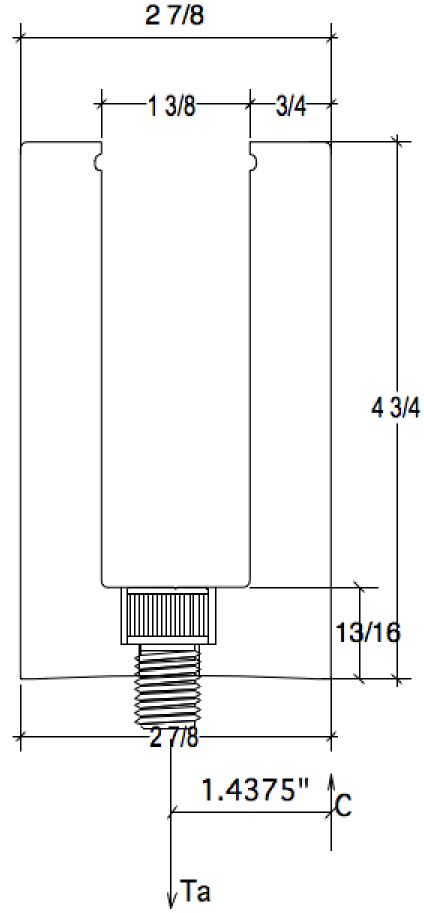
9/16" LAMINATED GLASS BASE SHOE
L56S BASE SHOE
6063-T52 Aluminum extrusion
Fully tempered glass glazed in place, using the Taper-Loc dry-glazing system.



Shoe strength – Vertical legs:
Glass reaction by bearing on legs to form couple. Allowable moment on legs per 2020 ADM Chapter F.
$M_a = 1.5SF_y/\Omega_y$ or $\leq ZF_u/\Omega_r$
S_y = 12"*0.75"^{2}*/6 = 1.125 in^3/ft
Z_y = 12"*0.75"^{2}*/4 = 1.6875 in^3/ft
M_{ay} = 16ksi*1.5*1.125 in^3/ft/1.65 = 16,364#"/ft or (controls)
M_{ar} = 22ksi*1.6875 in^3/ft/1.95 = 19,038#"/ft

Leg shear strength @ bottom 2020 ADM G.1
t_{min} = 0.75"
F_{so}= 0.6*F_{ty} = 0.6*16 ksi = 9.6 ksi
V_{all} = 0.75"*12"/ft*9.6 ksi/1.65 = 52.36 k/ft

Base shoe anchorage:
Typical Guard design moment = 175#' = 2,100#" or (maximum allowable moment) = 211.6'# = 2,539"# Based on glass strength

Typical Anchor load – 12" o.c. – T_a = 2,539"#/(1.4375") = 1,766#

For 1/2" cap screw to tapped steel, CRL Screw part SHCS12x34 or SHCS12x1
$T_n = A_{sn}*t_c*0.6*F_{tu}$
where t_c = 0.25"; A_{sn} = 1.107" and F_{tu} = 58 ksi (A36 steel plate)
T_n = 1.107"*0.25*0.6*58 ksi = 9.63 k
Bolt tension strength = 0.75*67.5 ksi*0.1419 in^2 = 7.18 k
Use 5/16" minimum for maximum load:
Maximum service load: 7.18k/2 = 3,592#
Maximum allowable moment for 12" on center spacing and direct bearing of base shoe on steel:

M = 3,592#*[1.4375"-0.5*3,592/(30ksi*12)] = 5,146"# per anchor

for 6" o.c.

M = 2*3,592#*[1.4375"-0.5*3,592/(30ksi*6)] = 10,255"# per foot

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ANCHORAGE TO CONCRETE

Anchorage designed for concrete with strength $f'_c \geq 4{,}000$ psi for cracked condition or $f'_c \geq 2{,}500$ psi for uncracked condition. The post-installed concrete anchor strength was determined according to ACI 318-19 Chapter 17. Hilti Profis software was used to do the calculations. Tension and shear condition B assumed - no supplemental concrete reinforcement assumed. The anchorage was evaluated based on a 11 13/16” segment of base shoe and supporting concrete.

Unit loads used in the reports:
V_u = 80 lbs (50 plf live load x 1.6 load factor)
M_u = 80lbs*42” = 3,360”#

Hilti HUS-EZ 3/8” x 4” screw in anchor into 4” deep holes. Installation per ESR-3027.
Nominal embed depth = 3.25”; Effective embed depth = 2.5”:
For anchors at 12” on center:
For 4,000 psi cracked concrete:

3 Tension load

	Load N_{ua} [lb]	Capacity ϕN_n [lb]
Steel Strength*	2528	6718
Pullout Strength*	N/A	N/A
Concrete Breakout Strength**	2528	2546

* anchor having the highest loading **anchor group (anchors in tension)

4 Shear load

	Load V_{ua} [lb]	Capacity ϕV_n [lb]
Steel Strength*	80	3111
Steel failure (with lever arm)*	N/A	N/A
Pryout Strength**	80	5483
Concrete edge failure in direction y+**	80	4943

For shear loads less than 20% of strength there is no reduction in the tension load strength:
$V \leq 0.2*3111 = 622\#$ - As this greatly exceeds wind loads can check capacity based only on

For 2,500 psi uncracked concrete

Moment resistance of each anchor:
$øM_n$ = 2,546#*[1.4375-0.5*2,546/(2*0.85*2.5ksi*12)] = 3,607#” = 300.58#’ per anchor
$M_a = øM_n/\lambda$ = 300.58’#/1.6 = 187.86#’

For 6” spacing:
$øM_n$ = 2*2,546#*[1.4375-0.5*2,546/(2*0.85*2.5ksi*6)] = 7,108#” = 592.3#’ per anchor
$M_a = øM_n/\lambda$ = 7,108”#/1.6 = 4,442#’

Installation to wood:

1/2” x 6” socket head lag screws into solid wood, Douglas Fir or Southern Pine or equivalent density wood.

Typical anchor to wood: 1/2” socket head lag screw. Withdrawal strength of the lags from *National Design Specification For Wood Construction* (NDS) Table 12.2A.

For Doug-Fir Larch or denser, G = 0.50

W = 378#/in of thread penetration.

C_D = 1.6 for guardrail live loads (impact loads) and 1.6 for wind loads.

C_m = 1.0 for weather protected supports (lags into wood not subjected to wetting).

$T_b = WC_DC_ml_m$ = total withdrawal load in lbs per lag

$W' = WC_DC_m$ =378#/”*1.6*1.0 = 605#/in

Determine lag screw thread embedment - assume 1-1/2” thick decking over structural beam/block

Lag screw design strength – l_m = 6”-13/16”-5/16”-1.5”-1/16 = 3.31”

T_b = 605*3.31” = 2,005#

Steel strength = 60ksi*A_t/1.67 = 35.93ksi*0.110in^2 = 3,952# > 2,005#

$Z'_{ll} = C_D$*Z_{ll}= 520#*1.6 = 832# per lag, (horizontal load) NDS Table 12K

$Z'_{\perp} = C_D$*$Z_{\perp}$= 1.6*320# = 512# per lag, (horizontal load)

Determine moment strength of anchorage:

For pivoting about edge of base shoe:

Required compression area based on wood strength:

F_{cT} = 560psi; F'_{cT}*C_d*C_b = 560psi*1.33 = 745psi

For C = T =2,000#

A = 2,000#/745psi = 2.685in^2

b = A/(12”) = 2.685/(12) = 0.224”

M_a = 2,000#*(1.4375-0.224/2) = 2,651#” = 220.9#’ For 12” o.c. spacing

M_a = 2*2,000#*(1.4375-2*0.224/2) = 4,854#” = 220.9#’

NOTE: DO NOT DIRECTLY LAG BASE SHOE TO WOOD WHERE EXPOSED TO WEATHER OR DIRECT SUNLIGHT BECAUSE BASE SHOE WILL LOOSEN WITH TIME AND WILL NOT BE ADEQUATELY ANCHORED.

Summary of surface mounted base shoe strength - Must verify glass strength too.

Table 5		**Allowable wind load in psf**						
Surface Mounted	Allowable. Moment in-lbs/ft	Overall Guard height from bottom of base shoe top of top rail, ft.						
Mounting Substrate		3.00	3.25	3.5	3.75	4.0	4.5	5.0
Steel 12” o.c	5146.0	86.6	73.8	63.6	55.4	48.7	38.5	31.2
Steel 6” o.c	10255.0	172.6	147.1	126.8	110.5	97.1	76.7	62.2
Concrete 12” o.c.	2254.0	37.9	32.3	27.9	24.3	21.3	16.9	13.7
Concrete 6” o.c.	4442.0	74.8	63.7	54.9	47.9	42.1	33.2	26.9
Wood 12” o.c.	2651.0	44.6	38.0	32.8	28.6	25.1	19.8	16.1
Wood 6” o.c.	4854.0	81.7	69.6	60.0	52.3	46.0	36.3	29.4

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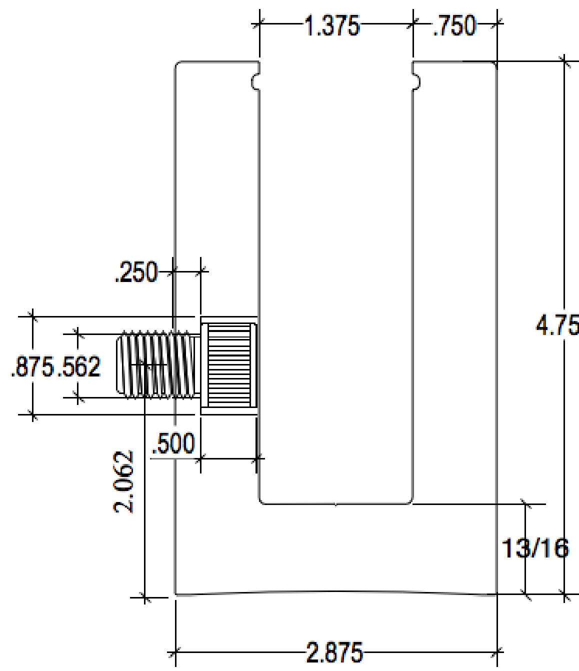


Fascia Mounted Base Shoe:
Verify Anchor Pull through on base shoe:
For counter sunk screw
$P_{nov} = (0.27+1.45t/D)DtF_{ty}$
$=(0.27+1.45*.5*/.5).5*.5*16$ ksi = 6,880#

For inset bolt
$t_{min} = 0.25$”
$P_{nov} = 0.6*F_{tu}*(A_v)$
$A_v = 0.25$”$*\pi*.75$” = 0.589 in^2
$P_{nov} = 0.6*22$ksi$*(0.589$ in$^2) = 7.775$k
$P_a = 7.775$k$/1.95 = 3{,}987$#

For standard installation, 42” guard height and 25 psf max uniform load

Anchor Load T_a
$T_a = M_a/2$”
T_a= 2,100”#/2.125”= 988.2#

For anchors into steel support:
M = 3,592#*[2.25”-0.5*3,592/(30ksi*12)] = 8,064”# = 672.00 per anchor
M = 2*3,592#*[2.25”-0.5*3,592/(30ksi*6)] = 16,092”#/ft anchors 6” o.c.
For anchor into concrete:

3/8” diameter x 4” Screw-in anchor Powers Wedge-Bolt® (CRL #WBA38X4)

Strength same as previously calculated,
M_a=øM_n/1.6= 2,546#*[2.25-0.5*2,546/(2*0.85*2.5ksi*12)]/1.6 = 3,547#” = 295.6#’ per anchor
M_a=øM_n/1.6= 2*2,546#*[2.25-0.5*2,546/(2*0.85*2.5ksi*6)]/1.6 = 7,002#”/ft anchors 6” o.c
Lag screw strength same as previously calculated.
T_a = 2,005#
Note: Fascia mounted base shoe may be directly lagged to wood beam where weather exposed because of reduced wood stresses.

Allowable wind load on balustrade must be reduced for the dead load moment effect
$V_d = h_g*6.8$psf + 15psf
$M_d = [h_g*6.8$psf + 15psf]*1.52” 10.5 plf for base shoe and glazing + 4 plf for cap rail
h_g = actual height of glass (Typical approx 3.833’ for 42” guard height above finish floor)
Assume h_g = guard height in feet + 0.333’
$M_d = h_g*10.3$”#/ft + 22.8”#/ft = 10.3h + 26.2”#
V_d = (h+0.333)*6.8psf + 15psf = (6.8h + 17.3)plf

Since the total shear load will typically by less than 20% of the shear strength for steel and concrete installations there is nor reduction required for combined shear and tension load on anchors.

For wood the allowable tension load must be adjusted for the shear loading effects:

$Z'_a = [(W'p)Z']/[(W'p)\cos^2 \alpha + Z'\sin^2 \alpha]$ (NDS 12.4.1)

$\alpha = \tan^{-1}V/T$

W’p = 2,005# from previous calculations

$Z'_\perp = Z_\perp * C_D = 320\# * 1.6 = 512$ $Z_\perp$ from NDS Table 12K for 1/2” lag and ≥ 1/4” side plate.

For typical installation with 42” height AFF:

$V_d = (6.8*3.5 + 17.3)plf = 41\#$

Assume T = 2000#

$\alpha = \tan^{-1}2000/41 = 88.83°$

$Z'_a = [(2005)512]/[(2005)\cos^2 88.83 + 512\sin^2 88.83] = 2002\#$

Allowable tension component for 47# shear:

$T = \sqrt{(2002^2 - 41^2)} = 2002 \geq 2000\#$ assumed

Since it would require significant increase in guard height for shear load to be large enough to reduce allowable tension load under 2,000# can assume 2,000# tension load on anchor for determining allowable wind loads:

M_a = 2,000#*(2.25”-0.224/2) - 10.3h - 26.2”# = 4,250”# - 10.3h

M_a = 2*2,000#*(2.25”-2*0.224/2) - 12.6h - 27”# = 8,104”# - 12.6h 6” o.c.

Allowable wind load for fascia mounted base shoes: Assumes top of base shoe is flush with finish floor:

Summary of fascia mounted base shoe strength - Must verify glass strength too.

Table 6		Allowable wind load in psf						
Fascia Mounted	Allowable. Moment in-lbs/ft	Overall Guard height from bottom of base shoe top of top rail, ft.						
Mounting Substrate		3.00	3.25	3.5	3.75	4.0	4.5	5.0
Steel 12” o.c	8064.0	134.8	114.8	99.0	86.2	75.7	59.8	48.4
Steel 6” o.c	16092.0	269.9	230.0	198.3	172.7	151.7	119.9	97.1
Concrete 12” o.c.	3547.0	58.8	50.0	43.1	37.5	33.0	26.0	21.0
Concrete 6” o.c.	7002.0	116.9	99.6	85.8	74.7	65.7	51.8	42.0
Wood 12” o.c.	4250.0	70.6	60.1	51.8	45.1	39.6	31.3	25.3
Wood 6” o.c.	8104.0	135.5	115.4	99.5	86.6	76.1	60.1	48.6

NOTE: The wind load must be checked for the glass based on the specific light size and interlayer. The allowable wind load is the lesser of the anchorage strength or glass strength.

Tables 7 and 8 are applicable where glass balustrades is used as a wind screen only - no fall protection required.

TABLE 7

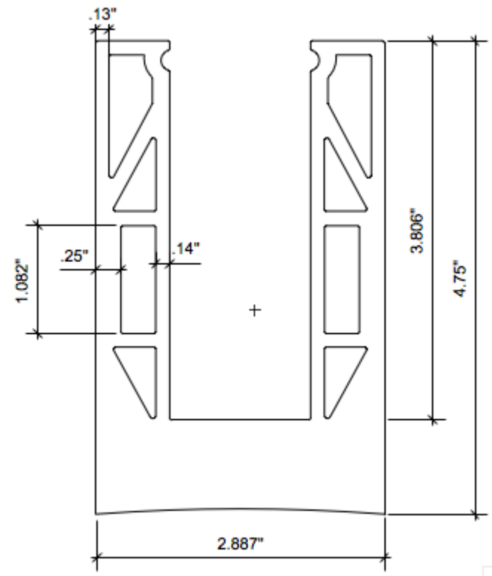
9/16”	EFFECTIVE THICKNESS		PVB Interlayer	Allowable wind Pressure, psf for glass height in inches				
width inches	t_∂ for defl.	t_e for stress	All. Moment “#/ft	36	42	48	60	72
12	0.2825	0.3636	2538	42.7	31.4	24.0	15.4	10.7
24	0.2997	0.4333	3605	60.7	44.6	34.1	21.8	15.2
36	0.3222	0.4628	4112	69.2	50.9	38.9	24.9	17.3
41	0.3319	0.4697	4236	*	52.4	40.1	25.7	17.8
48	0.3454	0.4764	4358	*	*	41.3	26.4	18.3
60	0.3669	0.4835	4488	*	*	*	27.2	18.9
72	0.3858	0.4876	4565	*	*	*	*	19.2

TABLE 8

9/16”	EFFECTIVE THICKNESS		SentryGlas+ Interlayer	Allowable wind Pressure, psf for glass height in inches				
width inches	t_∂ for defl.	t_e for stress	All. Moment “#/ft	36	42	48	60	72
12	0.4578	0.5114	5021	84.5	62.1	47.6	30.4	21.1
24	0.5427	0.5850	6571	110.6	81.3	62.2	39.8	27.7
36	0.5883	0.6132	7219	121.5	89.3	68.4	43.8	30.4
41	0.5987	0.6194	7366	*	91.1	69.8	44.6	31.0
48	0.6092	0.6255	7512	*	*	71.1	45.5	31.6
60	0.6205	0.6317	7662	*	*	*	46.4	32.2
72	0.6271	0.6352	7747	*	*	*	*	32.6

* Allowable load is same as last value in column
Calculated from: $w_{all} = M_{all}*12/(0.55*h_g^2)$

9BL56 - Square, Cored Base Shoe



6063-T52 Aluminum extrusion
Shoe strength – Vertical legs:
Glass reaction by bearing on legs to form couple.
Allowable moment on legs: Same for all widths of 9B series base shoes.
Tension force on inside element will control moment strength of the base shoe legs- 2020 ADM Chapter D
At 3rd cell - Rectangular cell used for fascia mounted option. Based on yielding as rupture will result in higher allowable load.
Moment resistance across cell
$M_a = P_{nt}*e/\Omega = A_i*F_{ty}*c/1.65 =$
$0.14"*16ksi*(0.75-0.14)/1.65 = 828"\#/" = 9{,}937"\#/ft$
A_i = area of inside leg

Allowable shear across cell - based on shear bending across cell legs allowing rotation at top
$V_a = [1.5(S_i+S_o)*P_{nt}/b]/\Omega$
S_i, S_o = section modulus of inside or outside leg
b = height of cell = 1.082"
$V_a = [1.5(0.14^2/6+0.25^2/6)*16ksi/1.082"]/1.65 = 1{,}400$ pli Won't control
Strength at bottom cell
Vertical leg allowable tension load:
$M_a = P_{nt}*e/\Omega = A_v*F_{ty}*c/1.65 = 0.14"*16ksi*(0.75-0.14)/1.65 = 828"\#/" = 9{,}937"\#/ft$
A_v = area of vertical leg, A_d = Area of diagonal load
Allowable shear across cell:
$V_a = A_d*F_{ty}/\Omega$
$V_a = (0.14*16ksi)/1.65 = 1{,}358pli = 16{,}290$ plf (shear won't control)

Maximum allowable glass shear load reaction on top of base shoe, based on base shoe leg strength:
$V_a = M_a/B = 9{,}937"\#/ft/3.806" = 2{,}611$ plf

Check leg deflection for 3,000"#/ft moment on rail:
Strain in cell walls:
$\epsilon = (\sigma/E)*B = [(3{,}000/(0.14"*12"*0.61"))/10{,}100{,}000]*3.806" = 0.00107"$
$\Delta_\epsilon = (2*0.00107")/(0.75/2) = 0.0057"$
$\Delta_b = 3{,}000*3.806^2/(3*10{,}100{,}000*0.75^3) = 0.00339"$
$\Delta_T = \Delta_\epsilon + \Delta_b = 0.0057+0.00339 = 0.00909"$
Glass deflection at 42" above base shoe from base shoe leg deflection
$\Delta_g = 0.00909*(42/3.806) = 0.10"$ based on 3,000"# glass moment; 0.069" for typical 50 plf LL.
For mounting options, 9B series strength is same as for solid wall base shoes.

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Professional Certification. I hereby certify that these documents were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland,
License No. 52500, Expiration Date: 04/09/2022

COMMONWEALTH OF MASSACHUSETTS
EDWARD C. ROBISON
STRUCTURAL
No. 49757
REGISTERED
PROFESSIONAL ENGINEER
EXP 06/30/2022

EDWARD C. ROBISON
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STATE OF MISSISSIPPI

PROFESSIONAL ENGINEER-STATE OF NEVADA
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STATE OF MINNESOTA
I hereby certify that this plan, specification. or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.
Signature: Typed or printed name: Edward C. Robison
Date Lic. No. 58604

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