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24 March 2021

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SUBJ: CRL SRS STANDOFF RAILING SYSTEM
GLASS BALUSTRADE GUARDS

The SRS Standoff Railing System is a guardrail system that utilizes point supported glass balustrades. When constructed in accordance with the attached details and installation guidelines the guardrail can be designed to safely support the following loading conditions:

200 pound point load on top rail, vertical or horizontal or
50 plf load on top rail, vertical or horizontal or
25 psf uniform load on glass panel horizontal or
50 lb conc load on 1 sf or
Wind load - As listed with respect to glass size or determined by FEA modeling
Typical glass thickness: 3/4" monolithic or 13/16" laminated minimum thickness.

For exterior installations wind loads and glass stress must be calculated by a qualified licensed engineer.

For single family residential construction only the 200# concentrated top rail load, 50# concentrated load and wind load (exterior) are applicable (non-concurrent).

The SRS is to be used with tempered glass only, laminated or monolithic. Laminated glass must be made with Kuraray SentryGlas+ interlayer or an equivalent ionoplast interlayer.

Glass light stresses were evaluated using finite element analysis (FEA) with SCIA Engineer 18.1 in order to derive rules for designing a code compliant system. Only rectangular lights are considered in this report. Use of this report for other shapes such as a rhombus with angles other than 90 degrees such as often used along stairs is outside the scope of this report. Generally, a qualified licensed engineer must evaluate a specific installation for code compliance using a FEA model or other recognized method.

All results given in this paper are based on the assumption that the top rail has adequate strength and stiffness to cause significant load sharing between the glass lights except as specifically stated herein. Added support from stronger and stiffer top rails that anchor to posts or walls independent of the glass balustrade may significantly reduce the glass stresses and deflections. When designing a glass balustrade with the additional support a FEA model should be used which accounts for the proposed specific conditions.

The recommendations herein are intended to assist a qualified licensed engineer in developing a code compliant guard that meets the applicable requirements of the 2009, 2012, 2015 and 2018 International Building Code and state codes adopted from the IBC codes. This paper is not intended

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to demonstrate the code compliance of an installation but is to only be utilized by the qualified licensed engineer in charge of the glass balustrade guard in analyzing the glass stresses and anchorage.

This paper only evaluated 2 and 3 standoff pairs per light. Additional standoffs may be used and will decrease the glass stress. If additional standoffs are proposed a FEA model should be used to determine the glass stresses, deflections and standoff reactions.

Notes on developing an effective FEA model:
When developing a FEA model the glass stresses are very sensitive to small changes in the boundary conditions and how the supports are represented. It should be assumed that the clamping at the standoff fittings when using the fittings in this paper will provide reaction points at the horizontal centerline of the edges of the holes. No significant moment resistance will occur at the standoffs so that the reactions should be modeled as surface bearing only. Moment resistance is provided by the force couple developed between the two standoffs in a pair. These recommendations are based on creating a FEA model that is consistent with the results of physical testing by CRL

The standoffs must always be used in vertical pairs. Vertical loads should be assumed as acting on only a single standoff in each pair, and only on two standoffs when more than 2 pairs are used.

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GLASS BALUSTRADE GUARD RAIL
GLASS STRENGTH

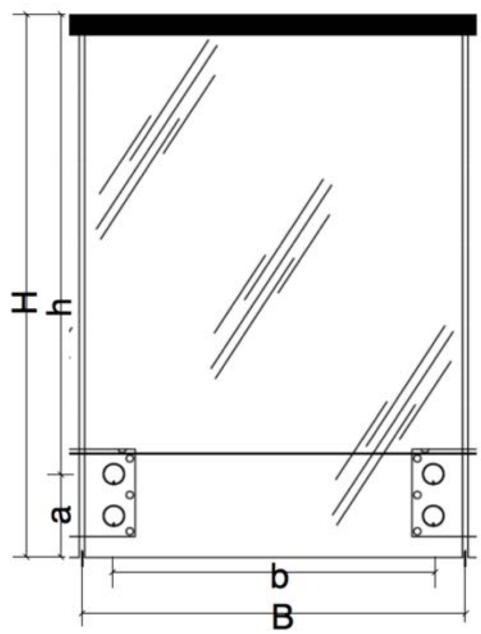
All glass is fully tempered glass conforming to the specifications of ANSI Z97.1, ASTM C 1048-97b and CPSC 16 CFR 1201. For the 1/2" glass the typical Modulus of Rupture, F_r is 24,000 psi. The applicable safety factor against glass rupture is 4.0 in accordance with IBC 2407.1.1 Allowable glass bending stress: 24,000/4 = 6,000 psi. – Tension stress calculated for live loads.

Bending strength of glass for the given thickness:

$$S = \frac{12\text{''} * (t)^2}{6} = 2 * (t)^2 \text{ in}^3/\text{ft}$$

Use the minimum glass thickness for stress calculations:

Figure 1



For 1/2" glass, t_{min} = 0.469" ; Weight = 6.5 psf
$S = 2*(0.469)^2 = 0.44$ in³/ft
M_{alive} = 6,000psi*0.44 in³/ft = 2,640"#/ft = 220'#

For 5/8" glass, t_{min} = 0.595" ; Weight = 8.1 psf
$S = 2*(0.595)^2 = 0.708$ in³/ft
M_{alive} = 6,000psi*0.708 in³/ft = 4,248"#/ft = 354'#

For 3/4" glass, t_{min} = 0.719" ; Weight = 9.8 psf
$S = 2*(0.719)^2 = 1.034$ in³/ft
M_{alive} = 6,000psi*1.034 in³/ft = 6,204"#/ft = 517'#

The allowable moments are based on the minimum glass thickness allowed for the nominal thickness. The section properties and allowable moments may be calculated based on the actual glass thickness supplied.

Laminated glass shall be evaluated based on the effective thickness determined in accordance with ASTM E1300-12a or the DuPont online laminated glass calculator.

For wind loading, allowable glass stress is 10,600psi.

Allowable wind load pressures vary depending on glass thickness, width, height and standoff spacing. Allowable wind loads are according to the tables on the following pages.

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Laminated Glass Sizes

Effective glass thickness is determined according to ASTM E1300. The assumed glass interlayer is SGP at high temperatures (130˚ F) based on exterior application.

9/16" Glass:

Laminated Glass Effective Thickness				
h1	h2	hv	E	g
0.219	0.219	0.06	10400000	1640
hs	hs;1	hs;2	Is	
0.279	0.1395	0.1395	0.00852359	
a	Γ	hef;w	h1;ef;σ	h2;ef;σ
36	0.76416501	0.462868129	0.47900772	0.47900772

Variable	Description
H1 & H2	Glass pane thicknesses
Hv	Interlayer thickness
E	Young's Modulus
g	Shear Modulus
Hs	.5(h1+h2)+hv
Hs;1	hsh1/(h1+h2)
Hs;1	hsh2/(h1+h2)
Is	$h1(hs;2)^2+h2(hs;1)^2$
a	Minimum Pane Width
Γ	$1/(1+9.6(Eishv/(G(ahs)^2))$
hef;w	$\sqrt[3]{((h1)^3+(h2)^3+12\Gamma Is)}$
h1;ef;σ	$\sqrt{((hef;w)^3/(h1+2\Gamma hs;2))}$
h2;ef;σ	$\sqrt{((hef;w)^3/(h2+2\Gamma hs;1))}$

13/16" Glass:

Laminated Glass Effective Thickness				
h1	h2	hv	E	g
0.355	0.355	0.06	10400000	1640
hs	hs;1	hs;2	Is	
0.415	0.2075	0.2075	0.030569938	
a	Γ	hef;w	h1;ef;σ	h2;ef;σ
36	0.666546243	0.693818411	0.727180009	0.727180009

The effective thickness of other laminated glass configurations may be evaluated using this procedure.

The standoffs may be used with thicker glass than considered in this report to provide greater load resistance.

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WIND LOADING ON GLASS

Allowable wind loads are based on the wind load that causes the maximum allowable stress in the glass. Allowable wind load tables do not account for standoff anchorage strength which must be considered separately. These tables are for wind load only and the configuration might not comply for a guard application.

Allowable Wind Load (psf), Two Standoff Pairs At 4” Spacing, 1/2” Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	38.5	30.4	24.9	21.0
42	27.3	21.7	17.8	15.0
50	18.6	14.0	12.3	10.4
60	12.5	10.0	8.3	7.1

Allowable Wind Load (psf), Two Standoff Pairs At 4” Spacing, 5/8” Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	62.0	49.0	40.1	33.7
42	43.9	34.9	28.7	24.2
50	30.0	22.5	19.7	16.7
60	20.2	16.2	13.4	11.4

Allowable Wind Load (psf), Two Standoff Pairs At 4” Spacing, 3/4” Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	90.6	71.5	58.6	49.3
42	64.2	51.0	41.9	35.4
50	43.8	32.9	28.8	24.4
60	29.5	23.6	19.5	16.6

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Laminated glass should only be made with the SentryGlas+ or equivalent ionoplast interlayer.

Allowable Wind Load (psf), Two Standoff Pairs At 4" Spacing, 9/16" Laminated Glass

Glass Height (in)	**Glass Width (in)**			
	36	48	60	72
36	40.2	31.8	26.0	21.9
42	28.5	22.6	18.6	15.7
50	19.4	14.6	12.8	10.8
60	13.1	10.5	8.7	7.4

Allowable Wind Load (psf), Two Standoff Pairs At 4" Spacing, 13/16" Laminated Glass

Glass Height (in)	**Glass Width (in)**			
	36	48	60	72
36	92.6	73.1	59.9	50.4
42	65.6	52.1	42.8	36.2
50	44.7	33.6	29.4	24.9
60	30.2	24.1	20.0	17.0

For wind loads under 10 psf the configuration may only be used for an interior application only.

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Allowable Wind Load (psf), Three Standoff Pairs At 4" Spacing, 1/2" Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	52.2	43.6	37.0	31.5
42	36.8	30.4	26.0	22.4
50	23.9	20.1	17.7	15.3
60	15.9	13.4	11.5	9.9

Allowable Wind Load (psf), Three Standoff Pairs At 4" Spacing, 5/8" Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	84.0	70.1	59.6	50.7
42	59.2	49.0	41.8	36.0
50	38.5	32.3	28.5	24.6
60	25.6	21.6	18.5	15.9

Allowable Wind Load (psf), Three Standoff Pairs At 4" Spacing, 3/4" Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	122.7	102.4	87.0	74.0
42	86.4	71.5	61.0	52.6
50	56.3	47.2	41.6	35.9
60	37.4	31.5	27.0	23.3

For wind loads under 10 psf the configuration may only be used for an interior application only.

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Allowable Wind Load (psf), Three Standoff Pairs At 4" Spacing, 9/16" Laminated Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	54.4	45.4	38.6	32.8
42	38.4	31.7	27.1	23.4
50	25.0	20.9	18.5	16.0
60	16.6	14.0	12.0	10.3

Allowable Wind Load (psf), Three Standoff Pairs At 4" Spacing, 13/16" Laminated Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	125.4	104.7	88.9	75.6
42	88.4	73.1	62.4	53.8
50	57.5	48.2	42.5	36.8
60	38.3	32.2	27.6	23.8

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Allowable Wind Load (psf), Two Standoff Pairs At 6" Spacing, 1/2" Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	51.2	41.3	31.5	27.8
42	35.7	28.0	23.2	19.7
50	23.3	18.3	15.8	13.4
60	15.4	12.6	10.6	9.1

Allowable Wind Load (psf), Two Standoff Pairs At 6" Spacing, 5/8" Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	82.4	66.4	50.6	44.7
42	57.5	45.1	37.3	31.7
50	37.6	29.5	25.4	21.6
60	24.9	20.4	17.1	14.6

Allowable Wind Load (psf), Two Standoff Pairs At 6" Spacing, 3/4" Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	120.3	97.0	73.9	65.3
42	83.9	65.9	54.5	46.2
50	54.9	43.1	37.1	31.6
60	36.3	29.7	24.9	21.3

For wind loads under 10 psf the configuration may only be used for an interior application only.

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Allowable Wind Load (psf), Two Standoff Pairs At 6" Spacing, 9/16" Laminated Glass

Glass Height (in)	**Glass Width (in)**			
	36	48	60	72
36	53.4	43.1	32.8	29.0
42	37.3	29.2	24.2	20.5
50	24.4	19.1	16.4	14.0
60	16.1	13.2	11.1	9.5

Allowable Wind Load (psf), Two Standoff Pairs At 6" Spacing, 13/16" Laminated Glass

Glass Height (in)	**Glass Width (in)**			
	36	48	60	72
36	123.0	99.2	75.6	66.8
42	85.8	67.4	55.7	47.3
50	56.1	44.1	37.9	32.3
60	37.1	30.4	25.5	21.8

For wind loads under 10 psf the configuration may only be used for an interior application only.

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Allowable Wind Load (psf), Three Standoff Pairs At 6” Spacing, 1/2” Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	64.9	55.1	47.7	41.5
42	44.4	38.1	32.8	27.1
50	29.4	24.5	21.4	18.9
60	18.0	16.2	14.2	12.5

Allowable Wind Load (psf), Three Standoff Pairs At 6” Spacing, 5/8” Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	104.5	88.7	76.7	66.7
42	71.5	61.3	52.8	43.6
50	47.4	39.5	34.5	30.4
60	29.0	26.1	22.8	20.1

Allowable Wind Load (psf), Three Standoff Pairs At 6” Spacing, 3/4” Monolithic Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	152.6	129.6	112.0	97.5
42	104.5	89.5	77.1	63.7
50	69.1	57.6	50.4	44.4
60	42.3	38.1	33.3	29.4

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Allowable Wind Load (psf), Three Standoff Pairs At 6" Spacing, 9/16" Laminated Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	67.7	57.5	49.7	43.3
42	46.4	39.7	34.2	28.3
50	30.7	25.6	22.4	19.7
60	18.8	16.9	14.8	13.1

Allowable Wind Load (psf), Three Standoff Pairs At 6" Spacing, 3/4" Laminated Glass

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	156.0	132.4	114.5	99.6
42	106.8	91.5	78.8	65.2
50	70.7	58.9	51.5	45.4
60	43.3	38.9	34.0	30.1

GUARD RAIL APPLICATIONS

When used as a guard rail, the imposed live loading will generally control the glass design. For commercial applications, the guard rail is subject to a 50plf uniform top rail load or a 200# concentrated load. Most residential applications will only be subject to the 200# concentrated.

In most guard rail applications, 13/16" laminated or 3/4" monolithic glass is required. Maximum glass height is 50" and a continuous top rail must be used. Additionally, in most cases the unsupported corner of the end lite will require bracing. Otherwise, the specific installation must be analyzed to confirm it is capable of holding the 200# concentrated load. Minimum lateral stiffness of top rail (EI_y) is 747,400lbs-in^2. The below tables show allowable glass heights (measured from bottom of glass to top of glass), for different glass widths and stand off conditions.

Maximum heights in order to resist 50plf load along top.

3/4" Monolithic or 13/16" Laminated glass, 2 Standoff Pairs At 4" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	50	42	42	36

3/4" Monolithic or 13/16" Laminated glass, 3 Standoff Pairs At 4" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	50	50	42	36

3/4" Monolithic or 13/16" Laminated glass, 2 Standoff Pairs At 6" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	50	42	42	39

3/4" Monolithic or 13/16" Laminated glass, 3 Standoff Pairs At 6" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	50	50	42	36

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Allowable heights to resist 200# concentrated load:

3/4" Monolithic or 13/16" Laminated glass, 2 Standoff Pairs At 4" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	N/A	N/A	N/A	N/A

3/4" Monolithic or 13/16" Laminated glass, 3 Standoff Pairs At 4" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	36	42	36	36

3/4" Monolithic or 13/16" Laminated glass, 2 Standoff Pairs At 6" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	36	36	36	N/A

3/4" Monolithic or 13/16" Laminated glass, 3 Standoff Pairs At 6" Spacing

Glass Width (in)	36	48	60	72
Allowable Height (in)	42	42	42	42

Use of a stiffer and stronger top rail will allow the glass height to be increased to the same as the 50 plf tables for lights $L \leq 60$ inches for a top rail with EI exceeding 2.2×10^6 lb-in^2.
$E = 25 \times 10^6$ for stainless steel and 10×10^6 for aluminum
Example top rails-
For stainless steel $I_x \geq 0.094$ in^4 (weakest axis)

- GR16 and larger
- GRS15 and larger
- SRF15 and larger
- L10 or heavier U cap rail

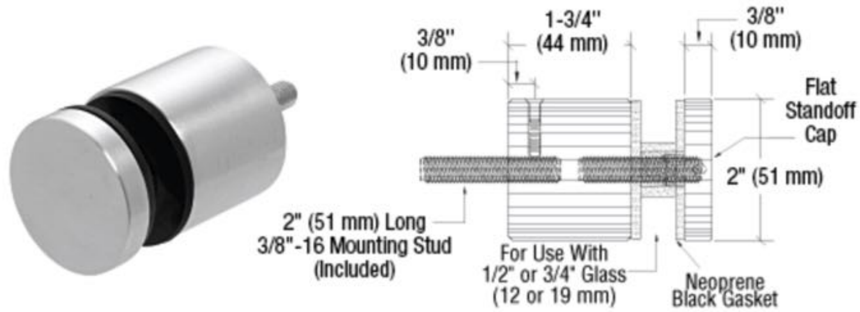
For aluminum $I_x \geq 0.22$ in^4 (weakest axis)

- GR19 and larger
- custom U cap rail with required stiffness

For brass $I_x \geq 0.18$ in^4 (weakest axis)

- GR25 or GR257 and larger
- GRS20 and larger
- SRF20 and larger
- custom U cap rail with required stiffness

GLASS STANDOFFS



To determine reactions on the standoffs:
Reactions are calculated using summation of forces and summation of moments:
V = D+L
where D = glass dead load plus cap rail or other attachments to the glass.
L = greater of 200# or 50plf* B

Vertical load share per standoff:
V_s = D/2 standoffs
Assumes vertical load is supported on any 2 standoffs to allow for construction tolerances, glass expansion and contraction and other factors that may cause uneven vertical loading on the standoffs
Moment on standoffs from vertical force:
$M_v = V_s*k$
where k = distance from centerline of glass to face of support attachment, typically 2" for RSOB2134 standard fitting.

For horizontal loading, moment about upper standoffs:
M_L = 50plf*B*h or 200#*h
$M_w = w*B*h^2*0.55$
W = w*B*h

M_T = greater of (M_L or M_w) +M_v

Glass standoffs resist loading by forming a couple (tension and compression reactions)
Two pairs of standoffs per panel
Calculate R_l by $\sum M$ about R_u
$\sum M = M_T+(a-c)* R_l = 0$
$R_l = M_T/(a-c)$
Typically a-c = 4" minimum
Load share to individual standoff:
$R_{sl} = R_l /n$ where n = number of standoff pairs, 2 or 3.

$R_u= R_l+F$ where F = either wind force or live load depending on which produced the greatest moment.

$R_{su} = R_u /n$

Standoff anchors – 3/8" stainless steel threaded rod to standoff and 3/8" rod to steel support.

Tensile area of 3/8" threaded rod (UNC) = 0.0775 in^2
Rod strength = (0.6*75ksi) * 0.0775 in^2 = 3,487#
Check thread strength into standoff – minimum thread embed = 3/8"
Internal thread stripping area = 0.828 in^2 for 3/8 – 16 threads
Allowable load on threads = $0.58*A_{sn}*t*F_{tu}/3$ = 0.58*0.828*(3/8)*45ksi/3 = 2,700#
Allowable shear strength = 0.3*75 ksi*0.0775 in^2 = 1,744#

Standoff welded to plate – 1/8" fillet weld: (welded option)

$T_a = 0.9*1/8"*\pi*2"*40\text{ ksi}/1.6 = 17.7\text{ k}$

$V_a = 0.3*17.7\text{ k} = 5.3\text{ k}$

For welded standoff case the button attachment strength limits the loading.

Determine tension and shear on mounting stud:
From ∑ forces:
Vertical loads will increase tension force in mounting stud:
$T = T_M+V*2"/1"$

Check Interaction of shear and tension.
Check combined tension and shear on anchors:

$$\frac{H\#}{2{,}700\#} + \frac{V\#}{1{,}744} = 0.44 < 1.2 \text{ Ok}$$

Example for a glass light, 3/4" x 52" tall x 72" long with 25 psf wind loading:

D = 9.8*(6'*4.333')/2 = 127# < 1,744#

Tension component of reaction

W = 25psf*3.667'*6'/2 = 275# to standoff

M = (25psf*3.667'^{2}*6'/2)*0.55 = 555'#

R_l = (555*12)/(4") = 1,664#

R_u = 1,664+275 = 1,939#

T = 1,939+127*2"/1" = 2,193< 2,700

Combined tension and shear:

$$\frac{2{,}193\#}{2{,}700\#} + \frac{127\#}{1{,}744} = 0.885 < 1.2 \text{ Ok}$$

STANDOFF STRENGTH IS ADEQUATE FOR ALL ACCEPTABLE LIGHT SIZES.

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CUSTOM STANDOFF SIZE:

The standoff design allows easy customization by changing the length of the standoff body so as to increase or decrease the standoff distance.

The moment and tension on the standoff is calculated the same as for the standard standoff:

$T = T_M+V*(J+t/2)/1”$

where:

T_m and V are as previously calculated based on light size and loading;

J = standoff body length

t = glass thickness

based on the calculated T and V the standoff is checked from:

$$\frac{T\#}{2,700\#} + \frac{V\#}{1,744} < 1.2 \text{ Ok}$$

and $T \leq 2,700\#$

For most cases $V \leq 0.2*1,744\# = 348.8\#$ so the combined check may be skipped.

Example:

Determine the maximum allowable standoff length for the glass light checked on previous page:

Example for a glass light, 3/4” x 52” tall x 72” long with 25 psf wind loading:

$D = 9.8*(7’*4.333’)/2 = 149\# < 1,744\#$

Tension component of reaction

$W = 25psf*3.667’*6’/2 = 275\#$ to standoff

$M = (25psf*3.667’^2*6’/2)*0.55 = 555’\#$

$R_l = (555*12)/(4”) = 1,665\#$

$R_u = 1,665+275 = 1,940\# < 2,700$

$T = 1,940+127*(J+0.75/2)/1” \leq 2,700\#$

$J=(2,700-1,940)*1”/(127\#)-0.375” = 5.61”$

For standoff bodies less than 5.61” the light sizes and wind loads are the same as for the standard standoff. For standoffs longer than 5.61” the light size and wind load must be checked for the standoff strength.

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RSOB20 STANDOFF FITTING

Bracket strength

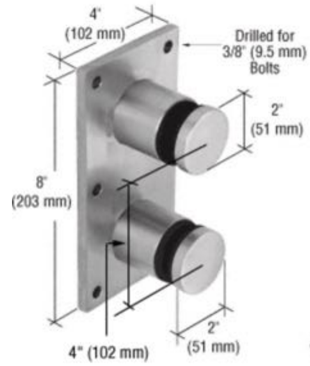
Bending in plate:

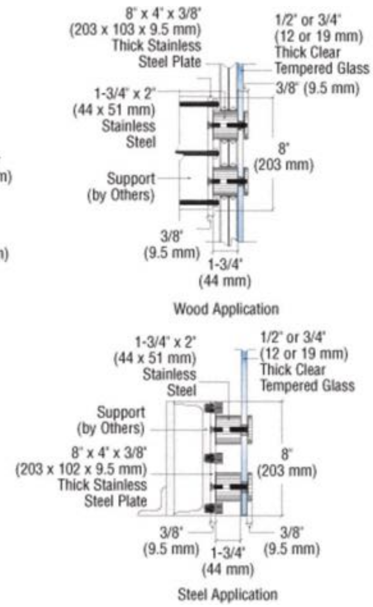
Bracket bending strength:

$Z = 4''*(0.375)^2/4 = 0.1406\ in^3$

$øM_n = 0.85*30\ ksi*\ 0.1406\ in^3 = 3{,}585''\#$

$M_s = øM_n/1.6 = 3{,}585/1.6 = 2{,}241''\#$





Allowable moment on glass standoff:

$M = 2*2{,}241''\# = 4{,}482''\#$

Or allowable tension

$T = 2{,}241*4.93/3.5'' = 3{,}157\#$

Bracket bending will not limit standoff loads below the values based on the stud strength.

Bracket reactions on anchors:

Anchors form couple to resist moment on the guards.

Determine anchor tension from $\sum M$ about the bottom of the bracket:

$\sum M_b = w*B*H^2/2 + V*2.25'' - n2T(7.5'' + 4^2/7.5)$

solving for T:

$T = (12''/ft*w*B*H^2 + 2.25V)/(38.5''n)$

If V is dead load only:

$V = 9.8psf*B*H/2$

substitute and simplify

$T = [12*w*B*H^2 + 11.025B*H)]/(38.5''n)$

where n = number of brackets

For typical maximum light size and load:

3/4" x 52" tall x 84" long with 25 psf wind loading

$T = [12*25*7*4.333^2 + 11.025*7*4.333)]/(38.5'')$

T = 344#/ fastener

Typical fastener:

1/2" x 3" lag screw to wood or

3/8" x 3" expansion bolt to concrete or

3/8" bolt to steel.

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Cap Rail/ Grab Rail
For guard installations – Fall protection required, a cap rail or grab rail is required.

Cap rails and grab rails are the same as used in the GRS – Glass Rail System, refer to the GRS engineering report for the cap rails and grab rails.

All cap rails intended for use with the GRS may be used with the SRS for the appropriate glass thickness.

All grab rail brackets used with the GRS may be used with the SRS. The grab rail brackets' installation and strength is the same as for the GRS.

Other Glass Thicknesses

The Standoffs may be used with glass thicknesses other than those given in this report. When used with other glass thicknesses of monolithic or laminated glass the glass bending moment shall be evaluated using a finite element analysis model or other rational method.

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Appendix A

FEA Model results for 1/2" monolithic glass, 9/16 laminated results are similar. Based on these results when 1/2" or 9/16" glass is specified for a guard application engineering analysis must be performed that evaluates the glass stresses for the specific project conditions.

4" Vertical Standoff Spacing

50plf Live Load

Glass Stress, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	9926	12310	15540	18290
42	11810	15230	18390	21610
50	14050	18460	22190	26050
60	18110	22450	26960	31600

Glass Stress, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	7937	9425	11020	12970
42	9492	11230	13510	15530
50	11540	14150	16510	18910
60	14660	17400	20220	23140

Glass Deflection, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.913	1.12	1.34	1.58
42	1.40	1.68	1.98	2.31
50	2.27	2.68	3.11	3.57
60	3.77	4.37	5.01	5.68

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Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.715	0.831	0.953	1.08
42	1.12	1.28	1.46	1.64
50	1.86	2.10	2.35	2.62
60	3.17	3.52	3.89	4.28

200# Live Load At Corner

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	16010	15950	16280	16770
42	18570	18290	18530	18970
50	22000	21410	21500	21870
60	26330	25380	25230	25490

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	12070	11950	12400	13690
42	14380	14120	14440	14890
50	17280	16150	16280	16750
60	20000	18870	18770	19100

As shown the glass stress for the live loads will typically exceed 6,000 psi when 1/2” monolithic or 9/16” laminated glass is used. Thus for most installations where the glass must act as a guard rail the 1/2” and 9/16” glass options will not meet the safety or design factor of 4.

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Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	1.40	1.38	1.42	1.48
42	2.09	2.01	2.02	2.07
50	3.310	3.09	3.03	3.05
60	5.39	4.90	4.69	4.63

Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	1.14	1.12	1.16	1.22
42	1.72	1.63	1.64	1.69
50	2.76	2.53	2.46	2.48
60	4.57	4.04	3.82	3.75

200# Live Load At Center

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	13770	12890	12480	12290
42	16370	15280	14750	14480
50	19840	19730	17780	17410
60	24170	22460	21590	21100

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Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	10780	9860	9540	9500
42	12730	11650	11130	10910
50	16000	14370	13170	12900
60	19630	17520	16450	16010

Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	1.25	1.18	1.16	1.19
42	1.90	1.74	1.68	1.68
50	3.06	2.74	2.59	2.52
60	5.07	4.44	4.11	3.93

Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.976	0.871	0.823	0.803
42	1.52	1.33	1.23	1.18
50	2.51	2.15	1.95	1.84
60	4.25	3.57	3.19	2.96

The glass stress (f_{bt}) for other glass thicknesses (t) may be reasonably estimated by multiplying the stress from the table (f_b) by $t^2/0.469^2$:
$f_{bt} = f_b * t^2/0.469^2$

FEA models show this will be within ± 5% of the stress determined directly by FEA model for the alternative glass thickness.

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10psf Wind Load

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	2750	3482	4254	5056
42	3882	4889	5948	7045
50	5694	7580	8652	10210
60	8447	10550	12750	15020

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	2031	2433	2864	3367
42	2882	3483	4083	4735
50	4426	5279	5986	6930
60	6658	7914	9242	10700

Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.214	0.269	0.329	0.397
42	0.385	0.474	0.571	0.676
50	0.747	0.903	1.07	1.25
60	1.49	1.77	2.07	2.38

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Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.161	0.191	0.222	0.254
42	0.296	0.347	0.400	0.454
50	0.589	0.680	0.774	0.872
60	1.21	1.37	1.54	1.72

6” Vertical Standoff Spacing

50plf Live Load

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	8442	10300	12240	13930
42	10400	12280	14580	16960
50	12940	14950	17700	20560
60	15530	18340	22600	25050

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	6785	7864	9009	9809
42	8249	9511	10860	12190
50	10900	11800	13370	15060
60	13280	14900	17708	19160

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Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	**Glass Width (in)**			
	36	48	60	72
36	0.582	0.687	0.807	0.946
42	0.935	1.08	1.24	1.43
50	1.59	1.80	2.03	2.29
60	2.77	3.08	3.42	3.79

Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	**Glass Width (in)**			
	36	48	60	72
36	0.480	0.532	0.587	0.645
42	0.791	0.864	0.943	1.03
50	1.38	1.49	1.61	1.73
60	2.46	2.62	2.79	2.98

200# Live Load At Corner

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	**Glass Width (in)**			
	36	48	60	72
36	13700	13670	14000	14330
42	16330	15580	15790	16200
50	18850	18190	18230	18550
60	22580	21520	21280	21470

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Glass Stress, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	10780	10720	11340	12500
42	12840	12550	13260	13890
50	15080	14420	14540	15290
60	18300	17070	16410	16690

Glass Deflection, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.936	0.914	0.935	0.982
42	1.45	1.37	1.36	1.40
50	2.38	2.17	2.11	2.11
60	4.02	3.55	3.35	3.27

Glass Deflection, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.812	0.790	0.814	0.862
42	1.27	1.18	1.18	1.21
50	2.10	1.88	1.81	1.81
60	3.60	3.10	2.88	2.80

200# Live Load At Center

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	10860	9874	10290	9590
42	13030	12270	11710	11400
50	16410	15420	14200	13780
60	20240	18300	17320	16760

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	9291	8433	8127	8158
42	11150	9917	9466	9895
50	13630	12360	11500	11120
60	18020	15060	13880	13280

Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.803	0.739	0.735	0.767
42	1.27	1.13	1.08	1.08
50	2.15	1.85	1.71	1.65
60	3.72	3.13	2.82	2.65

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Glass Deflection, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.664	0.573	0.53	0.511
42	1.08	0.907	0.819	0.775
50	1.87	1.53	1.36	1.25
60	3.30	2.66	2.31	2.09

10psf Wind Load

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	2071	2568	3370	3814
42	2968	3781	4572	5388
50	4540	5782	6723	7887
60	6863	8381	10000	11690

Glass Stress, Assuming t_{min}=0.469” (1/2” Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	1633	1923	2224	2556
42	2385	2785	3233	3909
50	3603	4323	4946	5608
60	5884	6545	7481	8469

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Glass Deflection, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 2 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.124	0.151	0.185	0.225
42	0.235	0.279	0.331	0.39
50	0.482	0.559	0.646	0.743
60	1.02	1.16	1.31	1.48

Glass Deflection, Assuming t_{min}=0.469" (1/2" Monolithic nominal), 3 pairs

Glass Height (in)	Glass Width (in)			
	36	48	60	72
36	0.098	0.111	0.124	0.138
42	0.191	0.213	0.237	0.262
50	0.404	0.443	0.486	0.532
60	0.873	0.945	1.02	1.11

For all tables in Appendix A

The glass stress (f_{bt}) for other glass thicknesses (t) may be reasonably estimated by multiplying the stress from the table (f_b) by $t^2/0.469^2$:
$f_{bt} = f_b * t^2/0.469^2$

The glass deflection (Δ_t) for other glass thicknesses (t) may be reasonably estimated by multiplying the deflection from the table (Δ) by $0.469^3/t^3$:
$\Delta_t = \Delta * 0.469^3/t^3$

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