Edward C. Robison, P.E.

28 March 2024

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

SUBJ: CRL P-SERIES POST RAILING SYSTEMS
STAINLESS STEEL MINI POSTS FOR GLASS GUARDRAILS

I have evaluated the stainless steel post kits to verify that they will safely support the following loads when used in building guardrails:

200 pound point load on top rail, vertical or horizontal
50 plf load on top rail, vertical or horizontal or
50 psf uniform load on glass panel horizontal or
50 lb conc load on 1 sf

Allowable post spacing is as given for the anchorage method and glass used.

For the installations using laminated tempered glass a top rail is optional. For installations using monolithic glass the top rail/cap rail is required when used as a guard. The top rail/cap rail may be as approved in ESR-3269 for the glass thickness, span and use.

Stainless steel members are analyzed according to the provision of AISC 370.

This report is intended to provide the design parameters and engineering properties of the system to assist a qualified design professional in designing a code compliant installation. Drawings and design details for the system, using the information noted in this report, must be included on design documents and construction plans submitted to the code official for approval. The drawings and details must be prepared by a qualified registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

Contents:	Pages:
Seal Page	2
Executive Summary	3 - 7
PWC1	8 - 12
PWC2	13 - 15
Anchorage	16 - 21
Glass and Full Assembly Analysis	22 - 37

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EXECUTIVE SUMMARY

Executive summary contents:
1) Standard anchorages and installations
2) Allowable Live Loads
3) Allowable Wind Loads

The mini most system uses short stainless steel posts to support monolithic or laminated glass panels. The glass panels can be used to create fences, dividers, wind screens or guards up 42" tall. The PWC1 post may be installed with a single standoff pair or with two standoff pairs. When used with two standoff pairs the post is placed in between panels and the post receives loading from two panels. The PWC2 is used in a single standoff pair configuration only.

Posts must be adequately anchored to use the design tables in this summary. Anchorages may be custom designed or may use these typical anchorage details:
Anchorage to concrete:
(4) 3/8"x4" Hilti KH-EZ, Minimum nominal embedment = 3.25". (May use 3/8" and 1/2" glass, design tables)
Or
(4) 3/8"x6" Hilti KH-EZ with Kwik-X dual action epoxy system, Minimum nominal embedment = 5". Minimum edge distance = 4" (May use 3/8", 1/2" and 3/4" glass design tables)
Anchorage to wood:
(4) 3/8"x4" lag screws. Minimum penetration not including the tip is 3-1/2". (May use 3/8" and 1/2" glass design tables)
Anchorage to steel:
(4) 3/8" cap screws or bolts. Use washer and nut or tap into 1/4" minimum penetration. (May use 3/8", 1/2" and 3/4" glass design tables)

Alternative anchorage may be designed for the specific project conditions by a qualified design professional.

The supporting structure must be designed and constructed to support the loads imposed by the GRS guards in accordance with the applicable code. The anchorage to the frame must be as specified in this report or designed to provide the required strength for the specified balustrade height and imposed loads.

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Guard rails must meet the requirements of the local code where they are being installed. The guard rail categories are shown below. Select the category that meets the local code for your installation, then use the tables on the following pages to select a glass thickness and geometry that meets your requirements. Generally, for residential applications a 36” tall guard and a 200# live load is required. To meet these requirements, generally a 9/16” laminated panel with a Sentry Glass interlayer and a cap rail is specified. The cap rail must attach to the structure or a 90˚ return to support the ends of guards. For commercial applications, a 42” tall guard, a 200# live load and 50plf uniform live load is required. To meet these requirements, generally a 13/16” laminated panel with a Sentry Glass interlayer is specified. A cap rail is not required when the 13/16” SG laminated glass is used. See below for more information on live load categories. The following pages include tables for different glass thicknesses and geometries.

Live Load resistance use categories: Applicable to tables on the next page.

A: Resists 200# and 50plf live loads. 50plf live load causes deflection less than the glass thickness so no top rail or glass to glass connection brackets are required if laminated glass is specified. A top rail is required for monolithic glass.

B: May be used as a guard rail when the following conditions are met: There is a cap rail that connects adjacent panels together and the cap rail is connected at the ends of the guard rail to a supporting structure. May be used as wind screen without a top rail or glass to glass connection brackets.

C: May be used as a guard rail when the following conditions are met: There is a cap rail that connects adjacent panels together and the cap rail is connected at the ends of the guard rail to a supporting structure. The guard rail must be in a residential application or other locations where the guard is exempt from the 50plf live load. May be used as a windscreen with a top rail or glass to glass connection brackets.

D: Not suitable as a guard rail. May be used as wind screen. A top rail or glass to glass connection brackets are required.

E: May be used as a guard rail when the following conditions are met: There is a cap rail that connects adjacent panels together and the cap rail is connected at the ends of the guard rail to a supporting structure. May be used as wind screen with a top rail or glass to glass connection brackets.

Note the conditions of use for each of the use categories must be followed for a code compliant installation.

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Refer to glass use categories on previous page.

Live Load Check On Glass
2 posts per panel, 1/2" or 9/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	A	A	A	A
	36	B	C	C	C
	42	D	D	D	D

Live Load Check On Glass
3 posts per panel, 1/2" or 9/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	A	A	A	A
	36	B	B	B	C
	42	E	D	D	D

Live Load Check On Glass
2 posts per panel, 3/4" or 13/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	A	A	A	A
	36	A	A	A	A
	42	A	A	A	A

1) Measured from bottom of baseplate to top of glass.

Example: For 13/16" laminated glass use category A is applicable for all the light sizes in the table.
For 9/16" glass with 36" glass height use category B requires panels under 36" long with 2 posts or may be up to 60" long with 3 posts.

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For exterior applications the wind load should also be checked. Use the allowable wind load tables below to determined the allowable wind load on the guard. Tables assume minimum anchorage criteria noted at the beginning of this executive summary.

Allowable Wind Load On Glass (psf)
PWC1 or PWC2 Posts
2 posts per panel, 3/8” or 7/16” Laminated

		Glass Width (in)			
		36	**48**	**60**	**72**
Screen Height[1] (in)	**24**	245	150	100	70

Allowable Wind Load On Glass (psf)
PWC1 or PWC2 Posts
2 posts per panel, or 1 post between each panel, 1/2” or 9/16” Laminated

		Glass Width (in)			
		36	**48**	**60**	**72**
Guard Height[1] (in)	**24**	200	150	120	100
	36	95	70	55	50
	42	65	50	40	30

Allowable Wind Load On Glass
PWC1 or PWC2 Posts
3 posts per panel, 1/2” or 9/16” Laminated

		Glass Width (in)			
		36	**48**	**60**	**72**
Guard Height[1] (in)	**24**	200	150	120	100
	36	130	100	80	65
	42	85	65	50	40

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Allowable Wind Load On Glass
PWC1 Posts (One standoff pair per post)
2 posts per panel, 3/4" or 13/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	300	225	180	150
	36	195	150	120	100
	42	120	100	80	65

Allowable Wind Load On Glass
PWC1 Posts (Two standoff pairs per post, post connects to two glass panels)
1 post in between each panel, 3/4" or 13/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	237	177	142	118
	36	105	79	63	53
	42	77	58	46	39

Allowable Wind Load On Glass
PWC2 Posts (One standoff pair per post)
2 posts per panel, 3/4" or 13/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	300	225	180	150
	36	192	150	120	100
	42	120	100	80	65

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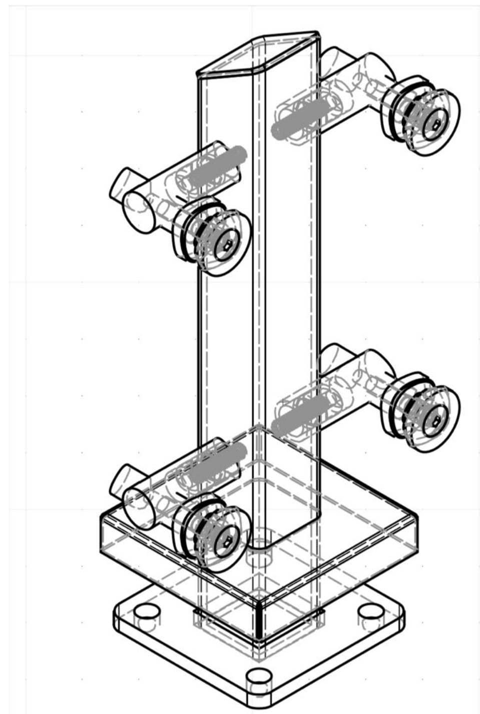
COMPONENT ANALYSIS

PWC1

HSS2X2X3/16” 304/316 Stainless steel

The PWC1 mini post is an HSS2x2x1/4 welded to a stainless steel baseplate. The post passes through a hole in the baseplate and is welded from top and bottom producing a weld that develops the full strength of the post.

The post forms a plastic hinge at the baseplate. The shape is compact, is a closed tube and is relatively short. Therefore, a plastic hinge will form and the post may be designed according to AISC 370 Appendix 2, continuous strength method.



Moment strength calculations for the HSS2x2x1/4 are shown on the following two pages.

The PWC1 can also be used in an eccentric condition that creates torsion on the post.

The torsion strength of the post is calculated following the flexural strength calculations.

Post strength summary:
M_a = 17,000”#

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Design of Stainless Steel HSS Using AISC Appendix 2 Continuous Strength Method			
AISC 370 A.2.6			
Case 1)	$\varepsilon_{csm}/\varepsilon_y < 1.0$	$M_n = \varepsilon_{csm}/\varepsilon_y M_y$	
Case 2)	$\varepsilon_{csm}/\varepsilon_y \geq 1.0$	$M_n = M_p(1+E_{sh}S/(EZ)*(\varepsilon_{csm}/\varepsilon_y-1)-(1-S/Z)/(\varepsilon_{csm}/\varepsilon_y)^{\alpha})$	
Use AISC 370 A.2.3.1 to determine failure strain.			
Case a)	$\lambda_l \leq 0.68$	$\varepsilon_{csm}/\varepsilon_y = 0.25/\lambda_l^{3.6} \leq$ minimum(Λ, $0.10(1-F_y/F_u)/\varepsilon_y$)	
Case b)	$\lambda_l > 0.68$	$\varepsilon_{csm}/\varepsilon_y = (1-0.222/\lambda_l^{1.05})1/\lambda_l^{1.05}$	
Material Properties:			
F_y (ksi)	Λ	E (ksi)	$\varepsilon_y = F_y/E$
30	15	28000	0.00107
F_u (ksi)	E_{sh} (ksi)	υ	α
75	474.04	0.3	2
Section Properties:			
t_p (in)	b_p (in)	S (in^3)	Z (in^3)
0.174	2	0.641	0.797
Find elastic buckling stress per AISC 370 C-A-1-2.			
Isolated flange	k	$F_{el,f}^{SS} = k\pi^2E/(12(1-\upsilon^2))(t_p/b_p)^2$ (ksi)	β_f
	4	766.18	1
Isolate web	k	$F_{el,w}^{SS} = k\pi^2E/(12(1-\upsilon^2))(t_p/b_p)^2$ (ksi)	β_w
	23.9	4577.96	1
$F_{el,p}^{SS} = \min(\beta_f F_{el}^{SS}{}_f\ ,\ \beta_w F_{el}^{SS}{}_{,w})$			
766.18			
Isolated flange	k	$F_{el,f}^{F} = k\pi^2E/(12(1-\upsilon^2))(t_p/b_p)^2$ (ksi)	β_f
	6.97	1335.08	1
Isolate web	k	$F_{el,w}^{F} = k\pi^2E/(12(1-\upsilon^2))(t_p/b_p)^2$ (ksi)	β_w
	39.6	7585.23	1

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$F_{el,p}^F = \min(\beta_f F_{el}^F{}_f , \beta_w F_{el}^F{}_{,w})$			
1335.08			
$ø = \beta_f F_{el}^{SS}{}_f / (\beta_w F_{el}^{SS}{}_{,w})$	If $ø < 1$	$a_f = 0.24-[0.1(t_f/t_w)^2(H/B-1)]^{1/0.6} \leq 0.24$	**af**
0.17	If $ø \geq 1$	$a_w=0.63-0.1H/B \leq 0.53$	0.24
	If $ø < 1$	$\zeta = t_w/t_f*(0.24-a_f*ø)^{0.6}$	ζ
	If $ø \geq 1$	$\zeta = t_f/t_w*(0.53-a_w/ø)$	0.38
$F_{el} = F_{el,p}^{SS}+\zeta(F_{el,p}^F-F_{el,p}^{SS})$ ksi	$\lambda_l = (F_y/F_{el})^{1/2}$	For $\lambda_l < 0.68$, $\varepsilon_{csm}/\varepsilon_y = 0.25/(\lambda_l)^{3.6}+0.002/\varepsilon_y \leq \Lambda$	$\varepsilon_{csm}/\varepsilon_y$
982.67	0.1747	For $0.68 < \lambda_l < 1.00$, $\varepsilon_{csm}/\varepsilon_y = (1-0.222/(\lambda_l)^{1.05})*(1/(\lambda_l)^{1.05})+0.002(f/F_y)^n/\varepsilon_y$	15
ε_{csm}	Case 1) $\varepsilon_{csm}/\varepsilon_y < 1.0$	$M_n=\varepsilon_{csm}/\varepsilon_y M_y$	
0.01607	Case 2) $\varepsilon_{csm}/\varepsilon_y \geq 1.0$	$M_n=M_P(1+E_{sh}S/(EZ)*(\varepsilon_{csm}/\varepsilon_y-1)-(1-S/Z)/(\varepsilon_{csm}/\varepsilon_y)^{\alpha})$	
M_y (in-kips)	M_p (in-kips)	M_n (in-kips)	**$M_a = M_n/1.67*1000$ (in-lbs)**
19.23	23.91	28.45	**17034**
Percent increase over Chapter F strength			
19.0			

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SS HSS Torsion Strength, Per AISC 370 G8-1 and G8.2.			
h(in)	t(in)	λ=h/t	E(ksi)
2	0.174	11.494	28000
F_y(ksi)	$0.74(E/F_y)^{1/2}$	$2.17(E/F_y)^{1/2}$	$5.99(E/F_y)^{1/2}$
30	22.607	66.295	182.998
See G8.2 a-d for calculation of C_v with respect to λ.	G8-10 controls	C_V	C (in^3) section constant for HSS2x2x1/4
		1.2	1.41
$T_n = 600CC_vF_y$ (in-lbs)	**$T_n/\Omega = T_n/1.67$ (in-lbs)**		
30456	**18237**		
Also check direct shear:			
Strength per AISC 370 G3	$A_w = 2ht$ (in^2)	λ=h/t	k_v
	0.696	11.494	5
$0.33(k_vE/F_y)^{1/2}$	$0.97(k_vE/F_y)^{1/2}$	$2.68(k_vE/F_y)^{1/2}$	See G2.2-8 - 11 for calculation of C_{v2}.
22.543	66.264	183.079	
G2-8 controls	C_{v2}	$V_n=600F_yA_WC_{v2}$ (lbs)	**$V_n/\Omega = V_n/1.67$ (lbs)**
	1.2	15034	**9002**

For combined forces, AISC 370 H2-1 controls.	Combined forces will be the worst for short guards with high loading. Check for 1000# test load at 24" total height. V_{max} = 500#*(24"-5")/8" (Shear is highest between standoffs) T = 500#*3.25", M = 500#*24"		
M_r (in-lbs)	V_r (lbs)	T_r (in-lbs)	Torsion and shear are insignificant compared to moment. Therefore, the intermediate posts that have twice the moment and no torsion will control over the end posts with torsion.
12000	1188	1625	
H2-1 states $(P_r/P_c+M_r/M_c)+(V_r/V_c+T_r/T_c)^2 \leq 1.0$		Utilization checking moment only,	
0.75		0.70	

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Allowable wind load chart, PWC1 (psf)					
		Post Spacing (in)			
Guard height (in)	**Allowable uniform load (pli)**	36	48	60	72
24	59	237	177	142	118
36	26	105	79	63	53
42	19	77	58	46	39

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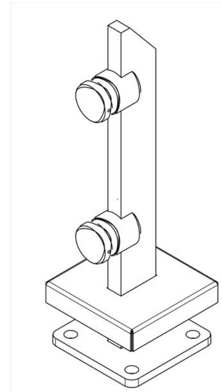
PWC2



Check 2"x3/4" flat bar strength. Strength is calculated per AISC 370 F9.			
d (in)	t (in)	S (in^3)	Z (in^3)
2	0.75	0.5	0.75
L (in)	Ld/t^2	F_y (ksi)	E (ksi)
12	42.6667	30	28000
0.306E/F_y	2.0E/F_y	M_a (in-lbs) See F9-1,2 or 3 as appropriate	
295.80	1866.67	13473	(Plastic moment strength controls for 2x3/4" flat bar, check strength based on Appendix 2. No flange elements and the flat bar has been shown to be compact so $\varepsilon_{csm}/\varepsilon_y$ = 15.
ε_{csm}	Case 1) $\varepsilon_{csm}/\varepsilon_y < 1.0$	$M_n=\varepsilon_{csm}/\varepsilon_y M_y$	
0.01607	Case 2) $\varepsilon_{csm}/\varepsilon_y \geq 1.0$	$M_n=M_P(1+E_{sh}S/(EZ)*(\varepsilon_{csm}/\varepsilon_y-1)-(1-S/Z)/(\varepsilon_{csm}/\varepsilon_y)^{\alpha})$	
M_y (in-kips)	M_p (in-kips)	M_n (in-kips)	**$M_a = M_n/1.67*1000$ (in-lbs)**
15	22.5	26.02	**15582**
Percent increase over Chapter F strength			
15.7		34.7	

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Also check for post rupture at the reduced section.

Notch depth, a (in)	Reduced section depth, d_{net} = 2”-a	$Z_{net} = d_{net}^2 t/4$ (in^3)	F_u (ksi)
0.75	1.25	0.293	75
$M_{a,net} = 1000 Z_{net} F_u/2$ (in-lbs)	Distance from bottom of notch to bottom of post, L_n(in)		
10986	5.75		
Check allowable top of post live loads:			
Total post height, H(in)	Maximum top of post load to cause failure at bottom of post = M_a/H	Maximum top of post load to cause failure at notch = $M_a/(H-L_n)$	
16	974	1072	
36	433	363	
42	371	303	
Next check allowable uniform live loads:			
Total post height, H(in)	Maximum uniform post load to cause failure at bottom of post = $M_a/(L^2/2)$	Maximum uniform post load to cause failure at notch = $M_a/((H-L_n)^2/2)$	
16	122	209	
36	24	24	
42	18	17	
Note that failure at bottom of the post or failure at the notch may control depending on the post height and type of loading. It can be seen from the calculations above that failure at the bottom of the post controls for the 16” tall guard but failure at the notch controls for taller guards.			

Allowable wind loads are shown on the following page.

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Allowable wind load chart, PWC2 (psf)						
		Glass Width (in)				
Guard height (in)	**Allowable uniform load (pli)**	36	42	48	60	72
24	122	974	835	730	584	487
36	24	192	165	144	115	96
42	17	134	115	100	80	67

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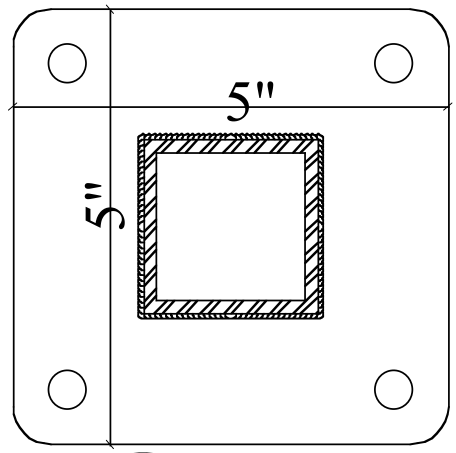
POST ANCHORAGE

Base Plate design:



for 3/8” plate $Z = \frac{5'' \bullet 3/8^2}{4} = 0.176\ in^3$

$F_y = 45$ ksi

$M_n = Z\,F_y$

$M_n = 0.176*45ksi = 7{,}910\#''$

$M_s = M_n/1.67$

$M_s = 7{,}910\#''/1.67$

$M_s = 4{,}737\#''$

Calculate base plate reactions and moment based on the maximum design load on posts.

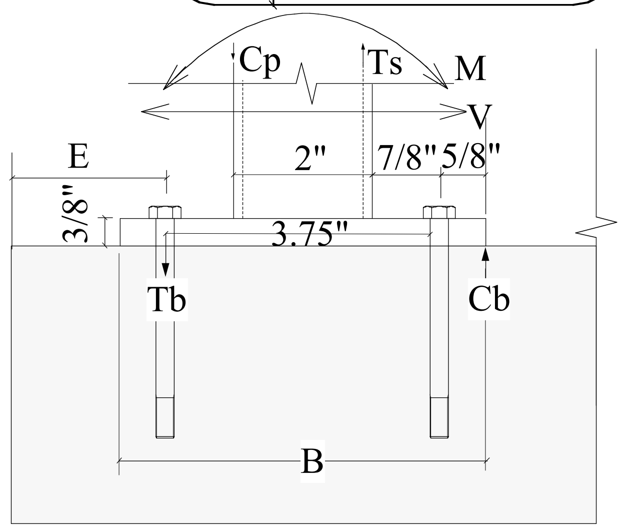
Live load

M = 300#x16” = 4,800”#

Maximum wind load:

W = 60psf*6’*1.333’ = 480#

M = 480#x16”*0.55 = 4,224”#



Live load controls for tension

$T_b = M/4.125''/2$ bolts

$T_b = 4800/(4.125*2) = 582\#$

Nominal anchor tension

Base plate moment

$M_u = 2*Tb*7/8''$

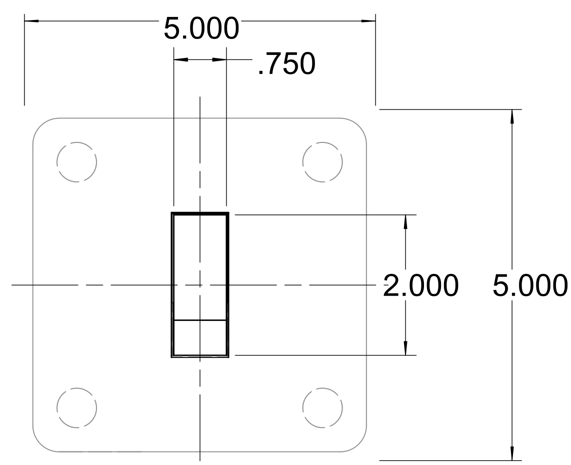
$M_u = 1.6*2*582*(7/8'') = 1{,}630\#''$

$M_u < øM_n$ therefore okay

Base plate anchor strength:

Service strength required for anchors

$T_s = 582\#$ (for allowable load on anchor)



This base plate is used with both of the posts in this series. the strength and anchorage will be the same for all post types.

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ANCHORAGE DESIGN

Based on achieving glass design strength. For 9/16" glass the design anchorage loading is 9,290"# + 600# shear. For 13/16" glass the design anchorage loading is 17,000"#+944# shear.

MOUNTED TO STEEL

Use 3/8" cap screws or machine bolts to attach to structural steel. The anchorage to steel design can meet the 1/2" and 3/4" glass wind load tables.

A_{net} (in^2)	F_u (ksi)	$T_a = 1000A_{net}F_u/2$ (lbs)	
0.0775	75	2,910	
Internal stripping area, A_{strip} (in^2/in)	Substrate strength, F_u(ksi)	Minimum embedment = T_a*2/(1000*F_u*0.6*A_{strip}) (in)	
0.828	58	0.202	Round up to 1/4" min penetration in substrate
$M_a = T_a$*2*4.375"			
25,462.5	> 17,000"# (Develops 13/16" glass wind load tables OK)	Shear strength of the four bolts is greater than 944# by inspection	

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MOUNTED TO WOOD - Lag Screw Alternative:
3/8" x 4" lag screws in structural wood. The wood should be protected from moisture. The standard anchorage to wood design develops the strength of the 1/2" glass wind load tables but not the 3/4". Custom anchorage should be designed when using the 3/4" glass wind load charts and anchoring to wood.

W (pli)	C_D (Wind load or short duration live load)	p(in)	W'p (lbs)
243	1.6	3.5	1360.8
Bearing block depth, a = W'p*2/(405psi*5")	M_a = 2W'p*(4.375"-a/2) (in-lbs)		
1.344	10078	> 7,300"# (Develops 9/16" wind load tables but not 13/16")	
Z (lbs)	Z' (lbs)	z (per lag) (lbs)	
160	256	150	OK

For 3/8" x 6" lag screws to wood

W (pli)	C_D (Wind load or short duration live load)	p(in)	W'p (lbs)
243	1.6	5.337	2075
Bearing block depth, a = W'p*2/(405psi*5")	M_a = 2W'p*(4.375"-a/2) (in-lbs)		
2	13904	< 17,000"# (Limits maximum wind load on 3/4" and 13/16")	
Z (lbs)	Z' (lbs)	z (per lag) (lbs)	
160	256	150	OK

Combined loading:	Shear and tension on lag screw		
V (lbs)	T (lbs) = W'p*(9290"#/ M_a)	V_a (lbs)	T_a (lbs)
150	1254	256	1360.8
α (rads)	V_α (lbs)	$V_{a,\alpha}$ (lbs)	Pass/Fail
1.45178	1263.3	1282.8	pass

Okay to design lag screws based on tension only.

ANCHORAGE TO CONCRETE

Typical anchorage is Hilti KH-EZ 3/8” with 3.25” nominal embedment (2.5” effective). This develops the 1/2” glass wind load charts but not the 3/4” glass wind load charts. The following page describes another anchorage design that does develop the 3/4” glass wind load charts. Equivalent anchor may be used with the same embedment. Use 3.75” edge distance minimum to achieve 9/16” glass wind load chart.

3/8” KH-EZ breakout per ACI 318 Chapter 17. Cracked concrete minimum concrete strength						
f’c (psi)	hef (in)	Edge distance anchors (in)	Spacing parallel to edge (in)	Concrete thickness (in)	D (in)	Lever arm to bolts (in)
3000	2.5	3.75	3.75	8	0.375	4.375
Area calculations						
A_{Vc} (in^2)	A_{nc} (in^2)	A_{vo} (in^2)	A_{No} (in^2)	C_{ac} (în)		
210.000	84.375	63.281	56.25	3.75		
Shear breakout						
$\Psi_{ec,V}$	$\Psi_{ed,V}$	$\Psi_{c,V}$	$\Psi_{h,V}$	V_b	V_{cbg}	
1	1	1	1	2492	8269	
Tension breakout						
$\Psi_{ec,N}$	$\Psi_{ed,N}$	$\Psi_{c,N}$	$\Psi_{cp,N}$	N_b	N_{cbg}	
1	1	1.0	1	3681	5521	
Design checks						
Nominal strengths are multiplied by the reduction factor of 0.65 and divided by the load factor of 1.6 to determined the allowable load.						
V_a	V	Pass/Fail				
3359	600	Pass				
T_a (lbs)						
2243	on anchor group					
$M_a = T_a$*(4.375”) (in-lbs)		M	$V/V_a+M/M_a < 1.2$			
9813		9300.00	1.13	< 1.2 OK	Pass	

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For 13/16” glass options, use KH-EZ Kwik X dual action system. The anchor system uses the KH-EZ anchor with a foil epoxy packet inserted in the hole. bThis installation allows for deeper effective embedment. Increase anchor embedment to 4.75” and increase edge distance to 4”.

Concrete breakout strength calculations use a confinement factor that accounts for the confining affect of the reaction at the toe of the base shoe. This factor is based on tests performed by Florida Tech for the Florida Department of Transportation on guard rail posts with small baseplates. The final report is dated August 2019. The report details a procedure for determining the moment resistance of narrow baseplate with relatively deep epoxy anchors. The procedure detailed in the report is to calculate the tension breakout strength of the epoxy anchor using an additional confinement factor that is calculated with respect to the embedment depth and lever arm to the toe of the baseplate. Then to multiply that tension strength by the lever arm to determine the moment resistance. Note that the procedure specifically states the bond strength of the anchor need not be calculated nor a bearing block depth. The confinement factor used accounts for these factors.
Confinement factor = $1.75-d/(2h_{ef})$
(Where d is the distance from the anchor to the toe of the baseplate.

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3/8” KH-EZ breakout per ACI 318 Chapter 17. Cracked concrete minimum concrete strength						
f’c (psi)	hef (in)	Edge distance anchors (in)	Spacing parallel to edge (in)	Concrete thickness (in)	D (in)	Lever arm to bolts (in)
3000	5	4	3.75	8	0.375	4.375
Area calculations						
A_{Vc} (in²)	A_{nc} (in²)	A_{vo} (in²)	A_{No} (in²)	C_{ac} (în)		
216.000	215.625	72.000	225	3.75		
Shear breakout						
$\Psi_{ec,V}$	$\Psi_{ed,V}$	$\Psi_{c,V}$	$\Psi_{h,V}$	V_b	V_{cbg}	
1	1	1	1	3153	9460	
Tension breakout						
$\Psi_{ec,N}$	$\Psi_{ed,N}$	$\Psi_{c,N}$	$\Psi_{cp,N}$	Ψ_{conf}	N_b	N_{cbg}
1	1	1.0	1	1.3125	10410	9977
Design checks						
Nominal strengths are multiplied by the reduction factor of 0.65 and divided by the load factor of 1.6 to determined the allowable load.						
V_a	V	Pass/Fail				
3843	944	Pass				
T_a (lbs)						
4053	on anchor group					
$M_a = T_a$*(4.375”) (in-lbs)		M	$V/V_a+M/M_a < 1.2$			
17732		17000	1.20	< 1.2 OK	Pass	

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GLASS STRENGTH

All glass is fully tempered glass conforming to the specifications of ANSI Z97.1, ASTM C 1048 and CPSC 16 CFR 1201. The median F_r for the tempered glass is 24 ksi. In accordance with IBC 2407.1.1 glass used as structural balustrade panels shall be designed for a safety factor of 4.0. For loads other than guard live loads glass may be designed for stresses in accordance with ASTM E1300.

Values for the modulus of rupture, F_r, modulus of Elasticity, E and shear modulus, G for glass are typically taken as:

F_r = 24,000 psi based on numerous published data from various glass manufacturers. This value is recognized in ASTM E 1300, ANSI Z97.1, ASTM C 1048 and CPSC 16 CFR 1201 (derivation of the value may be required). This value is referenced in numerous publications, design manuals and manufacturers' literature.

E = 10,400 ksi is used as the standard value for common glass. While the value of E for glass varies with the stress and load duration this value is typically used as an average value for the stress range of interest. It can be found in ASTM E 1300 and numerous other sources.

G = 3,800 ksi: This is available from various published sources but is rarely used when checking the deflection in glass. The shear component of the deflection tends to be very small, about 1% of the bending component and is therefore ignored.

$\mu = 0.22$ Typical value of Poisson's ratio for common glasses.

$\nu = 5x10^{-6}$ in/(inF°) Typical coefficient of thermal expansion.

Maximum allowable glass stress for tempered glass in guard rail application = 24,000psi/4 = 6,000psi

FEA models of different glass sizes were created using SCIA Engineer. The models were used to determine max stress from live loads and the maximum allowable wind load. The model uses a 3rd order analysis that accounts for large deflections. The glass models assume the PWC2 post because that post has the lowest standoff spacing which will result in the highest stresses on the glass.

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This report rates the glass for different glass sizes and thicknesses by its ability to carry the design live loads. The categories are shown below. Select the category that meets the requirements for the specific project, then use the tables on the following pages to select a glass size and thickness that meets that category. Wind load tables are also provided for different glass sizes and thicknesses.

Live Load resistance categories:
A: Resists 200# and 50plf live loads. 50plf live load causes deflection less than the glass thickness so no top rail or glass to glass connection brackets are required if laminated glass is specified. A top rail is required for monolithic glass.

B: May be used as a guard rail when the following conditions are met: There is a cap rail that connects adjacent panels together and the cap rail is connected at the ends of the guard rail to a supporting structure. May be used as wind screen without a top rail or glass to glass connection brackets.

C: May be used as a guard rail when the following conditions are met: There is a cap rail that connects adjacent panels together and the cap rail is connected at the ends of the guard rail to a supporting structure. The guard rail must be in a residential application or other locations where the guard is exempt from the 50plf live load. May be used as a windscreen with a top rail or glass to glass connection brackets.

D: Not suitable as a guard rail. May be used as wind screen or divider only. A top rail or glass to glass connection brackets are required to prevent excessive differential deflections.

E: May be used as a guard rail when the following conditions are met: There is a cap rail that connects adjacent panels together, and the cap rail is connected at the ends of the guard rail to a supporting structure. May be used as wind screen with a top rail or glass to glass connection brackets.

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3/8” OR 7/16” SG LAMINATED GLASS

The 3/8” or 7/16” glass may used as a short windscreen on top of another wall. It is not suitable to be used as a guard rail. Allowable wind loads for 24” max screen height are shown below.

Unadjusted Allowable Wind Load On Glass **2 posts per panel, 3/8” or 7/16” Laminated**					
		Glass Width (in)			
		36	48	60	72
Screen Height[1] (in)	24	245	150	100	70

Post Moment At Glass Failure **2 posts per panel, 1/2” or 9/16” Laminated**					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	8820	7200	6000	5040

No need to adjust wind loads. Max post moment = 8,820”#.

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1/2” OR 9/16” GLASS

May be used as windscreen or as a guard when certain criteria are met. See live load criteria definitions on page 23. The 1/2” glass may be used with 3 posts to increase the allowable wind load and live load category.

Live Load Check On Glass **2 posts per panel, 1/2” or 9/16” Laminated**					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	A	A	A	A
	36	B	C	C	C
	42	D	D	D	D

1) Measured from bottom of baseplate to top of glass.

Unadjusted Allowable Wind Load On Glass **2 posts per panel, 1/2” or 9/16” Laminated**					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	340	230	170	130
	36	95	70	55	50
	42	65	50	40	30

1) Measured from bottom of baseplate to top of glass.

Post Moment At Glass Failure **2 posts per panel, 1/2” or 9/16” Laminated**					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	12240	11040	10200	9360
	36	7695	7560	7425	8100
	42	7166	7350	7350	6615

Post Shear At Glass Failure 2 posts per panel, 1/2" or 9/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	1020	920	850	780
	36	427.5	420	412.5	450
	42	341	350	350	315

Live Load Check On Glass 3 posts per panel, 1/2" or 9/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	A	A	A	A
	36	B	B	B	C
	42	E	D	D	D

1) Measured from bottom of baseplate to top of glass.

Unadjusted Allowable Wind Load On Glass 3 posts per panel, 1/2" or 9/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	510	360	260	190
	36	130	100	80	65
	42	85	65	50	40

1) Measured from bottom of baseplate to top of glass.

Post Moment At Glass Failure 2 posts per panel, 1/2" or 9/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	15790	14861	13416	11765
	36	9056	9288	9288	9056
	42	8059	8217.3	7901	7585

Post Shear At Glass Failure 3 posts per panel, 1/2" or 9/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	1530	1440	1300	1140
	36	585	600	600	585
	42	446.25	455	437.5	420

Adjust 24" tall posts so max shear is 600#. This will make the moment less than 9,290"#. So the maximum design load on the post and anchorage is 9,290"# moment+600# shear.

Adjusted Allowable Wind Load On Glass 2 posts per panel, 1/2" or 9/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	200	150	120	100
	36	95	70	55	50
	42	65	50	40	30

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Adjusted Allowable Wind Load On Glass 3 posts per panel, 1/2" or 9/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	200	150	120	100
	36	130	100	80	65
	42	85	65	50	40

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3/4" OR 13/16" GLASS

May be used as windscreen or as a guard in any of the analyzed glass sizes. 13/16" SG laminated glass may be used without a cap rail. See live load criteria definitions on page 23.

Live Load Check On Glass
2 posts per panel, 3/4" or 13/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	A	A	A	A
	36	A	A	A	A
	42	A	A	A	A

1) Measured from bottom of baseplate to top of glass.

Unadjusted Allowable Wind Load On Glass
2 posts per panel, 3/4" or 13/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	650	515	390	305
	36	195	150	120	100
	42	120	100	80	65

1) Measured from bottom of baseplate to top of glass.

Post Moment At Glass Failure
2 posts per panel, 3/4" or 13/16" Laminated

		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	23400	24720	23400	21960
	36	15795	16200	16200	16200
	42	13230	14700	14700	14332.5

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Post Shear At Glass Failure 2 posts per panel, 3/4" or 13/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	1950	2060	1950	1830
	36	877.5	900	900	900
	42	630	700	700	682.5

Adjust 24" tall posts so max shear is 900#. This will make the moment less than 16,200"#. So the maximum design load on the post and anchorage is 16,200"# moment + 900# shear. The post will control when the PWC2 is used.

Adjusted Allowable Wind Load On Glass 2 posts per panel, 3/4" or 13/16" Laminated					
		Glass Width (in)			
		36	48	60	72
Guard Height[1] (in)	24	300	225	180	150
	36	195	150	120	100
	42	120	100	80	65

For cases where the post is placed in between panels and the post carries two panels the loading to the post will be doubled. The post strength will control in most cases. Design anchorage for 17,000"# + 17000/16200*900# = 944# to cover this case.

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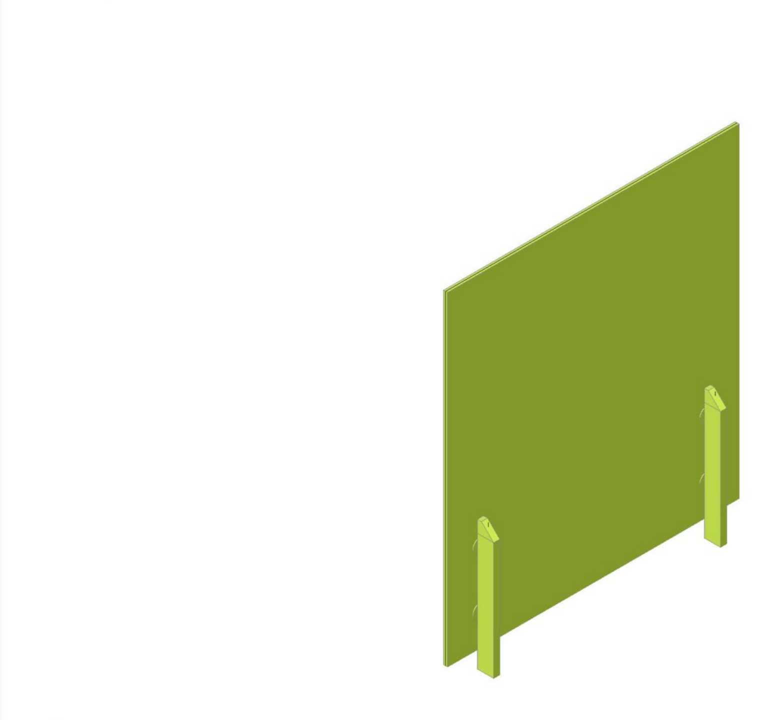
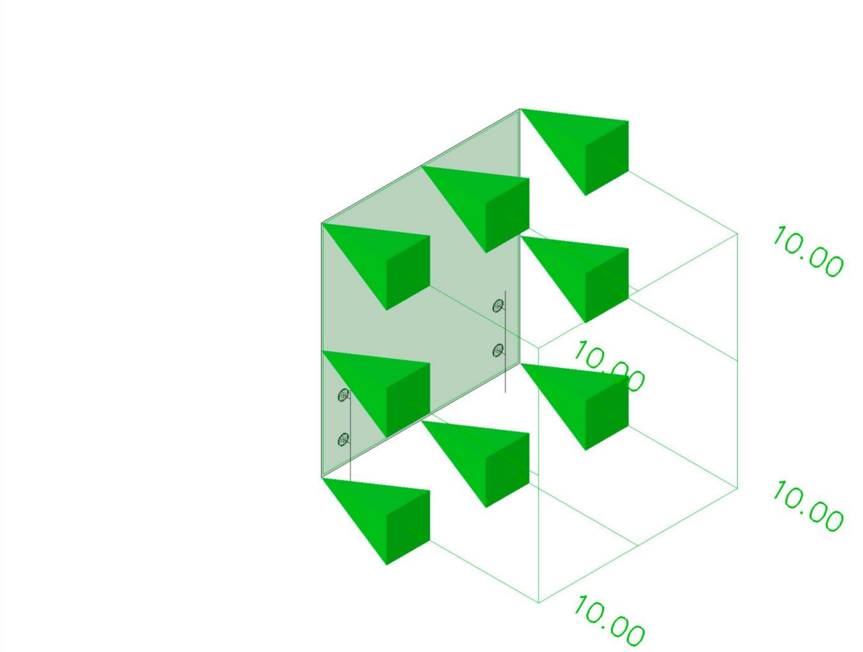
SCIA Result Diagrams:
A limited number of diagrams are shown below from the SCIA model. These models were repeated for each size and thickness considered. The 10psf uniform pressure shown is a test pressure that is scaled up to determine the max load that causes allowable stresses.

1. Analysis model



2. 10 psf Test Load / Tot. value



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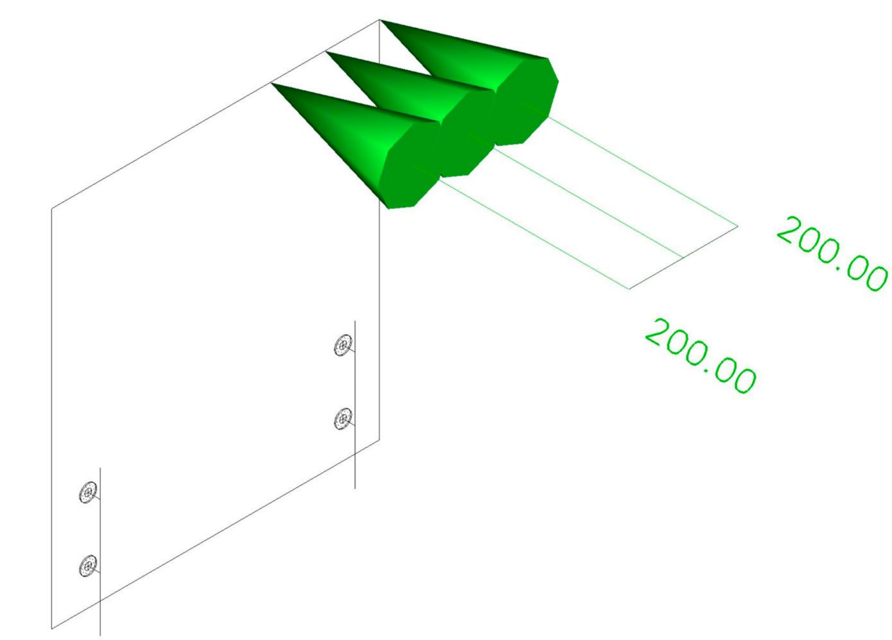
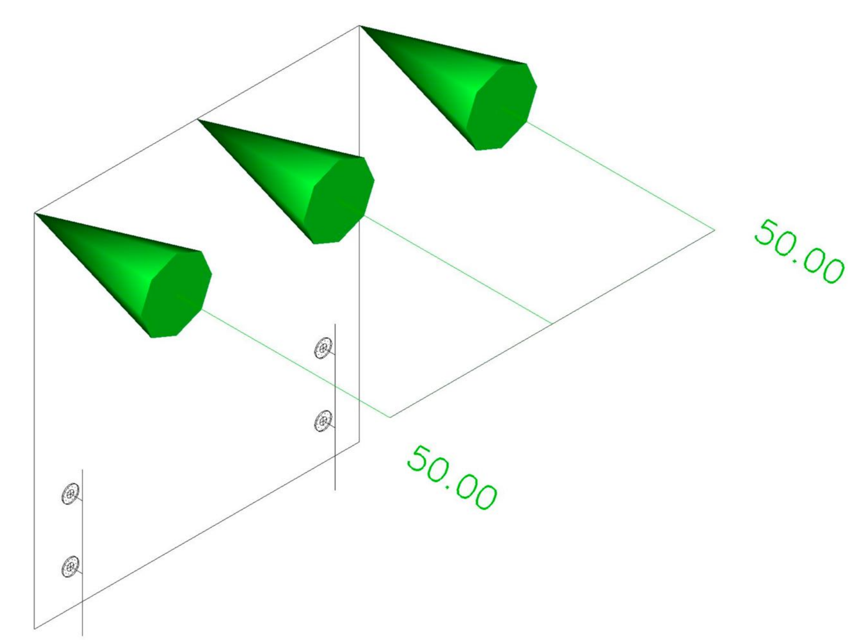
3. 200# Live Load / Tot. value



4. 50plf Live Load / Tot. value



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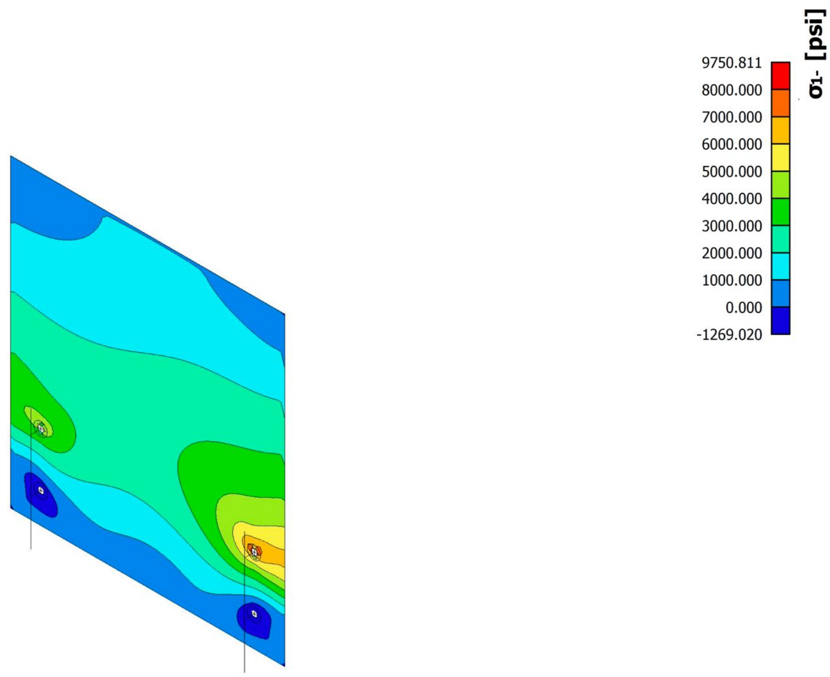
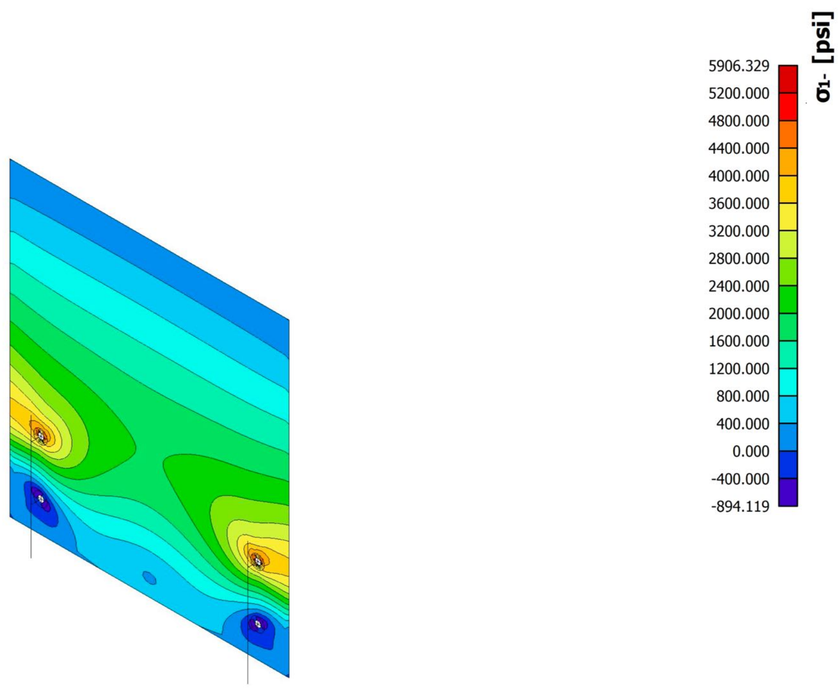
5. 2D stress/strain; σ_1-

Values: σ_{1-}
Nonlinear calculation
NonLinear Combi: D+200#
Extreme: Global
Selection: All
Filter: Material = Glass
Location: In nodes avg.. System: LCS
mesh element



6. 2D stress/strain; σ_1-

Values: σ_{1-}
Nonlinear calculation
NonLinear Combi: D+50plf
Extreme: Global
Selection: All
Filter: Material = Glass
Location: In nodes avg.. System: LCS
mesh element



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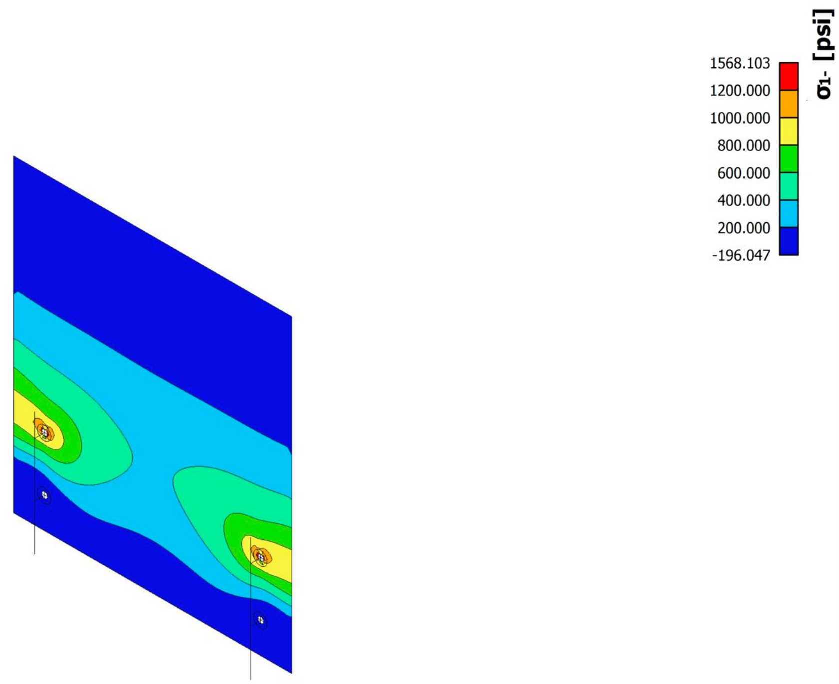
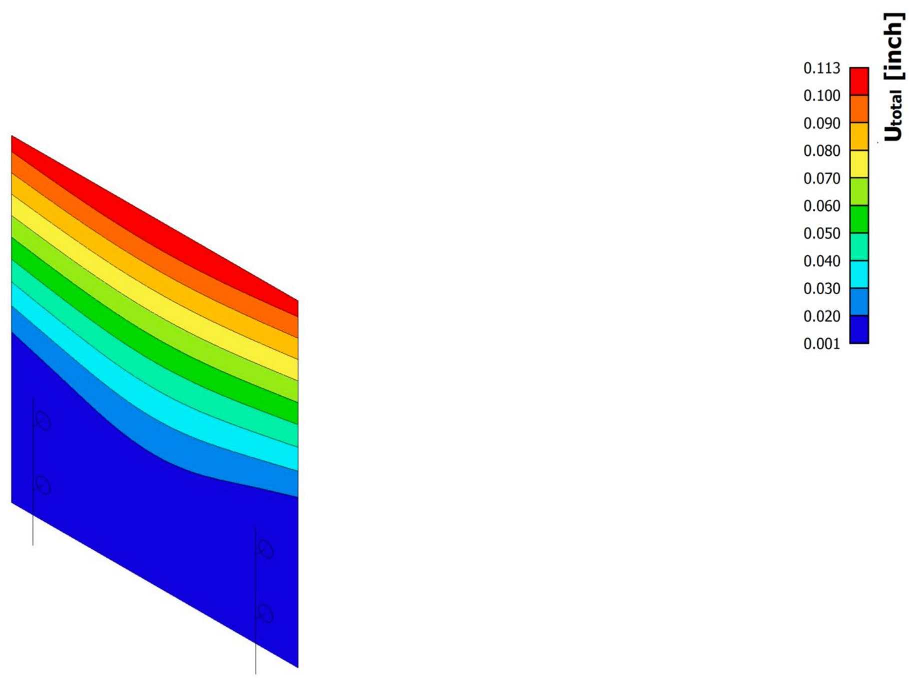
7. 2D stress/strain; σ_1-

Values: σ_{1-}
Nonlinear calculation
NonLinear Combi: D+W
Extreme: Global
Selection: All
Filter: Material = Glass
Location: In nodes avg.. System: LCS
mesh element



8. 2D displacement; U_total

Values: U_{total}
Nonlinear calculation
NonLinear Combi: D+W
Extreme: Global
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element



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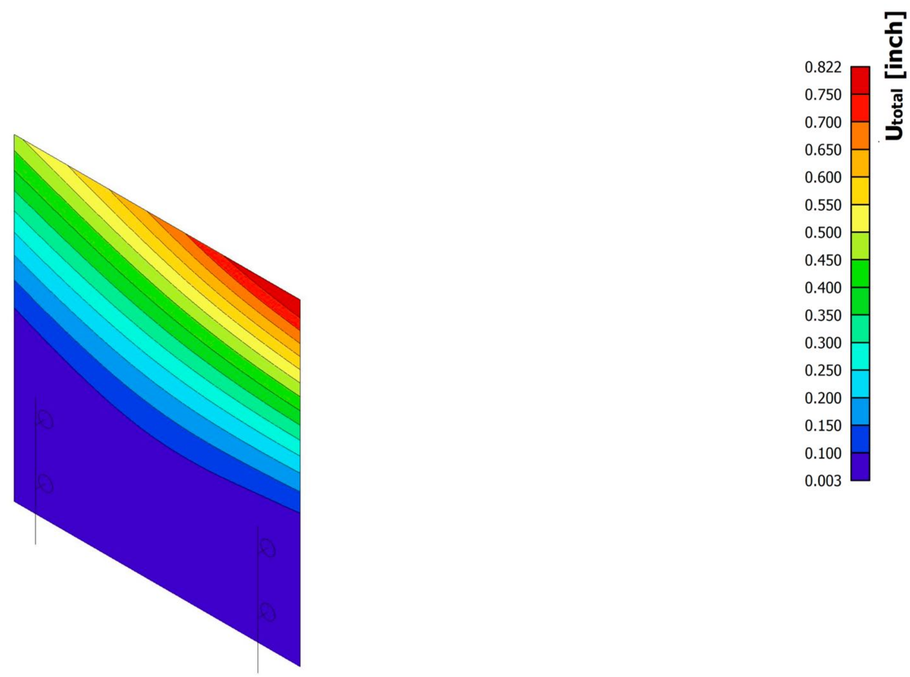
9. 2D displacement; U_total

Values: U_{total}
Nonlinear calculation
NonLinear Combi: D+200#
Extreme: Global
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element



10. 2D displacement; U_total

Values: U_{total}
Nonlinear calculation
NonLinear Combi: D+50plf
Extreme: Global
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element

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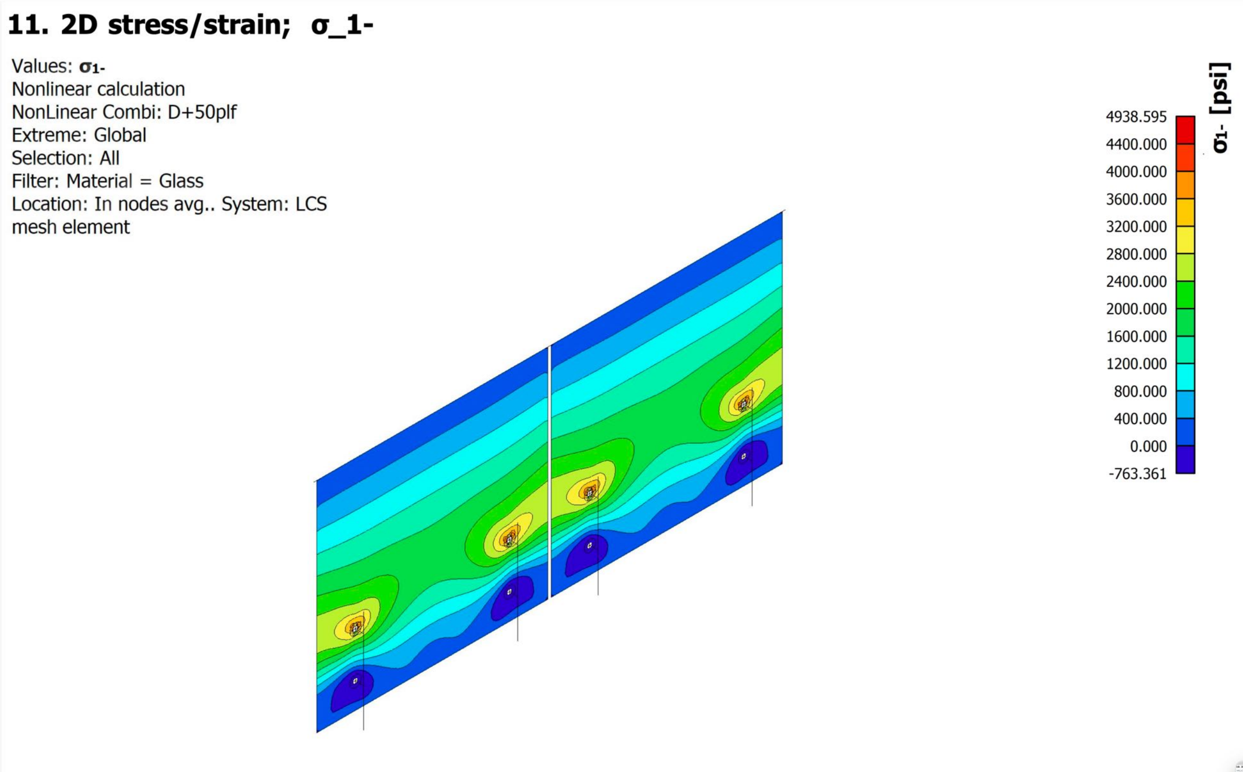

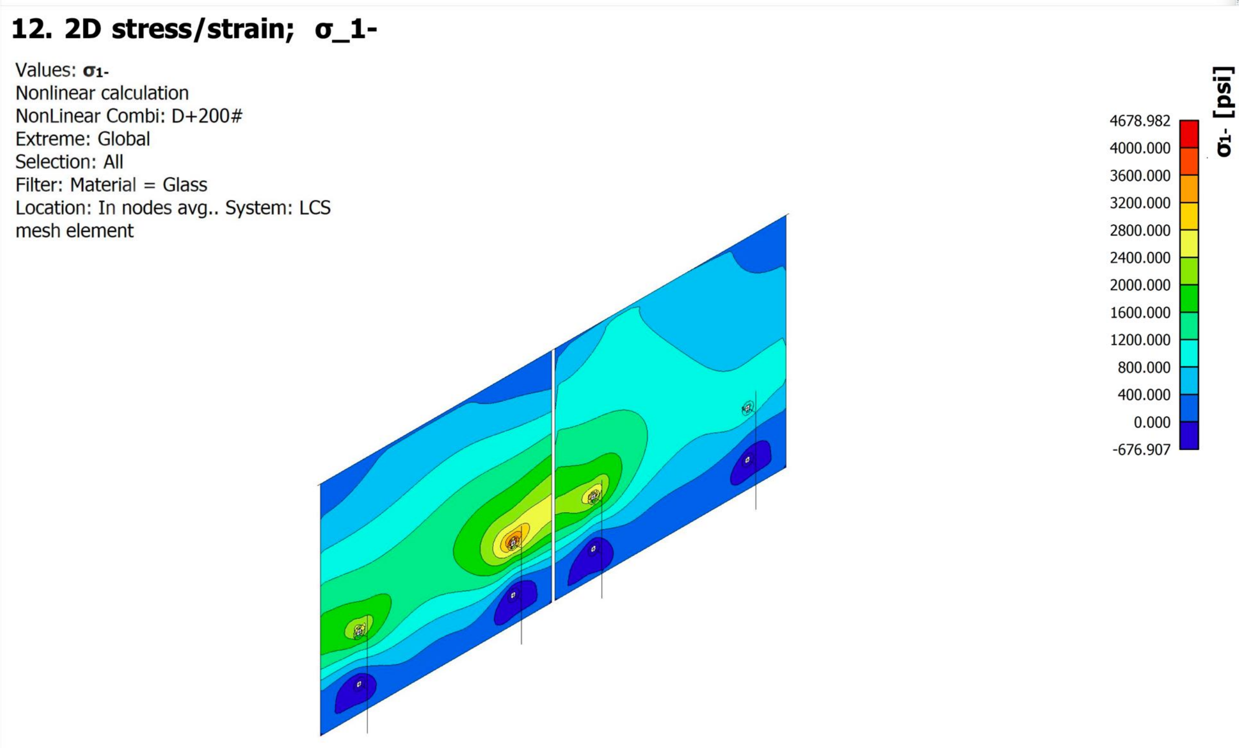

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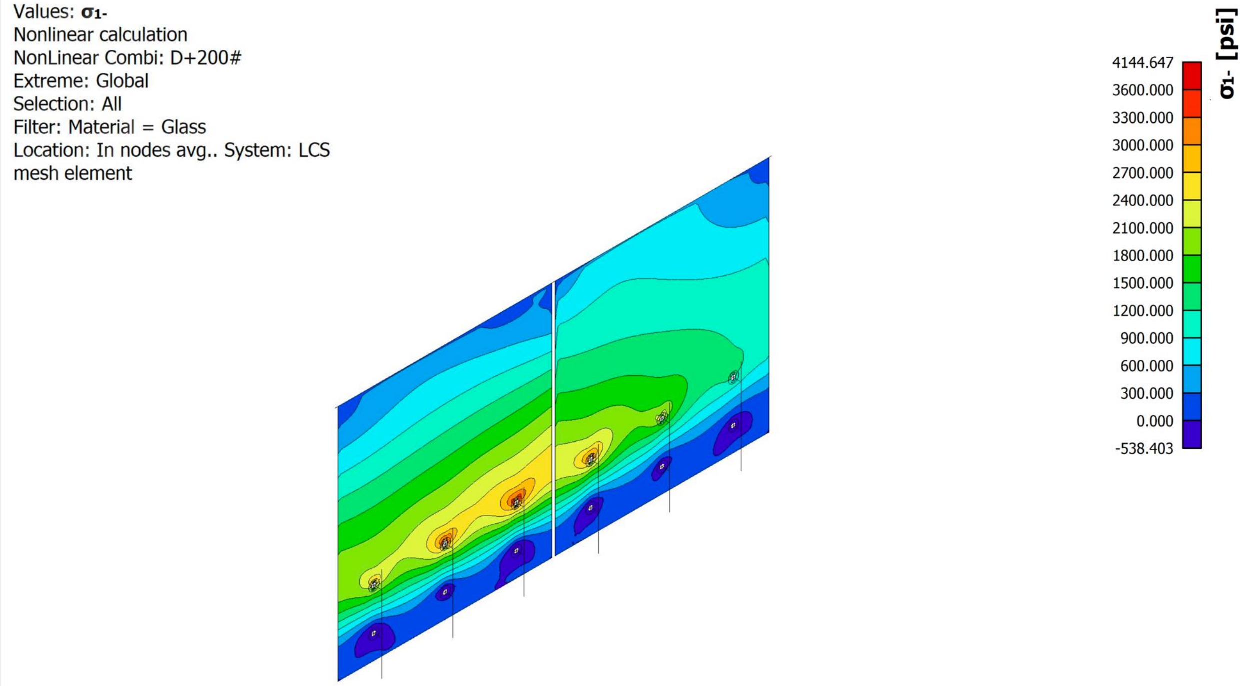
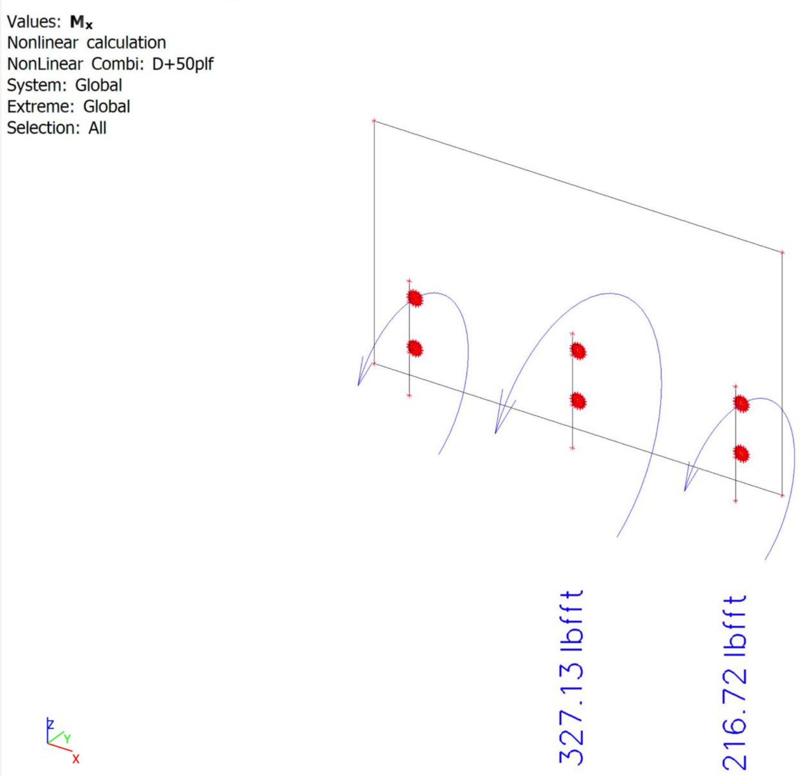
13. 2D stress/strain; σ_1-



14. Reactions; M_x



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