Architectural Railing Division
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SUBJ: GLASS WINDSCREEN SYSTEM
   FRAMELESS WINDSCREEN CLAMP SYSTEM
   AFWC1/AFWC6, AFWC2/AFWC7, AFWC3/AFWC8, AFWC4, AFWC1S. AFWC4
   DFWC3 - ALL VARIANTS
   FRICTION FIT CLAMPS FWCR10, FWCS10, FWCS20, FWCR20

The frameless windscreen system uses stainless steel clamps to point support fully tempered glass lights. The windscreen system is designed for the following loading conditions:
   50 plf load along glass at 42" above finish floor horizontal (where applicable) or
   200 lb concentrated load at 42" above finish floor horizontal (where applicable) or
   50 lbs on one square foot at any location on glass (always applicable) or
   wind load as shown in attached calculations for specified panel size.

The frameless windscreen clamps may be used for fall protection in one- and two-family residential occupancies and locations included in IBC 1607.8.1 Exceptions 1 and 2 when installed with 3 panels minimum of ½" tempered glass and installed with a top rail capable of spanning 10 feet. For these conditions the system will support the 200 lb load vertically or horizontally with a factor of safety of 4.0 against glass failure.   Allowable loading for given panel height shall be in accordance with table 2 or as calculated using the equations herein. This report is valid for glass light lengths from 36" to 72" long and up to 60" tall. Allowable loading for given panel height shall be in accordance with table 1. The clamps should be installed at 1/4 the panel length from each end. Loads on the clamps shall not exceed the values given herein and as summarized in Table 4.

For these conditions the railing meets all applicable requirements of the 2006, 2009, 2012 and 2015 International Building Codes and 2010 and 2013 California Building Codes, 2010 and 2013 California Residential Codes and other state and local building codes adopting the International Building Codes. Stainless steel components are evaluated 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. The glass components are evaluated in accordance with GANA *Glazing Manual*, *Tempered Glass Engineering Standards Manual* and *Laminated Glazing Reference Manual*. The system may be designed and constructed using the methodology detailed herein to be compliant with ASTM E 2358 *Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades* and ICC

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Acceptance Criteria AC 439 *Acceptance Criteria for Glass Railing and Balustrade Systems* (July 2015).

The specifier shall verify the suitability of the system for any specific installation to include but not limited to the wind load conditions, fall protection requirements, substrate support and any local codes or other requirements. This report may be used by a qualified professional as a guide in preparing a project specific design.

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                                               Signed 08/14/2015

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Typical loads:

Load cases illustrated on Figure 1.
Live Loads:
50 plf load along glass at 42" above
finish floor horizontal:

LOADS ON CLAMPS
V_c = shear load on clamp
M_c = Moment on clamp
$V_c = 50plf*S/2$
$M_c = 50plf*42"*S/2$

or
200 lb concentrated load at 42" above
finish floor horizontal
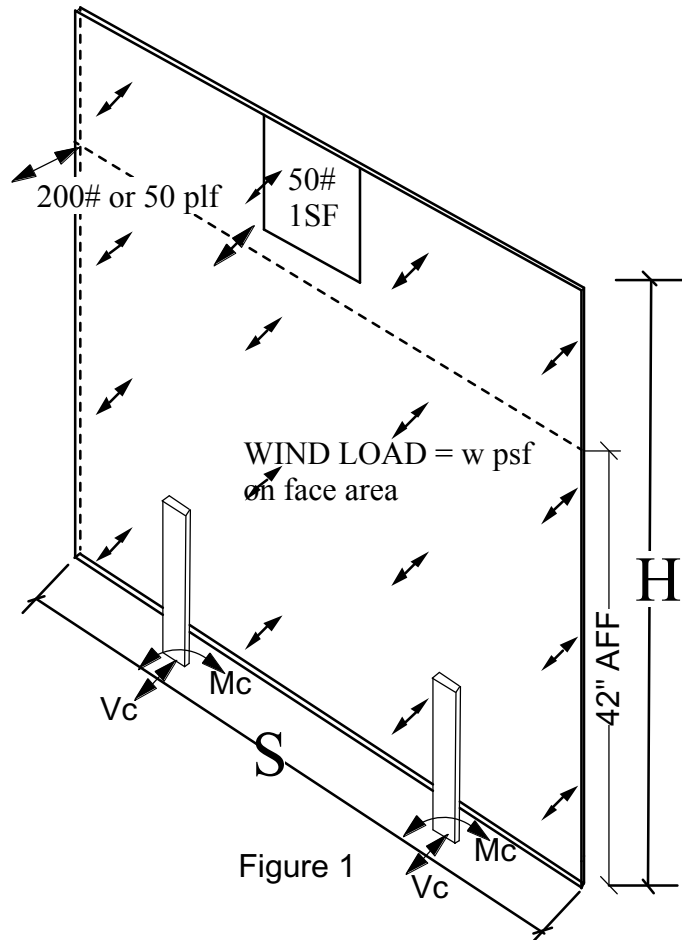$V_c = 200/Cc$ where
C_c from Figure 2
$M_c = V_c*42"$

or
Wind load uniform load over entire glass
light area. **Wind load must be
determined by a competent
professional for a specific installation.**

$V_c = w*H*S/2$
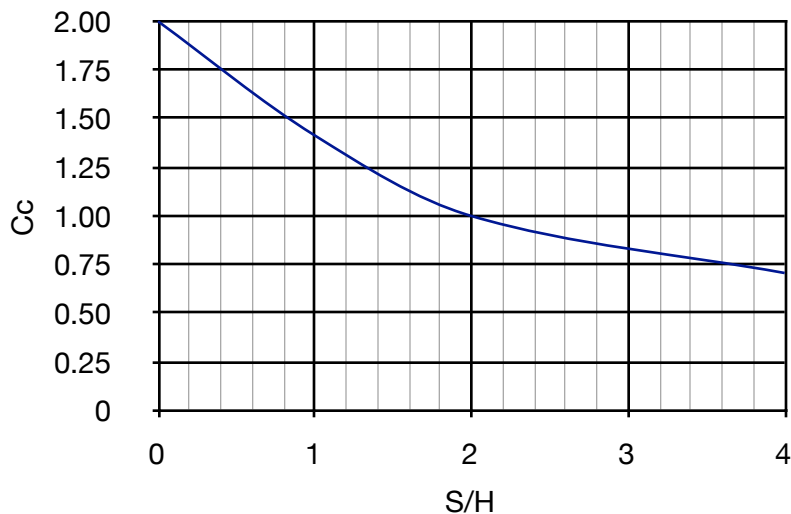$M_c = V_c*H*0.55$

All loads must be considered as
acting inwards or outwards.

**The clamp loads must be
determined to verify that the
allowable loads as shown in
table 4 aren't exceeded.**

Figure 1

Figure 2

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. The average Modulus of Rupture for the glass F_r is 24,000 psi. . In accordance with IBC 2407.1.1 glass used as structural balustrade panels shall be designed for a safety factor of 4.0. This is applicable only to structural panels (glass provides support to railing). Other locations the glass stress may be increased to as high as 10,600 psi edge stress in accordance with ASTM E1300-00.

> Allowable glass bending stress: 24,000/4 = 6,000 psi. – Tension stress calculated.
> Allowable compression stress = 24,000psi/4 = 6,000 psi.
> Allowable bearing stress = 24,000 psi/4 = 6,000 psi.
> For wind loads only: allowable stress from ASTM E-1300 = 10,600 psi

Bending strength of glass for the given thickness:

$$S = \frac{12" * (t_{min})^2}{6} = 2* (t_{min})^2 \text{ in}^3/\text{ft}$$

For 1/2" glass $t_{min} = 0.469"$; $t_{ave} = 0.50"$

$S = 2*(0.469)^2 = 0.44 \text{ in}^3/\text{ft}$

$M_{allowable} = 6,000\text{psi}*0.44 \text{ in}^3/\text{ft} = 2,640"\#/\text{ft} = 220'\#/\text{ft}$

For wind load case:

$M_{allowable} = 10,600\text{psi}*0.44 \text{ in}^3/\text{ft} = 4,664"\#/\text{ft} = 352'\#/\text{ft}$

For 3/8" glass $t_{min} = 0.355"$; $t_{ave} = 0.380"$

$S = 2*(0.355)^2 = 0.252 \text{ in}^3/\text{ft}$

$M_{allowable} = 6,000\text{psi}*0.252 \text{ in}^3/\text{ft} = 1,512.3"\#/\text{ft} = 126.0'\#/\text{ft}$

For wind load case:

$M_{allowable} = 10,600\text{psi}*0.252 \text{ in}^3/\text{ft} = 2,671"\#/\text{ft} = 222.6'\#/\text{ft}$

For 9/16" laminated glass fabricated with a 0.06" DuPont SentryGlass interlayer use the 1/2" glass design table. For laminated glass fabricated with PVB interlayer use the 3/8" glass tables. Or use the effective glass thickness shown in table 3 in the provided equations to evaluate the allowable glass loads and deflections.

For 7/16" laminated glass fabricated with a 0.06" DuPont SentryGlass interlayer use the 3/8" glass design table or use the effective glass thickness shown in table 3 in the provided equations to evaluate the allowable glass loads and deflections. For laminated glass fabricated with PVB interlayer use effective glass thickness shown in table 3 in the provided equations to evaluate the allowable glass loads and deflections.

Determine Glass Stresses:

The glass is subject to stress concentrations which are a function of the glass height and width. The stress concentrations were modeled using finite element analysis models-

Models were prepared using VisualFEA program flat plate analysis. The stress concentration effects were normalized by dividing the peak model stress by the calculated average stress to develop the proposed design curves for determining the peak glass stress. Based on the developed curves it was determined that the moment amplification factor could be simplified to a single value for each glass width.
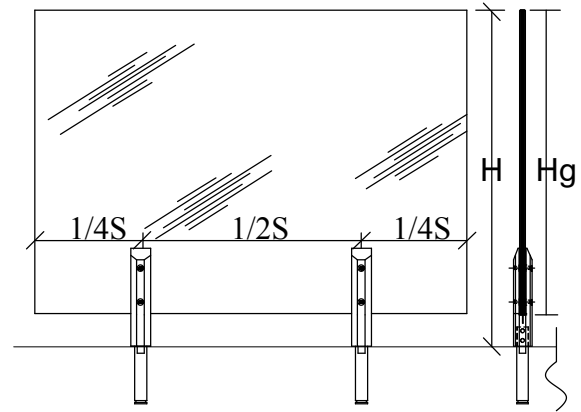
Figure 4

Linear interpolation for widths between those shown may be used to determine the amplification factor (ß).

Table 1: Moment Amplification Factor based on glass light width

Width B	≤36"	48"	60"	68"	72"
ß	1.84	2.12	2.53	2.87	3.00

To calculate the peak glass moment (in-lb per foot) the average bending moment is calculated based on a simple cantilever and then multiplied by the amplification factor ß:

For 50 plf live load at 42" above finish floor or top of glass whichever is less:

$M_{gL} = ß*50plf*h$ or $= ß*50plf*H_g$

where h = 42" minus height from walking surface to bottom of glass

For 200# concentrated load at 42" above finish floor or top of glass whichever is less:

$M_{gL} = ß*200\#*(h/B)*12$ (in-lb per foot)

For 50# concentrated load on one square foot at any location (top corner controls):

$M_{gL} = ß*50\#*(H_g/B)*12$ (in-lb per foot)

50 lbs on one square foot concentrated load doesn't need to be checked if the 50 plf or 200 lb loads are checked. 50plf and 200 lb load cases only need to be checked if installation is required to provide fall protection or pool/spa fence. 50 lbs on one square foot concentrated load is the only live load check required when used as a wind screen only.

For wind loads:

$M_{gw} = ßwH_g^2*0.55/12$ (in-lb per foot) for w in psf and H_g in inches

Peak Glass Stress:

$f_{bg} = M/(2*t_{min}^2)$ in psi

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GLASS DEFLECTIONS

There is no building code defined limit on the glass deflections. ASTM E 2358 *Standard Specification for the Performance of Glass in Permanent Glass Railing Systems, Guards, and Balustrades* limits deflection to H/12 (ASTM E 6.2.1.1). ICC Acceptance Criteria AC 439 *Acceptance Criteria for Glass Railing and Balustrade Systems* (July 2015) Paragraph 3.3 applies a 1 inch deflection limit to the glass for the live load cases.

The finite element models were used to determine the deflection amplification caused by the reduced stiffness provided by the point supports using the clamps.

The deflection of glass may be estimated using the following equation:

$\Delta = \lambda 50 H_g^3 / (3*10.4 \times 10^6 * t_{ave}^3)$

λ = deflection amplification factor which is a function of the height and width and may be taken from the appropriate width curve in figure 4 or assumed as:

0.82 for 36" width, 0.85 for 48" width, 0.92 for 60" width or 0.98 for 72" width.

λ is less than 1 because the glass clamp extends up the glass about 6 inches reducing the effective cantilever height of the glass while the total glass height is used in the calculation for consistency with the moment calculations, simplify the tables and figures and allow use with all clamp styles.
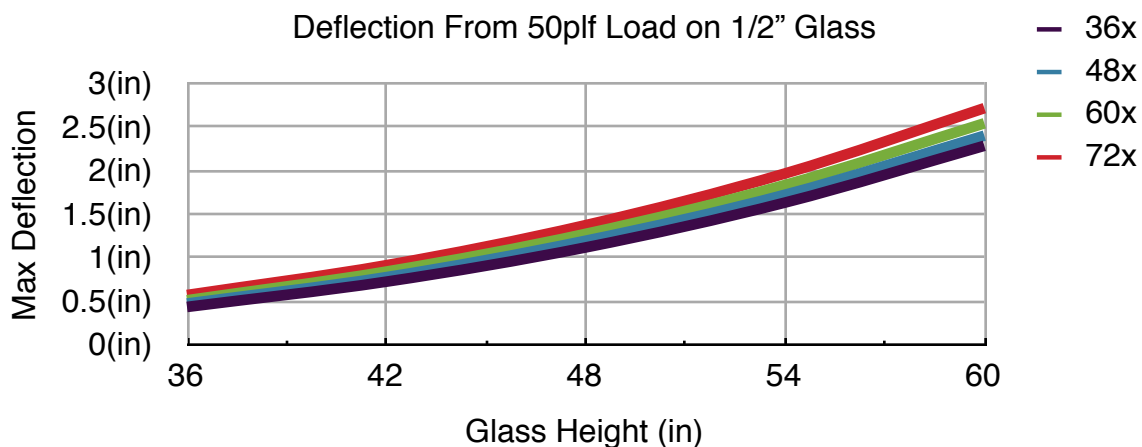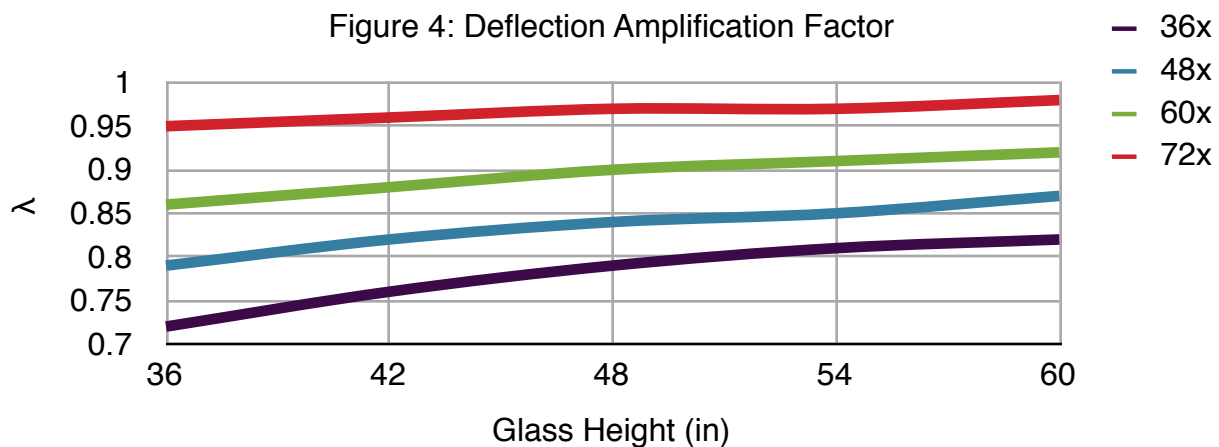
Figure 4: Deflection Amplification Factor

Deflection From 50plf Load on 1/2" Glass

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Allowable wind loads on the wind screen are a function of the glass light height and width. The allowable wind load may be calculated from :

$w_{all} = M_{all}*12/(ßH_g^2*0.55) = 462545t_{min}^2/(ßH_g^2)$

(derived from the equations on page 5)
Or taken from Table 3.

TABLE 2

			For 1/2" Glass		For 3/8" glass	
Glass Thickness (inches) t_{min}=			0.469		t_{min}	0.355
Width in	Height in	ß	1/2" M_{wall}	1/2" W_{all} psf	3/8" M_{wall}	3/8" W_{all} PSF
36	36	1.84	4663	42.7	2672	24.4
36	42	1.84	4663	31.3	2672	18.0
36	48	1.84	4663	24.0	2672	13.8
36	54	1.84	4663	19.0	2672	10.9
36	60	1.84	4663	15.4	2672	8.8
48	36	2.12	4663	37.0	2672	21.2
48	42	2.12	4663	27.2	2672	15.6
48	48	2.12	4663	20.8	2672	11.9
48	54	2.12	4663	16.5	2672	9.4
48	60	2.12	4663	13.3	2672	7.6
60	36	2.53	4663	31.0	2672	17.8
60	42	2.53	4663	22.8	2672	13.1
60	48	2.53	4663	17.5	2672	10.0
60	54	2.53	4663	13.8	2672	7.9
60	60	2.53	4663	11.2	2672	6.4
72	36	3.00	4663	26.2	2672	15.0
72	42	3.00	4663	19.2	2672	11.0
72	48	3.00	4663	14.7	2672	8.4
72	54	3.00	4663	11.6	2672	6.7
72	60	3.00	4663	9.4	2672	5.4

Minimum design wind load is typically 10 psf for exterior installations and 5 psf for interior installations. Linear interpolation between the dimensions shown may be used.

The wind loads for a specific installation shall be determined by a qualified professional considering wind speed, exposure, terrain, location on structure, use and other applicable factors.

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LAMINATED GLASS:

Laminated tempered glass may be used with the glass clamps. The effective thickness of the laminated glass may be determined per ASTM E1300-12a appendix X9.   For determining the effective glass thickness use the lesser of the glass width or glass height. Typically the laminated glass is fabricated with 0.06" interlayer of either PVB or DuPont SentryGlas+® ionoplast interlayer. Table 3 may be used to select the effective glass thickness for 7/16" and 9/16" laminated glass made with either PVB or SGP evaluated at 120˚F.

Table 3 - Effective Thickness of Laminated Glass:

		PVB		SGP (psi)	
G		70		1638.9	
	$h_1 = h_2$	h_v	$h_{s;1} = h_{s;2}$	l_s	h_s
5/16"	0.18	0.06	0.12	0.005184	0.24
1/4"	0.219	0.06	0.1395	0.008524	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

	Shortest Dimension	Γ PVB	Γ SGP	$h_{ef;w}$ PVB	$h_{ef;w}$ SGP	$h_{1;ef;\sigma}$ PVB	$h_{1;ef;\sigma}$ SGP
3/16+0.06+ 3/16 = 7/16" Laminated Glass	36	0.144	0.798	0.274	0.394	0.310	0.406
	42	0.186	0.843	0.285	0.400	0.322	0.409
	48	0.230	0.875	0.296	0.404	0.332	0.412
	54	0.275	0.899	0.306	0.407	0.342	0.413
	60	0.319	0.916	0.316	0.409	0.350	0.414
1/4"x0.06"x 1/4" = 9/16" Laminated Glass	36	0.121	0.764	0.322	0.463	0.364	0.479
	42	0.158	0.815	0.334	0.471	0.376	0.484
	48	0.197	0.852	0.345	0.476	0.388	0.487
	54	0.237	0.879	0.356	0.481	0.398	0.489
	60	0.278	0.900	0.367	0.484	0.408	0.490

$h_{ef;w}$ = effective glass thickness for deflections
$h_{1;ef;\sigma}$ = effective glass thickness for bending stress

GLASS CLAMPS
The glass clamp is composed of an adjustable clamping system which is made up of stainless steel clamp bodies (either cast or wrought depending on style), 5/16" diameter screws through the glass, and gaskets with varying thicknesses to accommodate selected glass thickness. The clamp varies in height by style but all styles have a similar glass bite.   Various clamps are available for installation on substrates of concrete, metal and wood and attachment to the surface or fascia.

The CRL clamps require either one or two 3/4" holes through the glass at each clamp depending on the specific style. The holes are used to tie the clamp bodies together through the glass to provide the clamping force and develop the full clamp strength. Where indicated herein some styles of clamps may be used without the glass hole at a reduced clamp strength.

The maximum allowable moment on the clamps shall not exceed the moments indicated herein.

Available clamp styles covered in this report

AFWC1/6   AFWC3/8   AFWC2/7   DFWC3   AFWC4   AFWC4S   AFWC1S
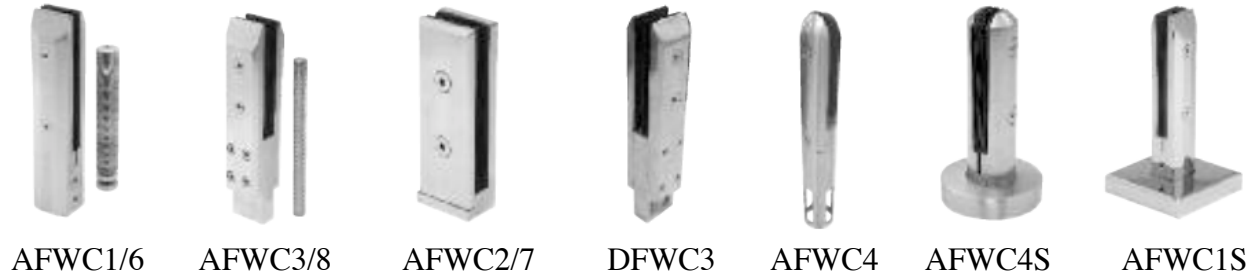
The Friction Fit Clamps are intended for installations without holes through the glass. These clamps don't have a through glass bolting option and are intended for locations with lesser wind loads or small light sizes and where fall protection typically isn't required.

FWCR10   FWCS10   FWCR20   FWCS20

AFWC1/AFWC6

One Piece Post Option: 316 Stainless Steel casting with glass pocket mounted on 1-3/16" (30mm) stainless steel rod core mounted into concrete.

Gasket for 3/8" or 1/2" (10 or 12 mm) Glass

1-15/16" (50 mm)

9-13/16" (250 mm)

CAT. NO. AFWC1

Check bending strength of bar:
Based on AISC Design Guide 27:
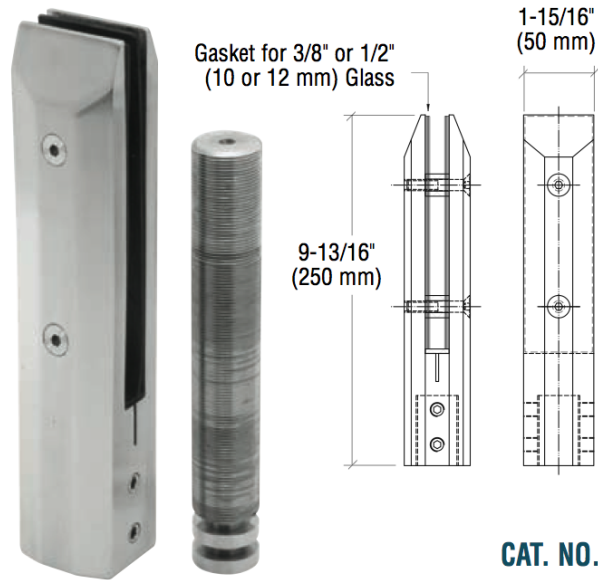$Z = d^3/6 = 1.181^3/6 = 0.2746$ in^3
Wrought 316 stainless steel bars
$F_y \geq 50$ ksi and $F_u \geq 75$ ksi
$M_n = 0.2746*50ksi = 13,730\#"$

$M_s = M_n/1.67$
$M_s = 13,730"\#/1.67$
$M_s = 8,222"\#$

Determine strength of anchorage into concrete:

Moment is resisted by vertical compression against the concrete by the embedded rod. The grooves on the end of the rod prevent withdrawal.
From Σ M about centroid of C_l:

$M_n = C_l*D(2/3)$
$C_u = \phi F_B$
F_B = shear block failure from ACI 318 App D.6.2
$F_B = 1.4*\sqrt{1.5}*7(6/1.181)^{0.2}(1.181*2500)^{1/2}*6^{1.5} = 13,267\#$
$C_u = 0.85*13,267\# = 11,277\#$
$M_n = 11,277\#*6*(2/3) = 45,108\#"$
$M_s = 0.70*45,108/1.6 = 19,735\#"$
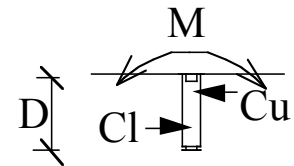
Minimum embed depth of 4.5"
$F_B = 1.4*\sqrt{1.5}*7(4.5/1.181)^{0.2}(1.181*2500)^{1/2}*4.5^{1.5} = 8,135\#$
$C_u = 0.85*8,135\# = 6,915\#$
$M_n = 6,915\#*4.5*(2/3) = 20,745\#"$
$M_s = 0.70*20,745/1.6 = 9,076\#"$

Check strength of clamp glass pocket.

Glass to clamp moment resisted by tension in cap screws:

Screw tension is proportional to distance from bottom screw to screw being considered:

      5/16" diameter cap screws upper two.

Screw tension strength - ASTM F 879

      $T = 3{,}980\#$ (ASTM F 879 Table 3)

      $T_a = 3{,}980/2 = 1{,}990\#$

Moment resistance M_a

      $M_a = 1{,}990\# * (5.625" + 3.6875"^2/5.625") = 16{,}004"\# \geq 8{,}222"\#$

ALLOWABLE DESIGN MOMENT = 8,222"# WITH BOLTS THROUGH GLASS

For installations without bolts through glass:

Check for bending of side plates:

      $S = 0.160 \text{ in}^3$

      $F_y = 30$ ksi for cast 316 Stainless steel

      $M_n = ZF_y = 0.160 * 30 \text{ ksi} = 4{,}800 "\#$

      $M_a = 4{,}800/1.67 = 2{,}874"\#$

ALLOWABLE DESIGN MOMENT = 2,874"# WITHOUT BOLTS THROUGH GLASS

AFWC2/7

CRL Two-Piece Side Mount Frameless Windscreen Clamp

new

- **316 Grade Stainless Steel in Two Architectural Finishes**
- **Great for Windscreens or Glass Partitions (Not Designed for Guard Rail Applications)**
- **For 3/8" or 1/2" (10 or 12 mm) Tempered Monolithic Glass and 9/16" (13.52 mm) Tempered Laminated Glass**

CRL Two-Piece Side Mount Frameless Windscreen Clamps are designed for attachment to the front side of walls or planter boxes. Due to the number of varying mounting conditions, anchors and mounting screws are not supplied. The back plate is fabricated to accept 8 mm (5/16") flat head screws. Glass fabrication requires two 3/4" (19 mm) holes per Clamp. An instruction sheet and glass fabrication template are supplied.
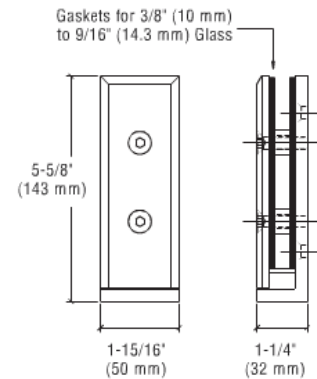
CAT. NO.	FINISH
AFWC2	Brushed Stainless
AFWC7	Polished Stainless

Minimum order: 1 each.

CAT. NO. CAP35S — Replacement Bolt

Gaskets for 3/8" (10 mm) to 9/16" (14.3 mm) Glass

5-5/8" (143 mm)
1-15/16" (50 mm)
1-1/4" (32 mm)

Clamp is mounted to a deck edge, beam web or wall face to support the glass light. Clamp may be installed to concrete, steel or other metal or wood. Clamp body is attached to the supporting structure using two 5/16" dia countersunk screws.

For anchorage to steel use two countersunk stainless steel screws:
Screw tension strength - ASTM F 879

$T = 3,980\#$ (ASTM F 879 Table 3)
$T_a = 3,980/2 = 1,990\#$
$V_a = 0.6*1990 = 1194\#$

Moment strength of anchorage to steel:
$M_s = 1,990\#*4.75" = 9453"\#$
$V_s = 0.2*2*1194 = 478\#$

7/8" (22.2 mm)
3-1/2" (88.9 mm)
5-5/8" (142.9 mm)
1-15/16" (49.2 mm)
3-1/8" (79.4 mm)
1-3/16" (30.1 mm)
13/16" (20.6 mm)
1/8" (3 mm)
1-1/4" (31.7 mm)
1-1/4" (31.7 mm)
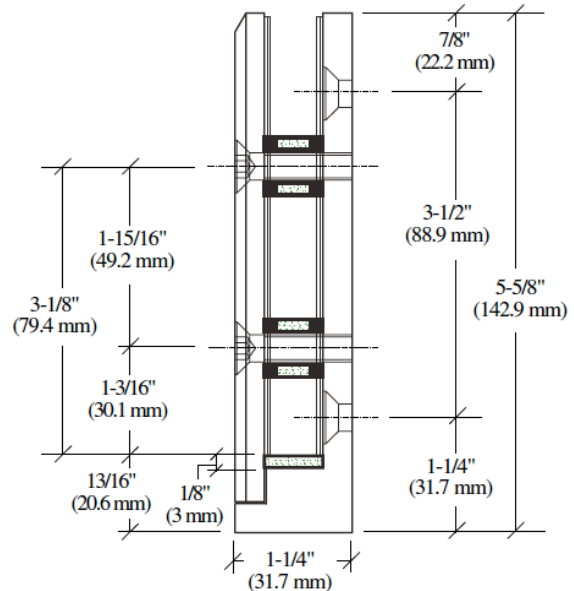
For anchorage to concrete - Assumed conditions:
Minimum concrete strength f'c = 3,000 psi
Minimum concrete edge distance = 1.75"
Alternative anchorage may be designed for specific project conditions.

For anchorage to concrete using two 1/4" x 2-1/2" Tapcon screws with 1.75" effective embedment:
$T_a = 550\#$ (ITW Red Head technical information)
$V_a = 420\#$
$M_s = 550*4.75" = 2,613"\#$
$V_s = 0.2*2*420 = 168\#$

For 1/4" countersunk screw into Red Head Multi-Set II Drop-In Anchor
T_a = 590# (ITW Red Head technical information)
V_a = 270#
M_s = 590*4.75" = 2,803"#
V_s = 0.2*2*270 = 108#

For wood:
5/16" x 4" wood screw into wood with G ≥ 0.46
Assumes installation is in location where wood moisture content remains below 19%
Withdrawal strength of screw from National Design Specification for Wood Construction 11.2.2:
$W = 2850G^2D = 2850*0.46^2*0.3125 = 180$ pli
$W' = C_DWe$
C_D = 1.6 for wind loads
e = 3 1/8"
W' = 1.6*180pli*3.125" = 900#

Shear strength based on NDS 11.3.1
$Z_\perp$ = 170#
$Z'_\perp = C_DZ_\perp = 1.6*170\# = 272\#$
Combined lateral and withdrawal loads (NDS Table 11.4)
$Z'_\perp = (W'Z')/[W'Cos^2\alpha + Z'sin^2\alpha]$
For assumed dead load of 78# on bracket (39# on screw) and W = 700#
$\alpha = \tan^{-1}(700/39) = 86.8°$ resultant = $\sqrt{(700^2+39^2)} = 702\#$
$Z'_\perp = (900*272)/[900Cos^286.8° + 272sin^286.8°] = 894\#$
Screw withdrawal strength may be increased to 890# for maximum light size:
M_s = 890*4.75" = 4,228"#
V_s = 2*39 = 78# dead load

When attached to wood subject to wetting where moisture content will exceed 19% at any time after installation then the allowable loads are to multiplied by C_M = 0.7.

AFWC3/8

Three Piece Core Mount Frameless Windscreen Clamp
Post is attached to 5/8" (16mm) rod set into concrete and grouted to base of side bars. For full clamp strength grout must be to base of side plates

Determine strength of anchorage into concrete:

Moment is resisted by a combination of vertical compression against concrete with tension in the anchor rod and by bending of center plate which is anchored by horizontal compression against concrete.

Nominal strength of vertical compression of side plate against concrete:

$\phi F_B = \phi \beta f'c$ where:

$\beta = \sqrt{(A2/A1)} = \sqrt{16}/(1/2"*1\ 15/16)$ but ≤ 2.0

and $f'_c = 6$ ksi for specified anchoring grout

$\phi F_B = 0.85*2*6,000 = 10,200$ psi

$Cp_n = 0.5"*1.9375"*10,200$ psi $= 9,881\#$

Bar tension strength, nominal

$F_y = 75$ ksi (1/4 hard A316)

$T_b = 0.195\ in^2*75$ ksi $= 14,625\#$

Cp_n controls

$M_{Cpn} = 0.6875"*9,881\# = 6,793\#"$

Nominal strength from bending of center flat bar

Bar bending:

$Z = 1.9375"*0.9375^2/4 = 0.4257\ in^3$

$F_y = 45$ ksi

$Mp_n = 45$ ksi$*0.425\ in^3 = 19,157\ \#"$
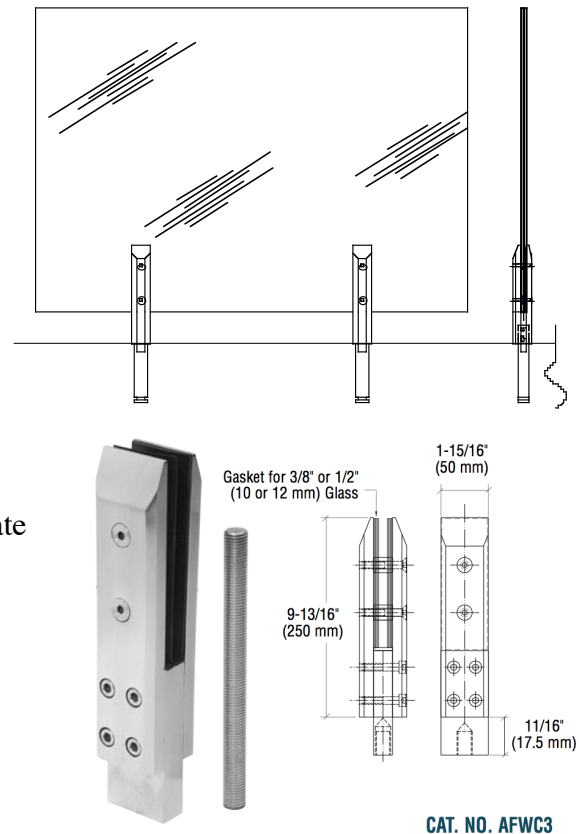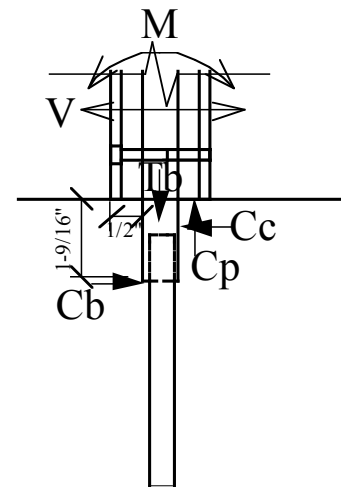
Gasket for 3/8" or 1/2" (10 or 12 mm) Glass

9-13/16" (250 mm)

1-15/16" (50 mm)

11/16" (17.5 mm)

CAT. NO. AFWC3

check anchorage:

Center plate is anchored into concrete:

V_n = shear strength of bar

$V_n = A*F_{yv} = 0.195*42ksi = 8,190\#$

Allowable shear in bar must be reduced for tension:

$1 \geq (T/T_n)^2 + (V/V_n)^2$

$V_b = V_n [1-(T/T_n)2] = 8190\#*[1-(9881\#/14625\#)^2] = 4,452\#$

Check anchor strength of bar:

$C_u = V_b + C_l$ and $V_b = C_l$

$C_u = 2*4,452\# = 8,904\#$

Bearing length along bar for:

$\qquad F_{BC} = 10,200$ psi

$\qquad L = [C_u/(d_b F_{BC})]/0.85$

$\qquad L = [8,904\#/(1/2"*10,200psi)]/0.85 = 2.05" < 4"$ Bar length is adequate

Determine C_c

Maximum value for C_c if in full compression:

$\qquad C = 1.56"*1.9375"*10,200$ psi$* 0.85 = 26,205\# >V_b$

C_c must be balanced with Vb and C_b

$\qquad a$ = compression depth for C_c

$\qquad C_b + V_b = C_c$ and

$\qquad C_b = (1.56"-a)*1.9375"*10,200$ psi

$\qquad C_c = a*1.9375"*10,200$ psi

substituting into above and solving for a:

$\qquad (1.56"-a)1.9375"*10,200psi+4,452\# = 1.9375"*10,200psi*a$

$\qquad (1.56"-a)+0.2253" = a$

$\qquad 1.79" = 2a$

$\qquad 0.89" = a$

Calculate C_c from a

$\qquad C_c = 0.89"*1.9375"*10,200psi = 17,589\#$

$\qquad C_b = 17,589-4,452 = 13,137\#$

Calculate the resisted moment by ΣM about Cc

$\qquad Mh_n = (1.56"-0.89/2)*4,452+(1.56"/2-0.89"/2)*13,137 = 9,365\#"$

The total nominal moment strength of the anchorage:

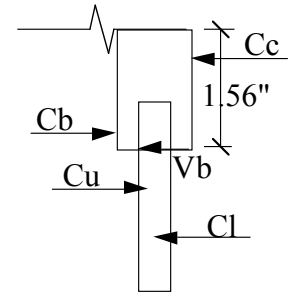$\qquad M_n = Mh_n+ Mc_{Pn} = 9,365\#"+ 6,793\#" = 16,158\#"$

$\qquad M_s = \emptyset M_n/1.6 = 0.75*16,158\#"/1.6 = 7,574\#"$

Allowable service moment based on clamp anchorage = 7,574#"

Minimum embed depth of rod into concrete = 3*1.9375 = 5.81 - Use 6" minimum

Minimum slab thickness at embed = 1.5*6" = 9"

Minimum slab thickness required for 1' radius or 6" radius if slab thickness is 12" minimum.

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Check moment strength of clamp
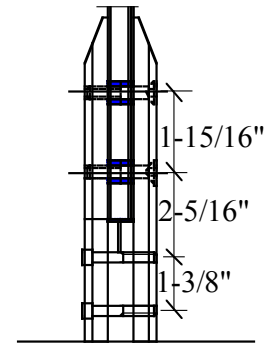Glass to bracket moment resisted by tension in cap screws:
Screw tension is proportional to distance from bottom screw to screw being considered:

> 5/16" diameter cap screws upper two.
> 1/4" diameter cap screws for lower four.
> $T_{5/16} = 3,980\#$ (ASTM F 879 Table 3)
> $T_{1/4} = 2,703\#$ (ASTM F 879 Table 3)

Moment resistance M_n

> $M_n = 3,980\#*(5.625"+3.6875"^2/5.625")+2,420\#*(1.375"^2/5.625")*2$
> $M_n = 33,635$
> $M_s = 33,635/2.0 = 16,818\#"$

Check for bending of side bars:

> $Z = 1.75"*0.5625^2/4 = 0.1384 \text{ in}^3$ (effective dimensions)
> $F_y = 30 \text{ ksi}$
> $M_n = 0.1384*30 \text{ ksi} = 4,153$
> $M_s = 4,153/1.67 = 2,487\#"$

Moment Strength of fully installed clamp:

> $M_s = 2*2,487 = 4,974$

ALLOWABLE DESIGN MOMENT = 4,974"# WITH BOLTS THROUGH GLASS
ALLOWABLE DESIGN MOMENT = 2,487"# WITHOUT BOLTS THROUGH GLASS

DFWC3

CRL Three-Piece Core Mount Clamp

- **Made of Duplex 2205 Grade Brushed Stainless Steel**
- **Designed for 3/8" or 1/2" (10 or 12 mm) Tempered Monolithic Glass and 9/16" (13.52 mm) Tempered Laminated Glass**

Duplex 2205 is a more corrosive-resistant, higher grade of stainless steel than #316. It is ideally suited for areas within 1 kilometer of saltwater environments due to higher chromium content in the metal. Glass fabrication required two 19 mm (3/4") holes per clamp.

Gaskets for 3/8" (10 mm) to 9/16" (14.3 mm) Glass

1-15/16" (50 mm)
1-15/16" (50 mm)
10-3/16" (259 mm)
1-3/4" (45 mm)
4-15/16" (125 mm)
1-9/16" (40 mm)
15/16" (24 mm)

CAT. NO.	FINISH
DFWC3	Brushed Stainless

Minimum order: 1 each.
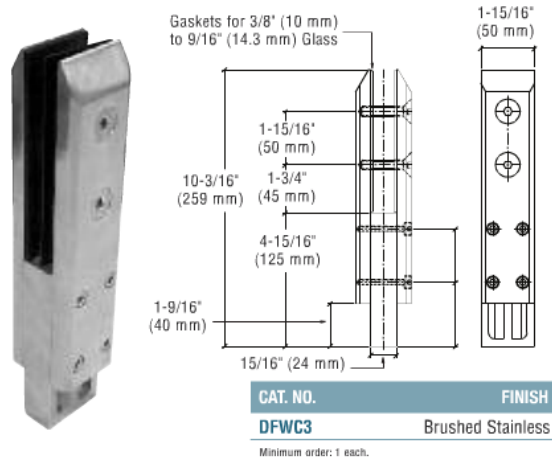
Clamp anchorage strength is same as calculated for the AFCW3 clamp.

Check moment strength of clamp

Glass to bracket moment resisted by tension in cap screws:

Screw tension is proportional to distance from bottom screw to screw being considered:

5/16" diameter cap screws upper two.

1/4" diameter cap screws for lower four.

$T_{5/16} = 3,980\#$ (ASTM F 879 Table 3)

$T_{1/4} = 2,703\#$ (ASTM F 879 Table 3)

Moment resistance M_n

$M_n = 3,980\#*(5.062"+3.125"^2/5.062")+2,420\#*(1.375"^2/5.062")*2$

$M_n = 29,635$

$M_s = 29,635/2.0 = 14,817\#"$

Check for bending of side bars:

$Z = 1.75"*0.5625^2/4 = 0.1384\ in^3$ (effective dimensions)

$F_y = 45\ ksi$

$M_n = 0.1384*45\ ksi = 6,228$

$M_s = 6,228/1.67 = 3,729\#"$

Moment Strength of fully installed clamp:

$M_s = 2*3,729 = 7,458$

ALLOWABLE DESIGN MOMENT = 7,458"# WITH BOLTS THROUGH GLASS

ALLOWABLE DESIGN MOMENT = 3,729"# WITHOUT BOLTS THROUGH GLASS

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AFWC4

CRL Two-Piece Core Mount Round Clamp

- Made of Duplex 2205 Grade Brushed Stainless Steel
- Designed for 3/8" or 1/2" (10 or 12 mm) Tempered Monolithic Glass and 9/16" (13.52 mm) Tempered Laminated Glass

Duplex 2205 is a more corrosive-resistant, higher grade of stainless steel than #316. It is ideally suited for areas within 1 kilometer of saltwater environments due to higher chromium content in the metal. Glass fabrication requires one 19 mm (3/4") hole per clamp.

CAT. NO.	FINISH
AFWC4	Brushed Stainless

Minimum order: 1 each.
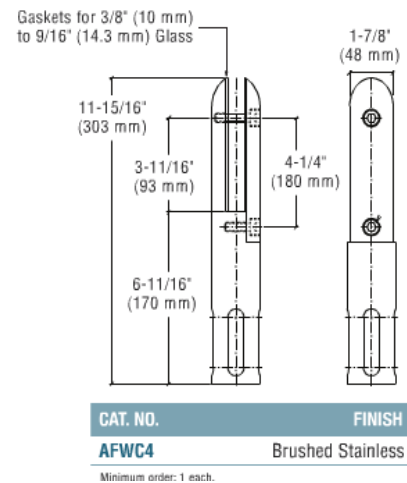
Clamp must be installed with bolt through the glass.

Strength of clamp anchorage into hole in concrete is similar to AFWC1 and won't control clamp strength.

Check moment strength of clamp:

Glass to clamp moment resisted by tension in cap screws:

Screw tension is proportional to distance from bottom screw to screw being considered:

   5/16" diameter cap screws connectig side plate to main clamp body

   $T_{5/16} = 3,980\#$ (ASTM F 879 Table 3)

Moment resistance M_n

   $M_n = 3,980\#*4.25"$

   $M_n = 16,915"\#$

   $M_s = 16,915/2.0 = 8,458\#"$

Check for bending of side bars:

   $Z = 0.083$ in^3 (effective dimensions)

   $F_y = 60$ ksi For cast Duplex 2205

   $M_n = 0.083*60$ ksi $= 4,980$

   $M_s = 4,980/1.67 = 2,982\#"$

Moment Strength of fully installed clamp:

   $M_s = 2*2,982 = 5,964"\#$

ALLOWABLE DESIGN MOMENT = 5,964"# WITH BOLTS THROUGH GLASS
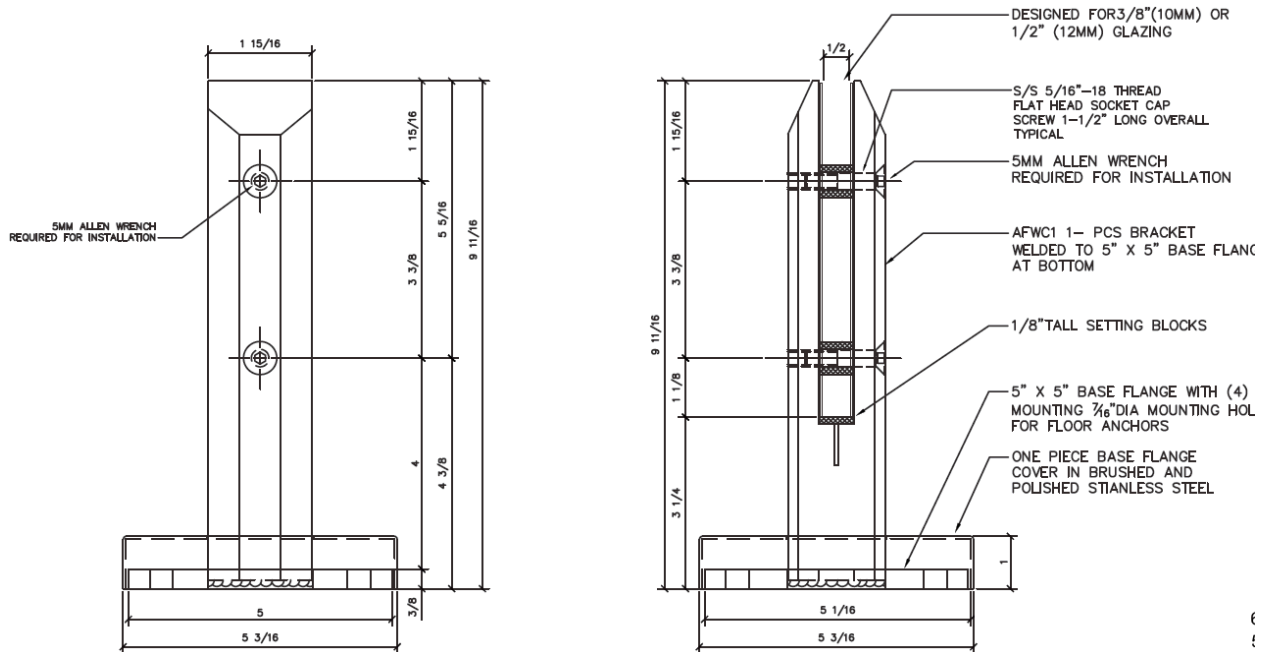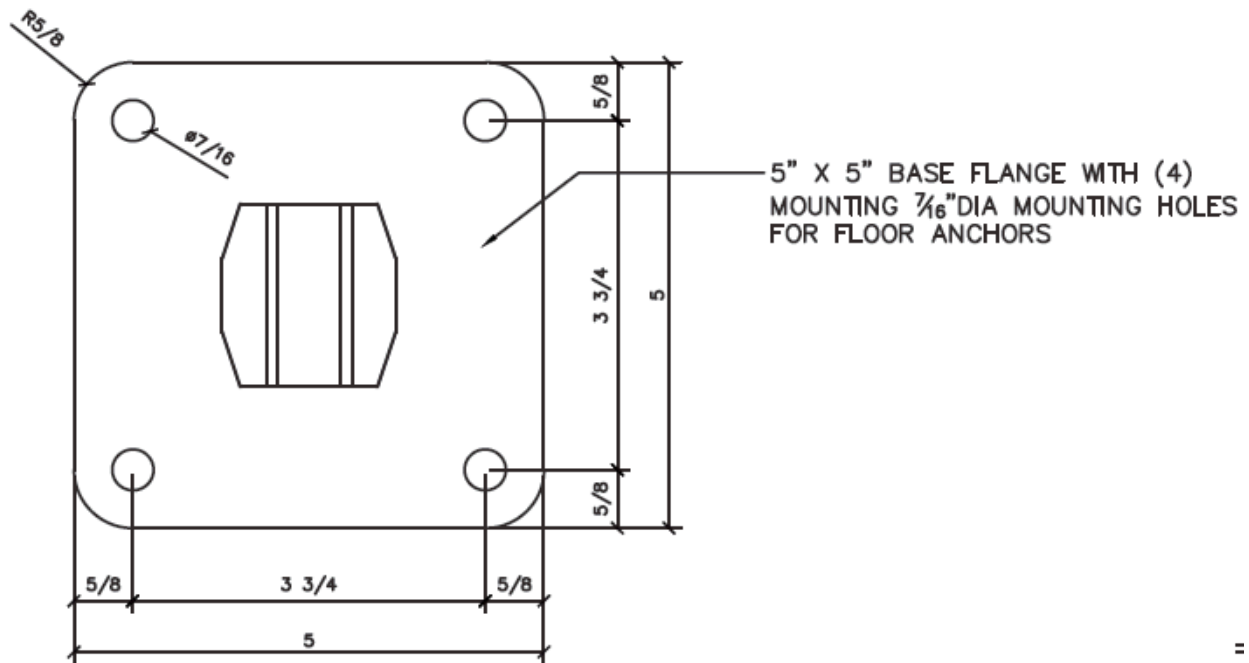
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AFWC1S
One piece surface mounted clamp. Clamp body is similar to the AFWC1 clamp.

Check strength of clamp:

Glass to clamp moment resisted by tension in cap screws:

Screw tension is proportional to distance from bottom screw to screw being considered:

    5/16" diameter cap screws upper two.

Screw tension strength - ASTM F 879

    $T = 3,980\#$ (ASTM F 879 Table 3)

    $T_a = 3,980/2 = 1,990\#$

Moment resistance M_a

    $M_a = 1,990\#*(4.5"+1.125"^2/4.5") = 9,515"\#$

For installations without bolts through glass:

Check for bending of side plates:

    $S = 0.160 \text{ in}^3$

    $F_y = 30$ ksi for cast 316 Stainless steel

    $M_n = ZF_y = 0.160*30 \text{ ksi} = 4,800 "\#$

    $M_a = 4,800/1.67 = 2,874"\#$

5" X 5" BASE FLANGE WITH (4) MOUNTING 7/16"DIA MOUNTING HOLES FOR FLOOR ANCHORS

CONNECTION TO STEEL:

3/8" SS Bolts to steel framing with sufficient strength to properly support the imposed loads-
Tension strength of 3/8" bolts (ASTM F 593)

$T_n = 0.0775in^2 * 70ksi = 5,425\#$

$T_s = 5,425\#/2 = 2,713\#$

Allowable moment based on anchor strength:

$M_s = 2 * 2,713\# * 3.75" = 20,344"\#$

BASE PLATE MOUNTED TO CONCRETE - Expansion Bolt Alternative:

Base plate mounted to concrete with ITW Red Head Trubolt wedge anchor 3/8"x3.75" concrete
anchors with 3" effective embedment. Anchor strength based on ESR-2427

Minimum conditions used for the calculations:

$f'_c \geq 3,000$ psi; edge distance =2.25"   spacing = 3.75"

h = 3.0": embed depth

For concrete breakout strength:

$N_{cb} = [A_{Ncg}/A_{Nco}]\varphi_{ed,N}\varphi_{c,N}\varphi_{cp,N}N_b$

$A_{Ncg} = (1.5 * 3 * 2 + 3.75) * (1.5 * 3 + 2.25) = 86.06$ in^2 2 anchors

$A_{Nco} = 9 * 3^2 = 81$ in^2

$C_{a,cmin} = 1.5"$ (ESR-2427 Table 3)

$C_{ac} = 5.25"$ (ESR-2427 Table 3)

$\varphi_{ed,N} = 1.0$

$\varphi_{c,N} =$ (use 1.0 in calculations with k = 24)

$\varphi_{cp,N} = $ max (1.5/5.25 or 1.5*3"/5.25) = 0.857 ($c_{a,min} \leq c_{ac}$)

$N_b = 24 * 1.0 * \sqrt{3000} * 3.0^{1.5} = 6,830\#$

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N_{cb} = 86.06/81*1.0*1.0*0.857*6,830 = 6,219 ≤ 2*4,200

based on concrete breakout strength.

Determine allowable tension load on anchor pair

T_s = 0.65*6,219#/1.6 = 2,526#

Check shear strength - Concrete breakout strength in shear:

$V_{cb} = A_{vc}/A_{vco}(\varphi_{ed,v}\varphi_{c,v}\varphi_{h,v}V_b$

A_{vc} = (1.5*3*2+3.75)*(2.25*1.5) = 43.03

A_{vco}= 4.5$(c_{a1})^2$ = 4.5$(3)^2$ = 40.5

$\varphi_{ed,V}$= 1.0 (affected by only one edge)

$\varphi_{c,V}$= 1.4 uncracked concrete

$\varphi_{h,V}$= √(1.5c_{a1}/h_a) = √(1.5*3/3) =1.225

V_b= [7$(l_e/d_a)^{0.2}$√d_a]λ√$f'_c$$(c_{a1})^{1.5}$ = [7$(1.625/0.375)^{0.2}$√0.375]1.0√3000$(3.0)^{1.5}$ =1,636#

V_{cb} = 43.03/40.5*1.0*1.4*1.225*1,636# = 2,981#

Steel shear strength = 1,830#*2 = 3,660

Allowable shear strength

ØV_N/1.6 = 0.70*2,981#/1.6 = 1,304#

Shear load = 250/1,304 = 0.19 ≤ 0.2

Therefore interaction of shear and tension will not reduce allowable tension load:

M_a = 2,526#*4.375" = 11,053"# > 9,515"#

DEVELOPS FULL CLAMP STRENGTH.

ALLOWABLE SUBSTITUTIONS: Alternative concrete anchors may be designed for project conditions.

CONCRETE ANCHORS SHALL BE CHECKED FOR PROJECT CONDITIONS.

TO WOOD:

For 3/8" SS bolts to wood beams with bearing plates between bolt head and beam and framing has adequate strength to resist the loads:

Tension strength of 3/8" bolts (ASTM F 593)

$T_n = 0.0775in^2*70ksi = 5,425\#$

$T_s = 5,425\#/2 = 2,713\#$

Allowable moment based on anchor strength:

$M_s = 2*2,713\#*3.75" = 20,344"\#$

For 3/8" Lag screws:

For 8,400"# design load

$T_{200} = \dfrac{8,400}{2*4.375"} = 960\#$

Adjustment for wood bearing (assumes Hem-fir or similar wood):

$a = 2*960/(1.075*625psi*5") = 0.572"$

$T = 8,400/[2*(4.375-0.572/2)] = 1,027\#$

Required embed depth will depend on wood density and moisture content:

Withdrawal strength of 3/8" lag screw to wood with $G \geq 0.46$

$C_D = 1.6$ for guard impact loads and wind loads

$W = 269$ pli from NDS Table 11.2A

$W' = 1.6*269 = 430\#/in$

$Z_\perp = 170\#$ (NDS Table 11K)

$Z'_\perp = 1.6*170\# = 272\#$ each

Shear load will equal wind or live load - assume 100# per lag:

Combined lateral and withdrawal loads (NDS Table 11.4)

$Z'_\perp = (W'Z')/[W'Cos^2\alpha + Z'sin^2\alpha]$

Resultant $= \sqrt{(1027^2+100^2)} = 1,032\#$

$\alpha = tan^{-1}(1027/100) = 84.4°$

Try assuming 3" embedment: $W'e = 430*3 = 1,290\#$

$Z'_\perp = (272*1,290)/[1,290Cos^2 84.4° + 272sin^2 84.4°] = 1,246\# \geq 1,032\#$

3" embedment assumption is good.

For protected installations the minimum embedment is 3" with

Allowable shear load = 400#

Allowable moment = 8,400"#

For weather exposed installations the minimum embedment is:

$l_e = 3"/C_M = 3/0.7 = 4.286"$

Lesser embedment will reduce allowable load by:

$M' = l_e/3"*8,400"\#$ for moisture content always below 19%

$M' = l_e/4.286*8,400"\#$ for moisture content that may go over 19%

Minimum embedment depth $l_e \geq 2.375"$ with reduced allowable moment load.
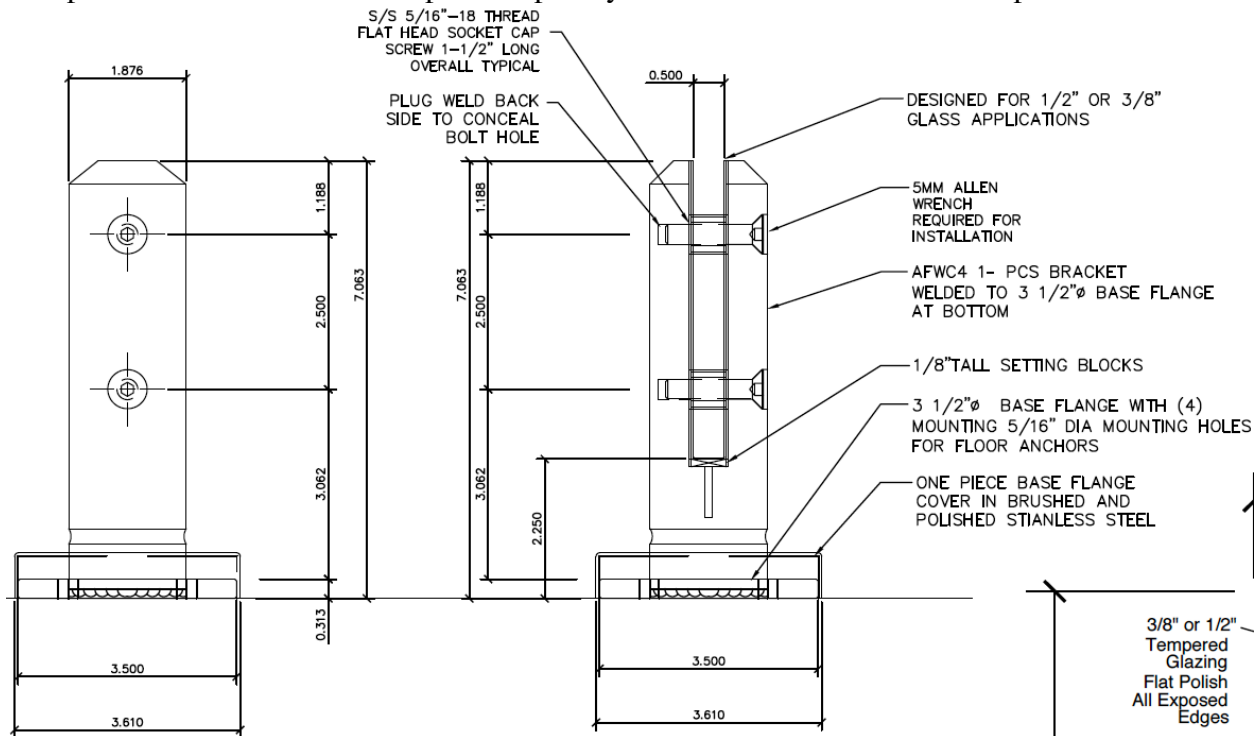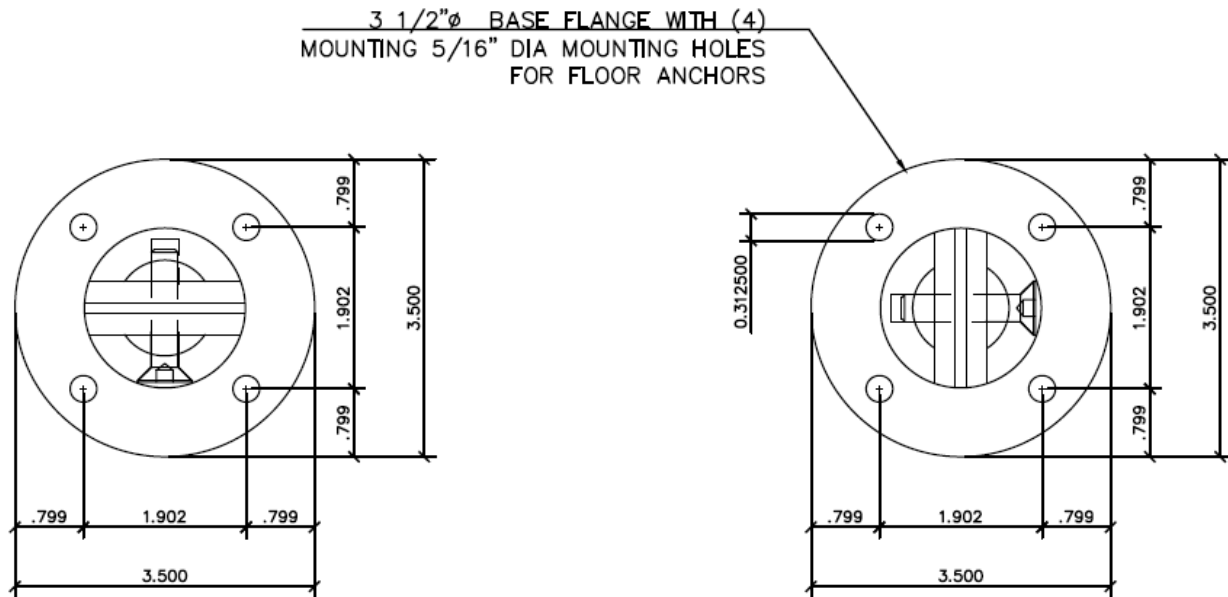
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AFWC4S
One piece surface mounted clamp. Clamp body is similar to the AFWC1 clamp.

Clamp must be installed with bolt through the glass.

Check moment strength of clamp body

Glass to bracket moment resisted by tension in cap screws:

Screw tension is proportional to distance from bottom screw to screw being considered:

> 5/16" diameter cap screws connecting side plate to main clamp body
>
> $T_{5/16} = 3,980\#$ (ASTM F 879 Table 3)
>
> $Ta = 3,980\#/2 = 1,990\#$

Moment resistance M_a

> $M_a = 1,990\#*(3.312"+0.812"^2/3.312") = 6,987"\#$

Check for bending of side bars:

> $Z = 0.114 \ in^3$
>
> $F_y = 30 \ ksi$ For cast 316 SS
>
> $M_n = 0.114*30 \ ksi = 3,420"\#$
>
> $M_s = 3,420/1.67 = 2,048\#"$

Moment Strength of fully installed clamp:

> $M_s = 2*2,048 = 4,096"\#$

CONNECTION TO STEEL:

3/8" SS Bolts to steel framing with sufficient strength to properly support the imposed loads-
Tension strength of 3/8" bolts (ASTM F 593)

$T_n = 0.0775in^2*70ksi = 5,425\#$

$T_s = 5,425\#/2 = 2,713\#$

Allowable moment based on anchor strength:

$M_s = 2*2,713\#*1.902" = 10,320"\#$

BASE PLATE MOUNTED TO CONCRETE -

Base plate mounted to concrete with Hilti HUS anchors with 3" embedment. Anchor strength
based on ESR-3027 and ACI 318-08 Appendix D.

Minimum conditions used for the calculations:

$f'_c \geq 3,000$ psi; edge distance = 2.25"   spacing = 1.902"

h = 3.0": embed depth

For concrete breakout strength:

$N_{cb} = [A_{Ncg}/A_{Nco}]\varphi_{ed,N}\varphi_{c,N}\varphi_{cp,N}N_b$

$A_{Ncg}= (1.5*3*2+1.902)*(1.5*3+2.25) = 73.589$ in^2 2 anchors

$A_{Nco}= 9*3^2 = 81$ in^2

$C_{a,cmin} = 1.5"$ (ESR-3027 Table 2)

$C_{ac} = 3.2"$ (ESR-3027 Table 2)

$\varphi_{ed,N} = 1.0$

$\varphi_{c,N} =$ (use 1.0 in calculations with k = 24)

$\varphi_{cp,N}= $ max (1.5/3.2 or 1.5*2.25"/3.2) = 1.05 but ≤ 1.0

$N_b = 24*1.0*\sqrt{3000}*3.0^{1.5} = 6,830\#$

$N_{cb} = 73.589/81*1.0*1.0*0.857*6,830 = 5,318$

based on concrete breakout strength.

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Steel strength:
$T_{ns} = 9,200\#$ each

Pullout strength - Per ESR-3027 Table 3 will not limit tension strength.

Determine allowable tension load on anchor pair
$T_s = 0.65 * 5,318\# / 1.6 = 2,160\#$

Check shear strength - Concrete breakout strength in shear:
$V_{cb} = A_{vc}/A_{vco}(\varphi_{ed,V}\varphi_{c,V}\varphi_{h,V}V_b)$
$A_{vc} = (1.5*3*2+3.75)*(2.25*1.5) = 43.03$
$A_{vco} = 4.5(c_{a1})^2 = 4.5(3)^2 = 40.5$
$\varphi_{ed,V} = 1.0$ (affected by only one edge)
$\varphi_{c,V} = 1.4$ uncracked concrete
$\varphi_{h,V} = \sqrt{(1.5c_{a1}/h_a)} = \sqrt{(1.5*3/3)} = 1.225$
$V_b = [7(l_e/d_a)^{0.2}\sqrt{d_a}]\lambda\sqrt{f'_c}(c_{a1})^{1.5} = [7(1.625/0.375)^{0.2}\sqrt{0.375}]1.0\sqrt{3000}(3.0)^{1.5} = 1,636\#$
$V_{cb} = 43.03/40.5*1.0*1.4*1.225*1,636\# = 2,981\#$
Steel shear strength $= 5,185*2 = 10,370\#$
Allowable shear strength
$\emptyset V_N/1.6 = 0.70*2,981\#/1.6 = 1,304\#$

Shear load $= 250/1,304 = 0.19 \leq 0.2$
Therefore interaction of shear and tension will not reduce allowable tension load for shear loads under 250#

$M_a = 2,160\# * 1.902" = 4,108"\# > 4,096"\#$
DEVELOPS FULL CLAMP STRENGTH.
ALLOWABLE SUBSTITUTIONS: Alternative concrete anchors may be designed for project conditions.
CONCRETE ANCHORS SHALL BE CHECKED FOR PROJECT CONDITIONS.

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TO WOOD:

For 3/8" SS bolts to wood beams with bearing plates between bolt head and beam and framing has adequate strength to resist the loads:

Tension strength of 3/8" bolts (ASTM F 593)

$T_n = 0.0775in^2*70ksi = 5,425\#$

$T_s = 5,425\#/2 = 2,713\#$

Allowable moment based on anchor strength:

$M_s = 2*2,713\#*1.902" = 10,282"\#$

For 3/8" Lag screws:

For 4,096"# design load based on clamp strength

$T_{200} = \dfrac{4,096}{2*2.30"} = 890\#$

Adjustment for wood bearing (assumes Hem-fir or similar wood):

$a = 2*890/(1.075*625psi*2.5") = 1.06"$

$T = 4,096/[2*(2.701-1.06/2)] = 943\#$

Required embed depth will depend on wood density and moisture content:

Withdrawal strength of 3/8" lag screw to wood with $G \geq 0.46$

$C_D = 1.6$ for guard impact loads and wind loads

$W = 269$ pli from NDS Table 11.2A

$W' = 1.6*269 = 430\#/in$

$Z_\perp = 170\#$ (NDS Table 11K)

$Z'_\perp = 1.6*170\# = 272\#$ each

Shear load will equal wind or live load - assume 63# per lag:

Combined lateral and withdrawal loads (NDS Table 11.4)

$Z'_\perp = (W'Z')/[W'Cos^2\alpha + Z'sin^2\alpha]$

Resultant $= \sqrt{(943^2+63^2)} = 945\#$

$\alpha = tan^{-1}(943/63) = 86.2°$

Try assuming 3" embedment: $W'e = 430*3 = 1,290\#$

$Z'_\perp = (272*1,290)/[1290Cos^2 86.2° + 272sin^2 86.2°] = 1,266\# \geq 945\#$

3" embedment assumption is good.

For protected installations the minimum embedment is 3"*945/1266 = 2.24 but not less then 2.375" with Allowable shear load = 250# and Allowable moment = 4,096"#

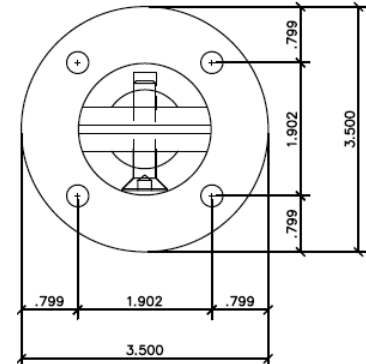For weather exposed installations the minimum embedment is:

$l_e = 3"/C_M = 2.24/0.7 = 3.2"$

Lesser embedment will reduce allowable load by:

no reduction for moisture content always below 19%

$M' = l_e/3.2*4,096"\#$ for moisture content that may go over 19%

Minimum embedment depth $l_e \geq 2.375"$ with reduced allowable moment load.

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FRICTION FIT CLAMPS
FWCR10
One piece stainless steel clamp for installation into cored
hole. Glass is locked into clamp by tightening two set
screws which press a bearing plate against the glass.
Check for bending of side bars:

$Z = 0.140$ in^3

$F_y = 45$ ksi For 316 SS based on tested strength

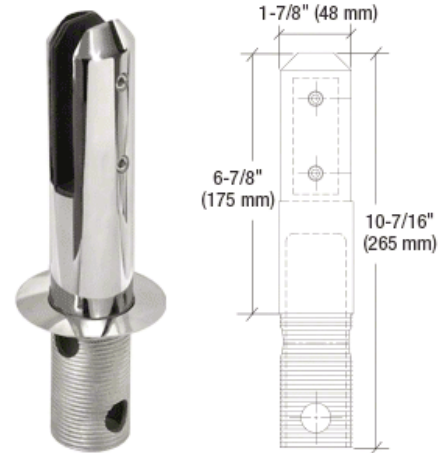$M_n = 0.140*45$ ksi $= 6,300$"#

$M_s = 6,300/1.67 = 3,772$#"

Allowable shear load:

$V_a = 0.6*45$ksi$*0.309$in$^2/2 = 4,171$#

Anchorage is achieved by embedding clamp base into
hole in concrete and grouted in place.

Moment is resisted by pry out from concrete. The grooves on the end of the rod prevent
withdrawal.
From $\sum M$ about centroid of C_l:
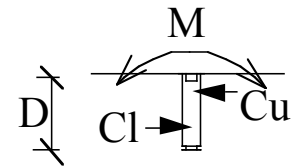
$M_n = C_l*D(2/3)$

$C_u = \phi F_B$

F_B = shear block failure from ACI 318 App D.6.2

$F_B = 2*1.4*7(3.5/1.875)^{0.2}(1.875*2500)^{1/2}*3.5^{1.5} = 9,956$#

$C_u = 0.85*9,956$# $= 8,463$#

$M_n = 8,463$#$*3.5*(2/3) = 19,746$#"

$M_s = 0.70*19,746/1.6 = 8,639$#"

NOTE ON CLAMP STRENGTH
The clamps were tested as part of a balustrade assembly in Australia by Azuma Design Pty Ltd,
test reports revision date 18 April 2012. Based on the test reports the allowable moment for the
clamp may be calculated as:

Maximum test load = 3.6 kN (809.3 lbs)

Maximum moment = 3.6kN*1035mm = 3.7778kN-m (809.3#*40.75" = 32,979"#)

Load resisted by 3 glass lights with two clamps on each.

Based on load distribution from top rail to glass, glass to clamp the load to the center for clamps
are assumed equal and the end clamps receive 1/2 the load of the middle clamps.

Maximum clamp moment = 32,979"#/4 = 8,245"# (test report indicated yielding of
clamp occurred at the final test load but ultimate strength of the clamp wasn't reached)

SF = 8,245/3,772 = 2.19

Recommended design moment on clamp $M_a = 3,772$"#
Allowable shear load: $V_a = 3,772/6.875$" = 549#

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FWCS10

One piece stainless steel clamp for installation into cored hole. Glass is locked into clamp by tightening two set screws which press a bearing plate against the glass.
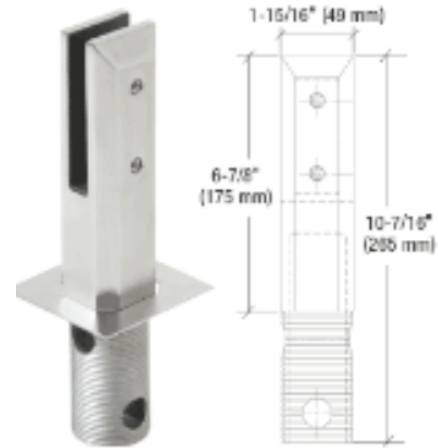
Check for bending of side bars:

$Z = 0.192$ in^3

$F_y = 45$ ksi For 316 SS based on tested strength

$M_n = 0.192*45$ ksi $= 8,640$"#

$M_s = 8,640/1.67 = 5,174$"#

Allowable shear load:

$V_a = 0.6*45ksi*1.117in^2/2= 15,082\#$

Anchorage is achieved by embedding clamp base into hole in concrete and grouted in place.

Moment is resisted by pry out from concrete. The grooves on the end of the rod prevent withdrawal.

From Σ M about centroid of C_l:
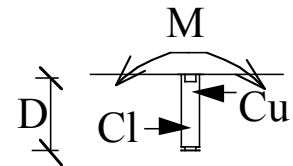
$M_n = C_l*D(2/3)$

$C_u = \phi F_B$

$F_B = $ shear block failure from ACI 318 App D.6.2

$F_B = 2*1.4*7(3.5/1.875)^{0.2}(1.875*2500)^{1/2}*3.5^{1.5} = 9,956\#$

$C_u = 0.85*9,956\# = 8,463\#$

$M_n = 8,463\#*3.5*(2/3) = 19,746\#$"

$M_s = 0.70*19,746/1.6 = 8,639\#$"

NOTE ON CLAMP STRENGTH

Based on the tests performed on the FWCR10 clamps and that the FWCR10 clamps are fabricated by the same methods from the same stainless steel grade and type the moment strength strength of the clamp may be calculated the same way. Thus as demonstrated for the FWCR10 clamp the yield strength of 45 ksi is appropriate.
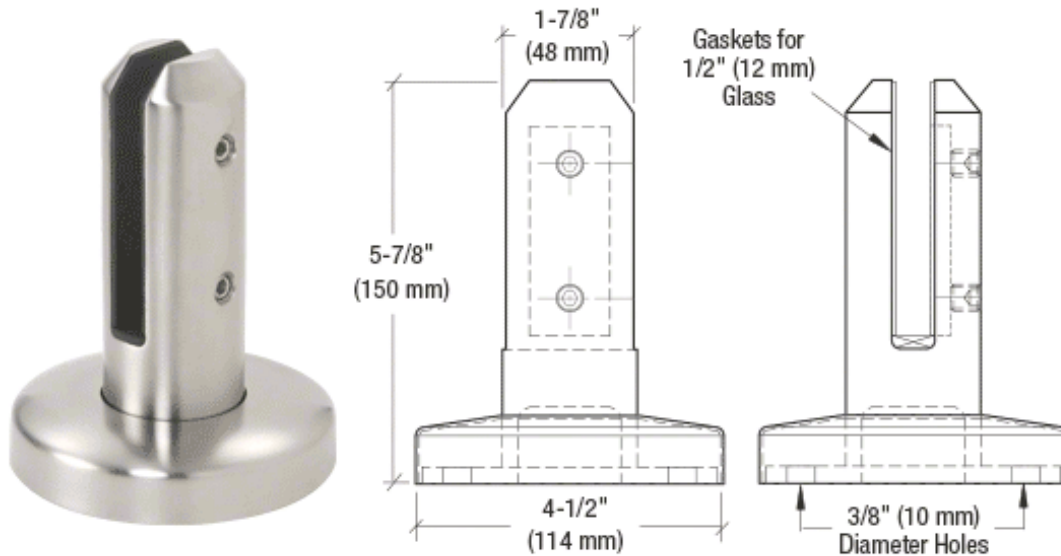
Recommended design moment on clamp $M_a = 5,174$"#

Allowable shear load: $V_a = 5,174/6.875$" $= 753\#$

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FWCR20

One piece stainless steel clamp with base shoe for surface mounting. Glass is locked into clamp by tightening two set screws which press a bearing plate against the glass.

Check for bending of side bars:

$Z = 0.140$ in^3

$F_y = 45$ ksi For 316 SS

$M_n = 0.140*45$ ksi $= 6,300$"#

$M_s = 6,300/1.67 = 3,772$#"

Allowable shear load:

$V_a = 0.6*45$ksi$*0.309$in$^2/2 = 4,171$#

Strength of base plate mounts:

CONNECTION TO STEEL:

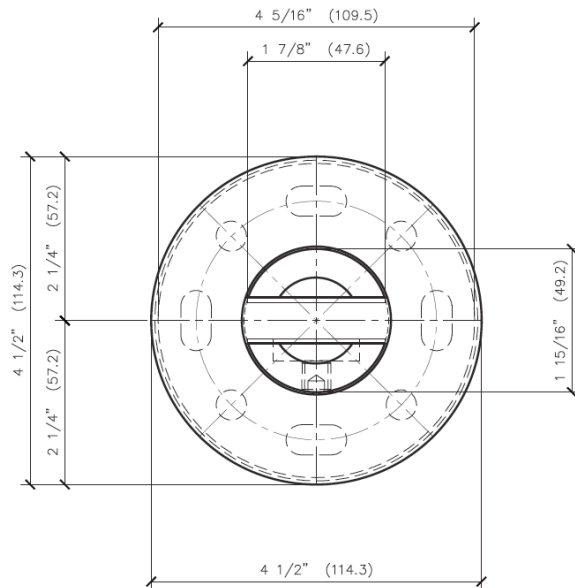3/8" SS Bolts to steel framing with sufficient strength to properly support the imposed loads-
Tension strength of 3/8" bolts (ASTM F 593)

$T_n = 0.0775$in^{2*70}ksi $= 5,425$#

$T_s = 5,425$#$/2 = 2,713$#

Allowable moment based on anchor strength:

$M_s = 2*2,713$#$*1.902$" $= 10,320$"#

BASE PLATE MOUNTED TO CONCRETE -

Base plate mounted to concrete with Hilti HUS anchors with 3" embedment. Anchor strength based on ESR-3027 and ACI 318-08 Appendix D.

Minimum conditions used for the calculations:

f'$_c \geq 3,000$ psi; edge distance $= 2.25$"   spacing $= 1.902$"

$h = 3.0$": embed depth

For concrete breakout strength:

$N_{cb} = [A_{Ncg}/A_{Nco}]\varphi_{ed,N}\varphi_{c,N}\varphi_{cp,N}N_b$

$A_{Ncg} = (1.5*3*2+1.902)*(1.5*3+2.25) = 73.589$ in^2 2 anchors
$A_{Nco} = 9*3^2 = 81$ in^2
$C_{a,cmin} = 1.5$" (ESR-3027 Table 2)
$C_{ac} = 3.2$" (ESR-3027 Table 2)
$\varphi_{ed,N} = 1.0$
$\varphi_{c,N} =$ (use 1.0 in calculations with k = 24)
$\varphi_{cp,N} = $ max (1.5/3.2 or 1.5*2.25"/3.2) = 1.05 but ≤ 1.0
$N_b = 24*1.0*\sqrt{3000}*3.0^{1.5} = 6,830\#$
$N_{cb} = 73.589/81*1.0*1.0*0.857*6,830 = 5,318$
based on concrete breakout strength.

Steel strength:
$T_{ns} = 9,200\#$ each

Pullout strength - Per ESR-3027 Table 3 will not limit tension strength.

Determine allowable tension load on anchor pair
$T_s = 0.65*5,318\#/1.6 = 2,160\#$

Check shear strength - Concrete breakout strength in shear:
$V_{cb} = A_{vc}/A_{vco}(\varphi_{ed,V}\varphi_{c,V}\varphi_{h,V}V_b$
$A_{vc} = (1.5*3*2+3.75)*(2.25*1.5) = 43.03$
$A_{vco} = 4.5(c_{a1})^2 = 4.5(3)^2 = 40.5$
$\varphi_{ed,V} = 1.0$ (affected by only one edge)
$\varphi_{c,V} = 1.4$ uncracked concrete
$\varphi_{h,V} = \sqrt{(1.5c_{a1}/h_a)} = \sqrt{(1.5*3/3)} = 1.225$
$V_b = [7(l_e/d_a)^{0.2}\sqrt{d_a}]\lambda\sqrt{f'_c}(c_{a1})^{1.5} = [7(1.625/0.375)^{0.2}\sqrt{0.375}]1.0\sqrt{3000}(3.0)^{1.5} = 1,636\#$
$V_{cb} = 43.03/40.5*1.0*1.4*1.225*1,636\# = 2,981\#$
Steel shear strength = $5,185*2 = 10,370\#$
Allowable shear strength
$\emptyset V_N/1.6 = 0.70*2,981\#/1.6 = 1,304\#$

Shear load = $250/1,304 = 0.19 \leq 0.2$
Therefore interaction of shear and tension will not reduce allowable tension load for shear loads under 250#

$M_a = 2,160\#*1.902" = 4,108"\# > 3,772"\#$
DEVELOPS FULL CLAMP STRENGTH.
ALLOWABLE SUBSTITUTIONS: Alternative concrete anchors may be designed for project conditions.
CONCRETE ANCHORS SHALL BE CHECKED FOR PROJECT CONDITIONS.

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TO WOOD:
For 3/8" SS bolts to wood beams with bearing plates between bolt head and beam and framing has adequate strength to resist the loads:
Tension strength of 3/8" bolts (ASTM F 593)
$T_n = 0.0775in^2 * 70ksi = 5,425\#$
$T_s = 5,425\#/2 = 2,713\#$
Allowable moment based on anchor strength:
$M_s = 2*2,713\#*1.902" = 10,282"\#$

For 3/8" Lag screws:
For 3,772#" design load based on clamp strength
$T_{200} = \dfrac{3,772}{2*2.30"} = 820\#$

Adjustment for wood bearing (assumes Hem-fir or similar wood):
$a = 2*820/(1.075*625psi*2.5") = 0.976"$
$T = 3,772/[2*(2.701-0.976/2)] = 852\#$
Required embed depth will depend on wood density and moisture content:
Withdrawal strength of 3/8" lag screw to wood with $G \geq 0.46$
$C_D = 1.6$ for guard impact loads and wind loads
$W = 269$ pli from NDS Table 11.2A
$W' = 1.6*269 = 430\#/in$
$Z_\perp = 170\#$ (NDS Table 11K)
$Z'_\perp = 1.6*170\# = 272\#$ each
Shear load will equal wind or live load - assume 75# per lag:
Combined lateral and withdrawal loads (NDS Table 11.4)
$Z'_\perp = (W'Z')/[W'Cos^2\alpha + Z'sin^2\alpha]$
Resultant $= \sqrt{(852^2+75^2)} = 855\#$
$\alpha = tan^{-1}(855/75) = 85.0°$
Try assuming 3" embedment: $W'e = 430*3 = 1,290\#$
$Z'_\perp = (272*1,290)/[1290Cos^285° + 272sin^285°] = 1,254\# \geq 855\#$
3" embedment assumption is good.

For protected installations the minimum embedment is 3"*855/1254 = 2.05" but not under 2.375" with Allowable shear load = 300# and Allowable moment = 3,772"#

For weather exposed installations the minimum embedment is:
$l_e = 3"/C_M = 2.05/0.7 = 2.93"$

Lesser embedment will reduce allowable load by:
No reduction below 2.375" for moisture content always below 19%
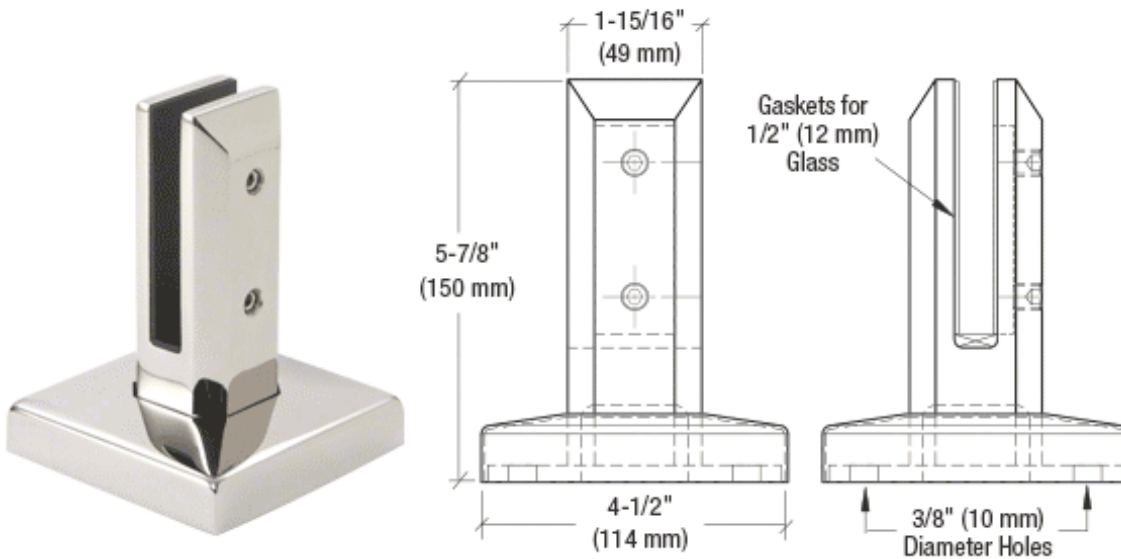$M' = l_e/4.286*2.93"\#$ for moisture content that may go over 19%
Minimum embedment depth $l_e \geq 2.375"$ with reduced allowable moment load.

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FWCS20

One piece stainless steel clamp with base shoe for surface mounting. Glass is locked into clamp by tightening two set screws which press a bearing plate against the glass.

Check for bending of side bars:

$Z = 0.192$ in^3

$F_y = 45$ ksi For 316 SS based on tested strength

$M_n = 0.192*45$ ksi $= 8,640$"#

$M_s = 8,640/1.67 = 5,174$"#

Allowable shear load:

$V_a = 0.6*45ksi*1.117in^2/2 = 15,082$#

Strength of base plate mounts:

CONNECTION TO STEEL:

3/8" SS Bolts to steel framing with sufficient strength to properly support the imposed loads-
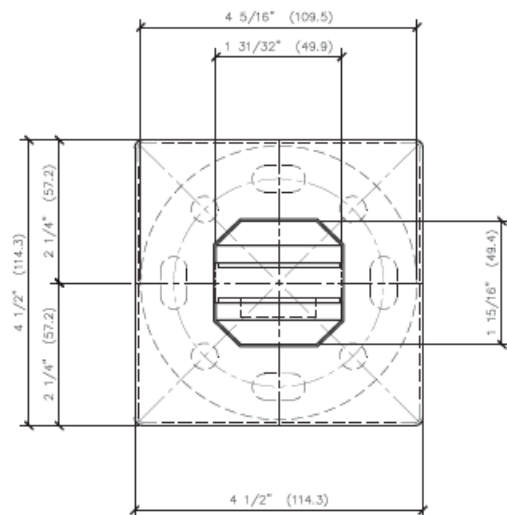
Tension strength of 3/8" bolts (ASTM F 593)

$T_n = 0.0775in^2*70ksi = 5,425$#

$T_s = 5,425\#/2 = 2,713$#

Allowable moment based on anchor strength:

$M_s = 2*2,713\#*1.902" = 10,320$"#

BASE PLATE MOUNTED TO CONCRETE -

Base plate mounted to concrete with Hilti HUS anchors with 3" embedment. Anchor strength based on ESR-3027 and ACI 318-08 Appendix D.

Minimum conditions used for the calculations:

$f'_c \geq 3,000$ psi; edge distance $= 2.25"$ spacing $= 1.902"$

$h = 3.0$": embed depth

For concrete breakout strength:

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$N_{cb} = [A_{Ncg}/A_{Nco}]\varphi_{ed,N}\varphi_{c,N}\varphi_{cp,N}N_b$

$A_{Ncg} = (1.5*3*2+1.902)*(1.5*3+2.25) = 73.589$ in^2 2 anchors

$A_{Nco} = 9*3^2 = 81$ in^2

$C_{a,cmin} = 1.5$" (ESR-3027 Table 2)

$C_{ac} = 3.2$" (ESR-3027 Table 2)

$\varphi_{ed,N} = 1.0$

$\varphi_{c,N} = $ (use 1.0 in calculations with k = 24)

$\varphi_{cp,N} = $ max (1.5/3.2 or 1.5*2.25"/3.2) = 1.05 but ≤ 1.0

$N_b = 24*1.0*\sqrt{3000}*3.0^{1.5} = 6,830\#$

$N_{cb} = 73.589/81*1.0*1.0*0.857*6,830 = 5,318$

based on concrete breakout strength.

Steel strength:

$T_{ns} = 9,200\#$ each

Pullout strength - Per ESR-3027 Table 3 will not limit tension strength.

Determine allowable tension load on anchor pair

$T_s = 0.65*5,318\#/1.6 = 2,160\#$

Check shear strength - Concrete breakout strength in shear:

$V_{cb} = A_{vc}/A_{vco}(\varphi_{ed,V}\varphi_{c,V}\varphi_{h,V}V_b$

$A_{vc} = (1.5*3*2+3.75)*(2.25*1.5) = 43.03$

$A_{vco} = 4.5(c_{a1})^2 = 4.5(3)^2 = 40.5$

$\varphi_{ed,V} = 1.0$ (affected by only one edge)

$\varphi_{c,V} = 1.4$ uncracked concrete

$\varphi_{h,V} = \sqrt{(1.5c_{a1}/h_a)} = \sqrt{(1.5*3/3)} = 1.225$

$V_b = [7(l_e/d_a)^{0.2}\sqrt{d_a}]\lambda\sqrt{f'_c}(c_{a1})^{1.5} = [7(1.625/0.375)^{0.2}\sqrt{0.375}]1.0\sqrt{3000}(3.0)^{1.5} = 1,636\#$

$V_{cb} = 43.03/40.5*1.0*1.4*1.225*1,636\# = 2,981\#$

Steel shear strength = 5,185*2 = 10,370#

Allowable shear strength

$\emptyset V_N/1.6 = 0.70*2,981\#/1.6 = 1,304\#$

Shear load = 250/1,304 = 0.19 ≤ 0.2

Therefore interaction of shear and tension will not reduce allowable tension load for shear loads under 250#

$M_a = 2,160\#*1.902$" = 4,108"# < 5,174"#

LIMITS CLAMP STRENGTH.

ALLOWABLE SUBSTITUTIONS: Alternative concrete anchors may be designed for project conditions.

CONCRETE ANCHORS SHALL BE CHECKED FOR PROJECT CONDITIONS.

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TO WOOD:

For 3/8" SS bolts to wood beams with bearing plates between bolt head and beam and framing has adequate strength to resist the loads:

Tension strength of 3/8" bolts (ASTM F 593)

$T_n = 0.0775in^2*70ksi = 5,425\#$

$T_s = 5,425\#/2 = 2,713\#$

Allowable moment based on anchor strength:

$M_s = 2*2,713\#*1.902" = 10,282"\#$

For 3/8" Lag screws:

For 5,174"# design load based on clamp strength

$T_{200} = \dfrac{5,174}{2*2.30"} = 1,125\#$

Adjustment for wood bearing (assumes Hem-fir or similar wood):

$a = 2*1,125/(1.075*625psi*2.5") = 1.34"$

$T = 4,096/[2*(2.701-1.34/2)] = 1,008\#$

Required embed depth will depend on wood density and moisture content:

Withdrawal strength of 3/8" lag screw to wood with $G \geq 0.46$

$C_D = 1.6$ for guard impact loads and wind loads

$W = 269$ pli from NDS Table 11.2A

$W' = 1.6*269 = 430\#/in$

$Z_\perp = 170\#$ (NDS Table 11K)

$Z'_\perp = 1.6*170\# = 272\#$ each

Shear load will equal wind or live load - assume 67# per lag:

Combined lateral and withdrawal loads (NDS Table 11.4)

$Z'_\perp = (W'Z')/[W'Cos^2\alpha + Z'sin^2\alpha]$

Resultant $= \sqrt{(1008^2+67^2)} = 1,010\#$

$\alpha = \tan^{-1}(1,010/67) = 86.2°$

Try assuming 3" embedment: $W'e = 430*3 = 1,290\#$

$Z'_\perp = (272*1,290)/[1290Cos^2 86.2° + 272sin^2 86.2°] = 1,266\# \geq 1,010\#$

3" embedment assumption is good.

For protected installations the minimum embedment is 3"*1010/1266= 2.4" with

Allowable shear load = 268#

Allowable moment = 5,174"#

For weather exposed installations the minimum embedment is:

$l_e = 3"/C_M = 2.4/0.7 = 3.42"$

Lesser embedment will reduce allowable load by:

$M' = l_e/2.4"*5,425"\#$ for moisture content always below 19%

$M' = l_e/3.42*5,425"\#$ for moisture content that may go over 19%

Minimum embedment depth $l_e \geq 2.375"$ with reduced allowable moment load.

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TABLE 4: CLAMP STRENGTH SUMMARY TABLE

CLAMP STYLE	BOLTS THRU GLASS		NO BOLTS THRU GLASS	
	SHEAR LBS	MOMENT IN-LBS	SHEAR LBS	MOMENT IN-LBS
AFWC1 AND AFWC6	1194	8,222	597	2,874
AFWC2 AND AFWC7	TO STEEL 478	TO STEEL 9,453	N/A	N/A
AFWC2 AND AFWC7	CONCRETE 108	CONCRETE 2,803	N/A	N/A
AFWC2 AND AFWC7	WOOD 78	WOOD 4,228	N/A	N/A
AFWC3 AND AFWC8	1194	4,974	597	2,487
DFWC3	1194	7,458	597	3,729
AFWC1S	400	8,400	400	2,874
AFWC4	597	5,964	N/A	N/A
AFWC4S	400	4,096	400	2,048
FWCR10	N/A	N/A	549	3,772
FWCS10	N/A	N/A	753	5,174
FWCR20 TO STEEL	N/A	N/A	1000	3,772
FWCR20 CONCRETE	N/A	N/A	600	3,772
FWCR20 WOOD	N/A	N/A	600	3,772
FWCS20 TO STEEL	N/A	N/A	1000	5,174
FWCS20 CONCRETE	N/A	N/A	250	4,108
FWCS20 WOOD	N/A	N/A	268	5,174

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