30 OCT 2008

Architectural Railing Division
C.R.Laurence Co., Inc.
2503 E Vernon Ave.
Los Angeles, CA 90058
(T) 800.421.6144
(F) 800.587.7501
www.crlaurence.com

SUBJ: FRAMELESS WINDSCREEN CLAMPS (SI)

The frameless windscreen is intended for use in locations where fall protection is not required. The maximum panel length should not exceed 1.5m. 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. The windscreen is designed for the following loading conditions:

> 0.73kN/m load along glass at no higher than 1.2m above finish floor horizontal or wind load as shown in attached calculations for specified panel size.

The frameless windscreen clamps may be used for fall protection in single family residential occupancies when limited to 1.066mm height, panel length of 1.5 m and installed with a top rail capable of safely spanning 3m while supporting a live load of 0.73kN/m or concentrated load of 0.89kN any direction. For these conditions the system will support the above stated loads on the top rail, vertically or horizontally with a factor of safety of 4.0 against glass failure.

Stainless steel components are evaluated in accordance with SEI ASCE 8-02, *Specification for the Design of Cold-Formed Stainless Steel Structural Members*. The glass components are evaluated in accordance with GANA *Glazing Manual*, *Tempered Glass Engineering Standards Manual* and *Laminated Glazing Reference Manual*.

If you have any questions please call me at 253-858-0855.

Edward Robison, P.E.

Attachments:

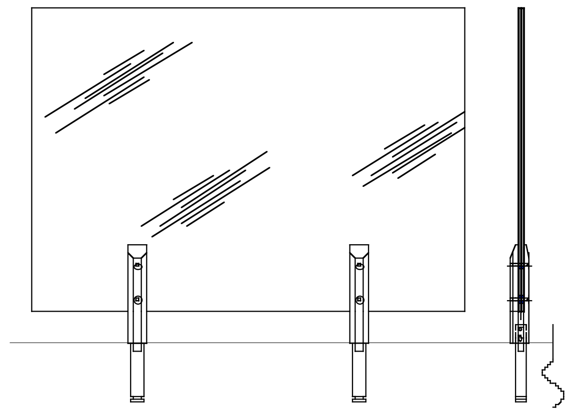
- Calculations – 7 pages
- Windscreen Layout - 1 page

REGISTERED PROFESSIONAL ENGINEER
EDWARD C. ROBISON
No. C 65883
CIVIL
STATE OF CALIFORNIA
EXP 12/31/2009
Stamped 10/30/2008

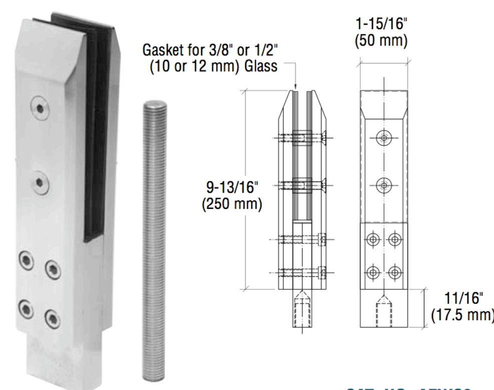
EDWARD C. ROBISON, PE
10012 Creviston Dr NW
Gig Harbor, WA 98329
253-858-0855/Fax 253-858-0856 elrobison@narrows.com

Three Piece Core Mount Frameless Windscreen Clamp

12mm Fully tempered glass panels supported by stainless steel posts anchored in concrete.



Three Piece Post Option:
Post is attached to 12mm rod set into concrete and grouted to base of side bars.



CAT. NO. AFWC3

Determine strength of anchorage into concrete:

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

Nominal strength of vertical compression of side plate against concrete:

$øF_B = øßf'c$ where:

$ß = \sqrt{(A_2/A_1)} = \sqrt{0.0103m^2/(12mm*49.2mm)}$ but ≤ 2.0

and $f'c > 41$ MPa for specified anchoring grout

$øF_B = 0.85*2*41$ MPa = 69.7 MPa

$Cp_n = 12mm*49.2mm*69.7MPa = 41.15kN$

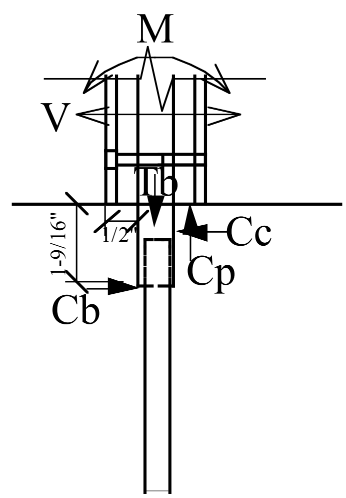
Bar tension strength, nominal

$F_y = 517.1$ MPa (1/4 hard 316 stainless steel)

$T_b = 1.26x10^{-4}m^2*517.1MPa = 65.06kN$

Cp_n controls

$M_{Cp_n} = 0.0175m*41.15kN = 767.5N\text{-}m$



Nominal strength from bending of center bar

Bar bending:

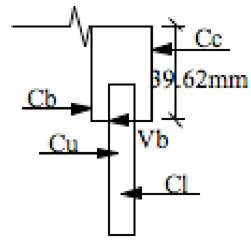
$Z = 0.0492m*0.0238^2/4 = 7.0x10^{-6}\ m^3$

$F_y = 310.3MPa$

$Mp_n = 310.3MPa*7.0x10^{-6}\ m^3 = 2{,}172N\text{-}m$ 45 ksi*0.425 in^3

EDWARD C. ROBISON, PE
10012 Creviston Dr NW
Gig Harbor, WA 98329
253-858-0855/Fax 253-858-0856 elrobison@narrows.com

check anchorage:
Center plate is anchored into concrete:



V_n = shear strength of bar
$V_n = A*F_{yv} = 1.26x10^{-4}m^2*289.6MPa = 36.5kN$ 8,190#
Allowable shear in bar must be reduced for tension:
$1 \geq (T/T_n)^2+(V/V_n)^2$
$V_b = V_n [1-(T/T_n)2] = 36.5kN *[1-(41.15kN/65.06kN)^2] = 21.6kN$
Check anchor strength of bar:
$C_u = V_b+C_l$ and $V_b = C_l$
$C_u = 2*21.6kN = 43.2kN$
Bearing length along bar for:

$F_{BC} = 70.33MPa$
$L =[C_u/(d_bF_{BC})]/0.85$
$L = [43.2kN/(12.7MM*70.33MPa)]/0.85 = 56.9mm < 100mm$ Bar length is adequate

Determine C_c
Maximum value for C_c if in full compression:

C = 1.56”*1.9375”*10,200 psi* 0.85 = 26,205# >V_b

Cc must be balanced with V_b and C_b

a = compression depth for C_c
$C_b+V_b = C_c$ and
$C_b = (39.62mm-a)*49.21mm*70.33MPa$
$C_c = a*49.21mm*70.33MPa$

substituting into above and solving for a:

(39.62mm-a)49.21mm*70.33MPa+21.6kN = 49.21mm*70.33MPa*a
(39.62-a)+6.24mm = a
45.86mm = 2a
22.93mm = a

Calculate C_c from a

$C_c = 22.93mm*49.21mm*70.33MPa = 79.36kN$
$C_b = 79.36kN-21.6kN = 57.76kN$

Calculate the resisted moment by $\sum M$ about C_c

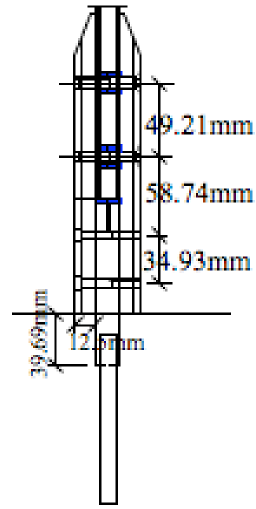
$Mh_n = (39.62mm-22.93mm/2)*21.6kN+(39.62/2-22.93/2)*57.76kN = 1.09kN-m$

The total nominal moment strength of the anchorage:

$M_n = Mh_n + Mcp_n = 1.09kN-m + 0.7675N-m = 1.8575kN-m$
$M_s = \o M_n/1.6 = 0.75*1.8575kN-m/1.6 = 870.7N-m$

Allowable service moment based on bracket anchorage = 870.7N-m

EDWARD C. ROBISON, PE
10012 Creviston Dr NW
Gig Harbor, WA 98329
253-858-0855/Fax 253-858-0856 elrobison@narrows.com



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

12mm diameter cap screws upper two.
6mm diameter cap screws for lower four.
$T_{1/2} = 17.8kN$ (Nominal)
$T_{1/4} = 4.45kN$ (Nominal)

Moment resistance M_n

$M_n = 17.8kN*(142.875mm+(93.663mm)^2/142.875mm)$
$+4.45kN*((34.925mm)^2/142.875mm)*2$
$M_n = 3.636kN\text{-}m+0.076kN\text{-}m = 3.712kN\text{-}m$
$M_s = 0.8*3.712kN\text{-}m/1.6 = 1.856kN\text{-}m$

Check for bending of side plates:

$Z = 44.45mm*(14.29mm)^2/4 *2 \text{ bars} = 4{,}538.4mm^2$ (effective dimensions)
$F_y = 310.3MPa$
$M_n = 2*4{,}538.4mm^2*310.3MPa = 2.817kN\text{-}m$
$M_s = 0.9*2.817 kN\text{-}m /1.6 = 1.583 kN\text{-}m$

Bracket plate bending strength will control design

Allowable load on each panel:

2 brackets per panel
$M_{total} = 2*1.583 kN\text{-}m = 3.166kN\text{-}m$

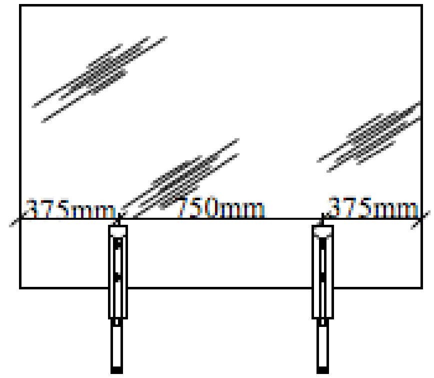
Check maximum panel length based on 0.73kN/m loading @ 1.22m height:

$L_p = 3.166kN\text{-}m /(0.73kN/m*1.22m) = 3.555m$

Bracket strength will not typically control for maximum load

Brackets will be placed at 1/4 length from each end.

EDWARD C. ROBISON, PE
10012 Creviston Dr NW
Gig Harbor, WA 98329
253-858-0855/Fax 253-858-0856 elrobison@narrows.com



Check glass strength:
For 0.73kN/m live load along top of glass
M_y = 0.73kN/m *1.22m*0.762m = 679N-m
M_x = 0.73kN/m*0.375m^2/2 = 103N-m
M_{xy} = √[(679N-m)^2+(103N-m)^2] = 687N-m

Determine glass stress:
Effective resistance width along XY
b = 0.762m/(Sin45°) = 1.0776m
S_{xy} = 1.0776* 24,000 mm^3/m = 25,863mm^3

Stress concentration factor for localized bearing:

c_l =[(H/h)$^{1/3}$]/(H/L/2)

c_l =[(1.22m/0.1365)$^{1/3}$]/(1.22m/0.762m)= 1.30

Finite element analysis models show stress concentration factors of between 1.1 and 1.28 depending on the panel dimensions therefore the factor of 1.3 will be conservative for all panel dimensions within the scope of the recommendations of this report.

f_b = 687N-m*1.3/25,863mm^3= 34.5MPa

Checked for wind loading:

W = M_s/(H^2/2*L)

M_s = 1.583 kN-m from page 4

Glass moment:

M_y = W*H^2/2*L/2

M_x = W*H*L_c^2/2

M_{xy} = (M_y^2+M_x^2) $^{1/2}$

f_b = M_{xy}/S_{xy}* c_l

Allowable wind load for 1.22m high panel x 1.5m long:

W = 1.583 kN-m /(1.22m^2/2*1.5m) = 1.42kN/m^2

M_y = 1.42kN/m^2*1.22m*1.22m/2*1.5m/2 = 793N-m

M_x = 1.42kN/m^2*1.22m*0.375^{2}m/2 = 122N-m

M_{xy} = (793^2+122^2) $^{1/2}$ = 802N-m

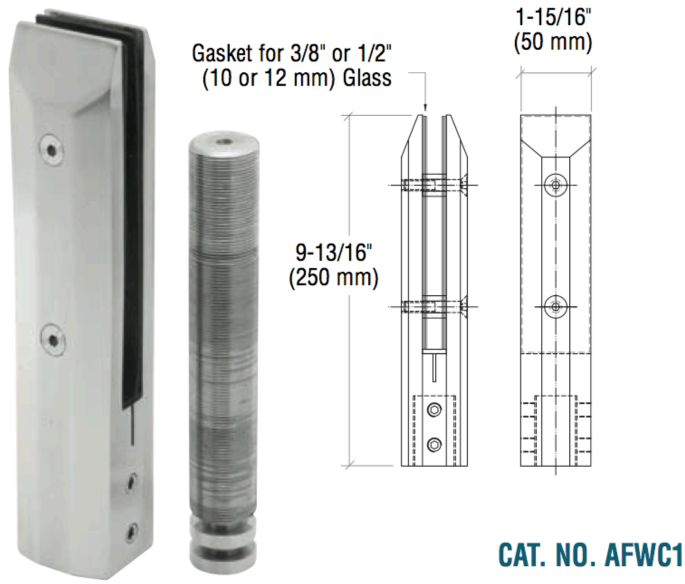
f_b = 802N-m/(25,863mm^3)*1.30 = 40.3 MPa

Allowable Wind load for other panel sizes:
TABLE 1
Allowable bracket moment =793N-m

Height m	Length m	W kN/m^2	M_y N-m	M_x kN-m	M_{xy} kN-m	b_{eff} m	C_f	S_{xy} mm^3	f_b MPa
1	1.5	2.115	0.793	0.14869	0.807	1.061	1.456	25455.8	46.1
1.15	1.5	1.599	0.793	0.12929	0.803	1.061	1.326	25455.8	41.9
1.3	1.5	1.251	0.793	0.11438	0.801	1.061	1.222	25455.8	38.5
1.45	1.5	1.006	0.793	0.10254	0.800	1.061	1.136	25455.8	35.7
1.6	1.5	0.826	0.793	0.09293	0.798	1.061	1.064	25455.8	33.4
1.8	1.5	0.653	0.793	0.0826	0.797	1.061	0.984	25455.8	30.8
1	1.35	2.350	0.793	0.13382	0.804	0.955	1.310	22910.3	46.0
1.15	1.35	1.777	0.793	0.11636	0.801	0.955	1.193	22910.3	41.8
1.22	1.35	1.579	0.793	0.10969	0.801	0.955	1.147	22910.3	40.1
1.3	1.35	1.390	0.793	0.10294	0.800	0.955	1.100	22910.3	38.4
1.45	1.35	1.118	0.793	0.09229	0.798	0.955	1.100	22910.3	38.3
1.6	1.35	0.918	0.793	0.08364	0.797	0.955	1.100	22910.3	38.3
1.8	1.35	0.725	0.793	0.07434	0.796	0.955	1.100	22910.3	38.2
1	1.25	2.538	0.793	0.12391	0.803	0.884	1.213	21213.2	45.9
1.15	1.25	1.919	0.793	0.10774	0.800	0.884	1.105	21213.2	41.7
1.22	1.25	1.705	0.793	0.10156	0.799	0.884	1.100	21213.2	41.5
1.3	1.25	1.502	0.793	0.09531	0.799	0.884	1.100	21213.2	41.4
1.45	1.25	1.207	0.793	0.08545	0.798	0.884	1.100	21213.2	41.4
1.6	1.25	0.991	0.793	0.07744	0.797	0.884	1.100	21213.2	41.3
1.8	1.25	0.783	0.793	0.06884	0.796	0.884	1.100	21213.2	41.3
1	1.15	2.758	0.793	0.11399	0.801	0.813	1.116	19516.1	45.8
1.15	1.15	2.086	0.793	0.09913	0.799	0.813	1.100	19516.1	45.0
1.22	1.15	1.853	0.793	0.09344	0.798	0.813	1.100	19516.1	45.0
1.3	1.15	1.632	0.793	0.08769	0.798	0.813	1.100	19516.1	45.0
1.4	1.15	1.407	0.793	0.08142	0.797	0.813	1.100	19516.1	44.9

EDWARD C. ROBISON, PE
10012 Creviston Dr NW
Gig Harbor, WA 98329
253-858-0855/Fax 253-858-0856 elrobison@narrows.com

One Piece Post Option:
Post is attached to 50mm (49.2mm) rod set into concrete post is screwed onto threads on top of embedded bar.



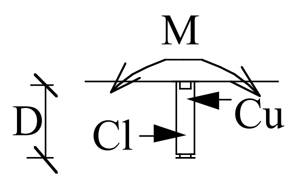
Check bending strength of bar:
$Z = d^3/4 = 49.2^3/6 = 19{,}849mm^3$
$F_y = 310.3MPa$
$M_n = 310.3MPa*19{,}849mm^3$
$= 6.159$ kN-m

$M_s = ø*M_n/1.6$
$M_s = 0.9*6.159$ kN-m $/1.6$
$M_s = 3.464$ kN-m

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. Minimum embed depth is 150mm

From $\sum$ M about centroid of Cl:



$M_n = C_l*D(2/3)$
$C_u = øF_B$
F_B = shear block failure from ACI 318 App D.6.2
$F_B = 1.4*\sqrt{1.5}*7(150mm/49.2mm)^{0.2}\sqrt{(49.2mm*20.68MPa/144)}*150^{1.5} = 73.25kN$
$C_u = 0.85*73.25kN = 62.26kN$
$M_n = 62.26kN*150*(2/3) = 6.226kN\text{-}m$
$M_s = 0.75*6.226/1.6 = 2.92kN\text{-}m$

Moment in bracket – bending at base of groove:
Side bars will be same strength as the three piece post because they are the same shape and material. Therefore post strength will be controlled by bending of upper side bars and will be the same as for the 3 piece option.

EDWARD C. ROBISON, PE
10012 Creviston Dr NW
Gig Harbor, WA 98329
253-858-0855/Fax 253-858-0856 elrobison@narrows.com

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 minimum Modulus of Rupture for the glass F_r is 165.5 MPa.. The actual F_r for the tempered glass is 165.5 MPa to 179.3 MPa, therefore the true Safety Factors are larger than the 4.0 shown herein. In accordance with UBC 2406.6 or 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 by 33% (SF = 3.0) for glass infill panels. Glass not used in guardrails may be designed for a safety factor of 2.5 in accordance with ASTM E1300-00.

Allowable glass bending stress: 165.5 MPa/4 = 41.375 MPa. – Tension stress.

For Glass side lites factor of safety is 2.5 therefore:

F_b = 165.5 MPa /2.5 = 66.2 MPa

Bending strength of glass for the given thickness:

$$I = \frac{1{,}000\text{mm}^* (t)^2}{12} = 83.3^* (t)^2 \text{ mm}^3/\text{m}$$

$$S = \frac{1{,}000\text{mm}^* (t)^2}{6} = 166.7^* (t)^2 \text{ mm}^3/\text{m}$$

For 12mm glass

$$I = 83.3^*(12)^3 = 144{,}000 \text{ mm}^4/\text{m}$$

$$S = 166.7^*(12)^2 = 24{,}000 \text{ mm}^3/\text{m}$$

For non-guard applications:

$$M_{allowable} = 66.2 \text{ MPa } ^*24{,}000 \text{ mm}^3/\text{m} = 1.589 \text{ kN-m/m}$$

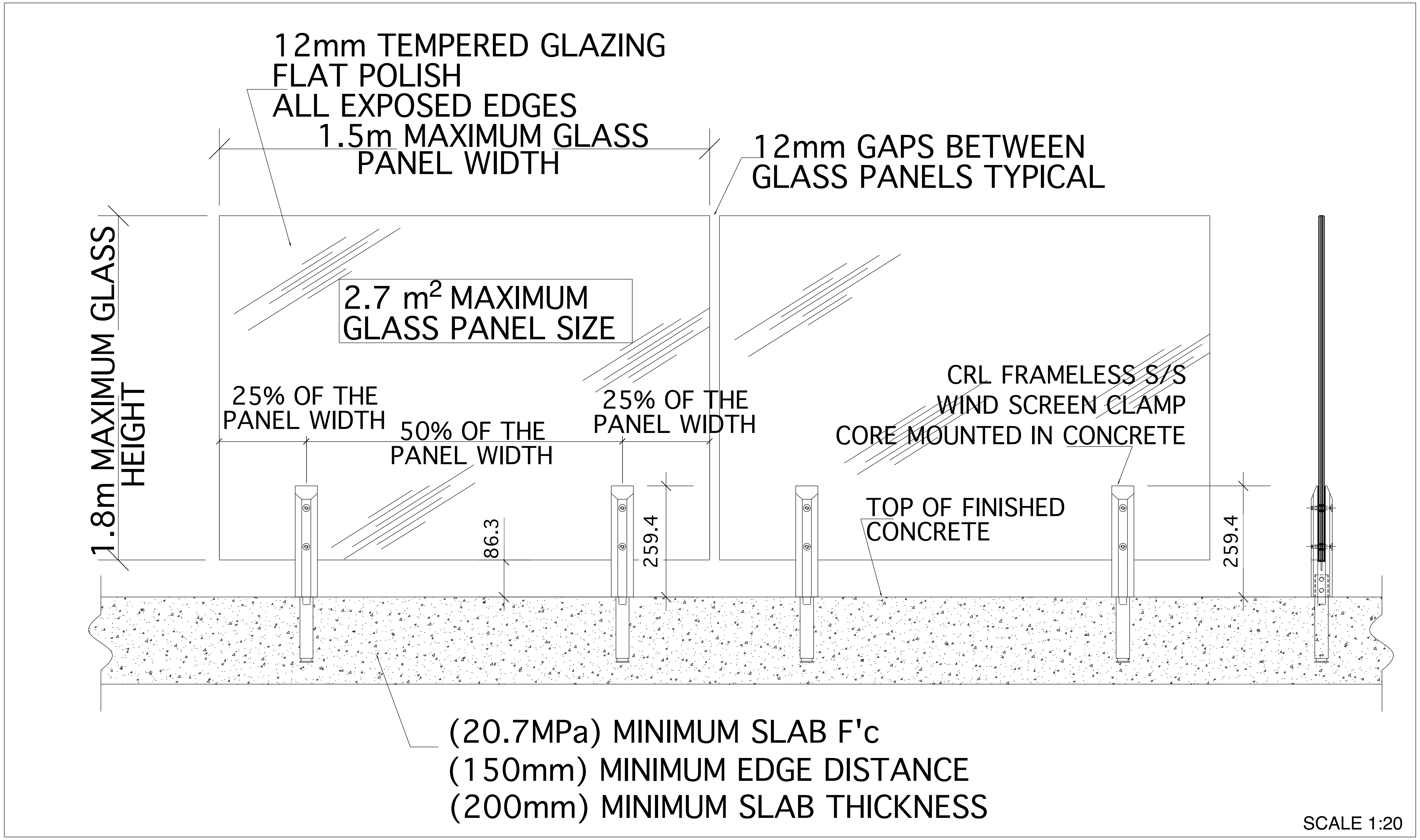
For lites simply supported on two opposite sides the moment and deflection are calculated from basic beam theory

$M_w = W^*L^2/8$ for uniform load W and span L or

$M_p = P^*L/4$ for concentrated load P and span L, highest moment P @ center

EDWARD C. ROBISON, PE
10012 Creviston Dr NW
Gig Harbor, WA 98329
253-858-0855/Fax 253-858-0856 elrobison@narrows.com

FRAMELESS GLASS WINDSCREEN SYSTEM (SI)



REVISIONS

C.R.LAURENCE CO.
ARCHITECTURAL PRODUCTS
2503 E. Vernon Avenue, Los Angeles, CA 90058
Phone: 800-421-6144 Fax: 800-262-3299
www.crlaurence.com

Job Name: CRL FRAMELESS WINDSCREEN CLAMPS (SI)

DATE:	10-30-08
DRAWN BY:	CH
CHECKED BY:	ECR
SCALE:	AS SHOWN
JOB #:	--------

SHT 1 OF 1