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SUBJ: TAPER-LOC SYSTEM DRY-GLAZE OR WET-GLAZED
GRS – GLASS RAIL SYSTEM (SI)

The Taper-Loc System dry-glaze with the GRS Glass Rail System utilizes tapered glass fiber reinforced polycarbonate plates to lock tempered glass in an aluminum extruded base shoe to anchor and support structural glass balustrades which support a variety of top rails and grab rails to construct guards and dividers. The system is intended for interior and exterior weather exposed applications and is suitable for use in all natural environments. The Taper-Loc or wet-glazing with the GRS may be used for residential, commercial and industrial applications. This is an engineered system designed for the loading conditions criteria from the BS 6399-1:1999 "Barriers in and about buildings- Code of practice" and the International Building Code (2006 and 2009).

The base shoe and Taper-Loc® system or wet-glazing with the GRS will meet or exceed the loading indicating in BS6399-1:1996 Table 4 for all occupancy types when secured with appropriate anchorage for the use and substrate. Glass thickness shall be determined from the required loading using the load tables contained herein.

The Taper-Loc with the GRS system will meet or exceed all requirement of BS 6180:1999 "Barriers in and about buildings- Code of practice" as to system performance when properly installed. The Taper-Loc with the GRS system will meet or exceed all requirements of the 2006 and 2009 International Building Codes. Aluminum components are designed in accordance with the 2000 and 2005 Aluminum Design Manuals. Stainless steel components are designed in accordance with SEI/ASCE 8-02 *Specification for the Design of Cold-Formed Stainless Steel Structural Members*.

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Refer to GRS Engineering Report for grab rail mounting.

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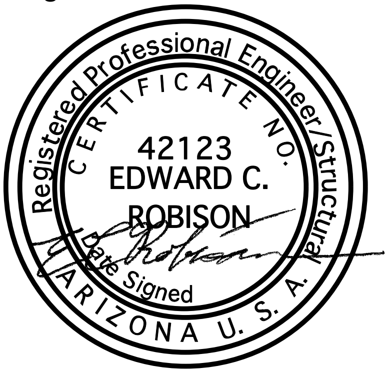
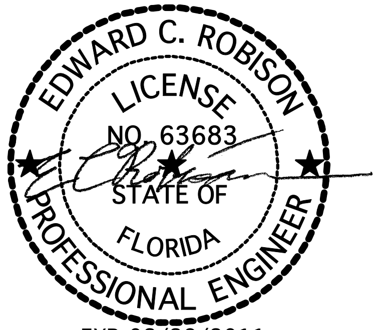
Signed 06/23/2010



EXP 03/21/2011

EXP 12/31/2011



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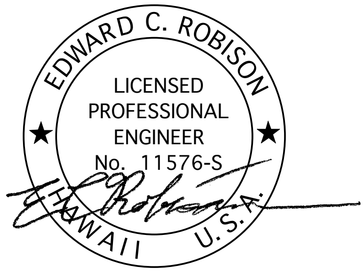

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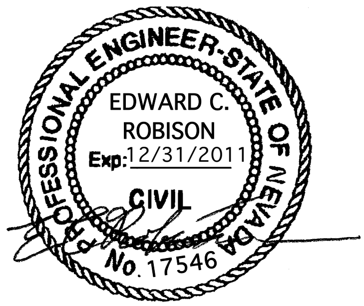

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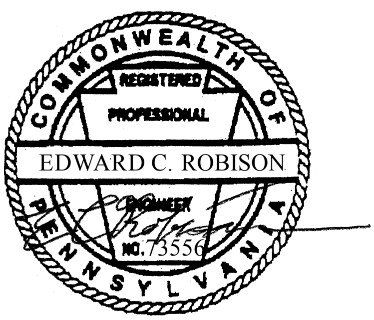

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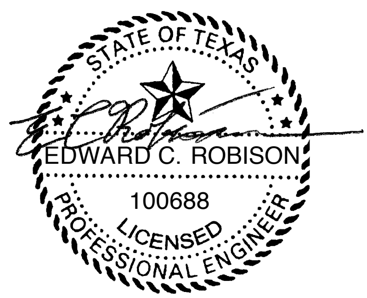


FIRM #F-12044
EXP 12/31/2010

It is a violation of NY law for any person, unless he is acting under the direction of a licensed professional engineer to alter this item in any way. If an item bearing the seal of an engineer is altered, the altering engineer shall affix to the item his seal and the notation "altered by" followed by his signature and the date of such alteration, and a specific description of the alteration.

Typical Installations:

Surface mounted to steel with anchors @ 300mm o.c.:

Residential, Commercial and Industrial Applications:
Rail Height 1,100mm above finish floor.
12mm cap screw to steel

Base Shoe	Allowable wind load
Standard/Tapered	Glass strength controls
Heavy	Glass strength controls
Low Profile	Glass strength controls (12, 15mm/16mm glass only)

8mm anchors to concrete @ 300mm o.c.

Rail Height 1,100mm above finish floor.

Base Shoe	Allowable wind load
Standard/Tapered	1.40 kN/m^2
Heavy	1.54 kN/m^2
Low Profile	1.28 kN/m^2

Embedded base shoe:

All base shoes: Glass strength controls for all cases

ALLOWABLE LOADS ON GLASS

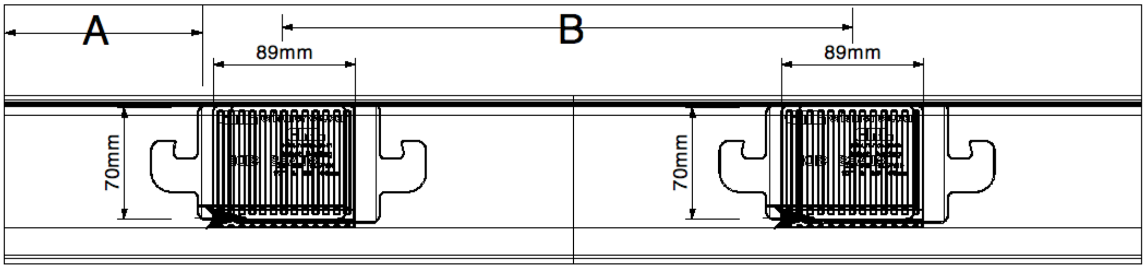
Rail Height 1,100mm above finish floor.
For wet glazed installation:

Glass thickness	Allowable uniform load	Conc load @ top
12mm	1.40 kN/m^2	0.523kN/m
15mm/16mm	2.725 kN/m^2	1.02kN/m
19mm	5.0 kN/m^2	2.07kN/m

For Taper-Loc® alone installation:

Glass thickness	Allowable uniform load	Conc load @ top
12mm	1.40 kN/m^2	0.523kN/m
15mm/16mm	2.725 kN/m^2	1.02kN/m
19mm	4.4 kN/m^2	2.07kN/m

Taper-Loc® System Typical Installation



For 12mm Fully Tempered Glass and maximum glass height = 1,000mm (1100mm rail height):
Edge Distance: 51mm ≤ A ≤ 219mm
Center to center spacing: 178mm ≤ B ≤ 356mm ;

Panel Width/Required quantity of Taper-Loc Plates:

152 to 356mm (6" to 14")	1 TL Plate
356 to 711 mm (14" to 28")	2 TL Plates
711 to 1,067 mm (28" to 42")	3 TL Plates
1,067 to 1,422 mm (42" to 56")	4 TL Plates
1,422 to 1,778 mm (56" to 70")	5 TL Plates
1,778 to 2,134 mm (70" to 84")	6 TL Plates

Minimum Glass Lite Width =152mm when top rail/guardrail is continuous, welded corners or attached to additional supports at rail ends.

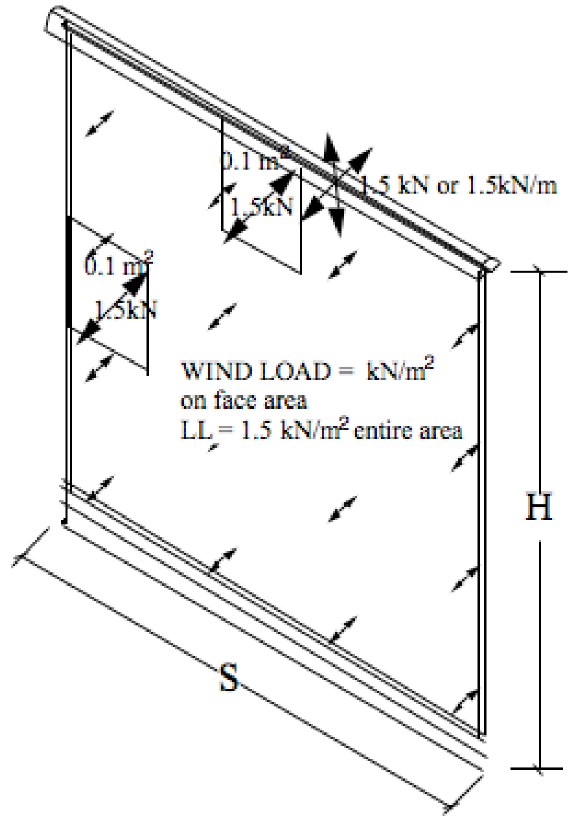
NOTES:
1. For glass light heights over 1,000 A_{max} and B_{max} shall be reduced proportionally.
   A_{max} = 219*(1,000/h)mm;
   B_{max} = 356*(1,000/h)mm;
2. For glass light heights under 1,000mm A_{max} and B_{max} shall not be increased.
3. A_{min} and B_{min} are for ease of installation and can be further reduced as long as proper installation is achieved.
4. For glass thicknesses greater than 12mm A_{max} and B_{max} may be increased as follows:
   15mm/16mm Glass
      Edge Distance: 51mm ≤ A ≤ 343mm;
      Center to center spacing: 178mm ≤ B ≤ 533mm;
   19mm Glass
      Edge Distance: 51mm ≤ A ≤ 483mm;
      Center to center spacing: 178mm ≤ b ≤ 787mm

A_{max} and B_{max} shall be reduced proportionally for heights over 1,000mm or loads greater than indicated for 12mm glass.

LOAD CASES:

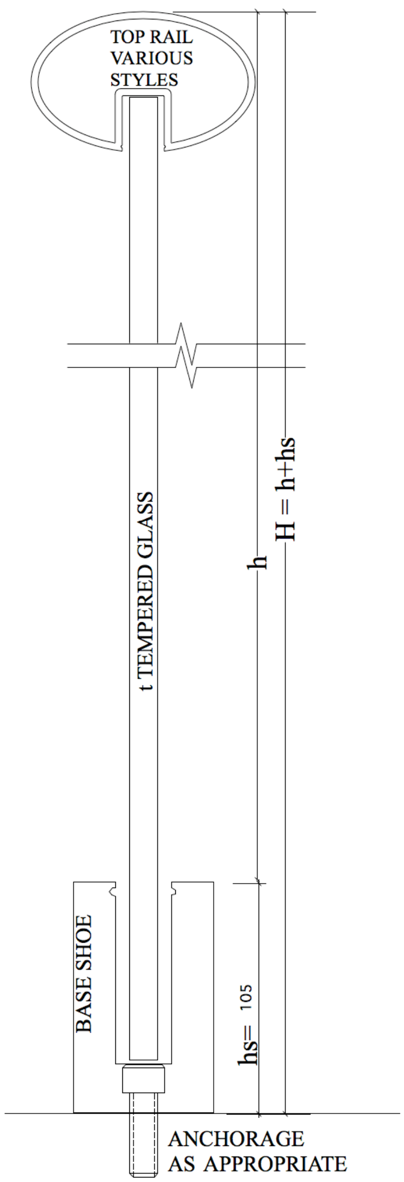
Dead load =

0.026kN/m top rail
0.125kN/m base shoe



Loading:
Horizontal load to base shoe
1.5kN/m^2*H or W*H
Balustrade moments
M_i = 1.5kN/m^2*H^2/2 or
M_w = 1.5kN/m^2* H^2/2

For top rail loads:
M_c = 1.5kN#*H
M_u = 1.5kN/m*H



Three options for glass thickness:
12mm glass, weight = 0.309 kN/m^2
15mm/16mm glass, weight = 0.385 kN/m^2
19.0mm glass, weight = 0.448 kN/m^2

For 1,100mm rail height:
h = 1100-100mm = 1,000m

The IBC design loading conditions are:
On Top Rail:
Concentrated load = 0.89 kN (200 lbs) any direction, any location
Uniform load = 0.73 kN/m (50 plf), any direction perpendicular to rail

On In-fill Panels:
Concentrated load = 0.22 kN on 0.093m^2 (50# on one sf).
Distributed load = 1.2 kN/m^2 (25 psf) on area of in-fill, including spaces
Wind load = As stated for the application and components
Refer to IBC Section 1607.7.1

GLASS BALUSTRADE GUARD RAIL

GLASS STRENGTH

All glass is toughened (fully tempered glass) conforming to the specifications of BS6206:1981, BS6262 and BS6262-4. The minimum Modulus of Rupture F_r is 165.5 MPa.

$E = 71{,}705$ MPa = 71.7×10^9 N/m^2

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

Bending strength of glass for the given thickness:

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

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

For 12mm glass

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

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

$M_{allowable} = 41.375$ MPa$*24{,}000$mm^3/m/$10^9 = 0.993$ kN-m/m

For cantilevered elements basic beam theory for cantilevered beams is used.

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

$M_p = P^*L$ for concentrated load P and span L,

Need to check deflection:

$\Delta = wl^4/(8EI)$ or

$\Delta = Pl^3/(3EI)$

$\Delta_{all} \leq l/65 = 1100/65 = 16.9mm \leq 25$ mm

Determine maximum allowable loads on 12 mm glass:

From stress:

Top load = 993Nm/1.m = 993 N per meter

Glass uniform load = $2^*993Nm/1.0^2 = 1.986$ kN/m^2

From deflections

Infill $\omega = 16.9mm^*(8^*71.7x10^9N/m^2{}^*144{,}000mm^4/m)/(1000mm)^4 = 1.40kN/m^2$

Top $P = 16.9mm^*(3^*71.7x10^9N/m^2{}^*144{,}000mm^4/m)/(1000mm)^3 = 523N/m$

For 15mm or 16mm glass (references to 15 mm thickness includes 16mm)

$I = 83.3*(15)^3 = 281{,}137\ mm^4/m$

$S = 166.7*(15)^2 = 37{,}507\ mm^3/m$

$M_{all} = 41.37MPa *37{,}507/10^8 = 1.55\ kNm/m$

From stress:

Top load = 1.55kNm/1.0m = 1.55 kN per meter

Glass uniform load = $2*1.55kNm/1.0^2 = 3.10\ kN/m^2$

From deflections

Infill $\omega = 16.9mm*(8*71.7x10^9N/m^2*281{,}137mm^4/m)/(1000mm)^4= 2.725kN/m^2$

Top $P = 16.9mm*(3*71.7x10^9N/m^2*281{,}137mm^4/m)/(1000mm)^3= 1.02kN/m$

For 19mm glass

$I = 83.3*(19)^3 = 571{,}355\ mm^4/m$

$S = 166.7*19^2 = 60{,}178.7\ mm^3/m$

$M_{all} = 41.37MPa *60{,}178.7/10^8 = 2.5\ kNm/m$

Maximum uniform load based on glass strength

$w = (2.5kNm/m*2)/(h^2)$

$h = \sqrt{(2.5kNm/m*2/w)}$

1,100mm (42") guardrail height: glass lite height = 1,000 mm

Calculate maximum uniform or wind load on glass:

$w = (2.5kNm/m*2)/(0.1^2) = 5.0\ kPa$

Top load = 2.5kNm/1.0m = 2.5 kN per meter

From deflections

Infill $\omega = 16.9mm*(8*71.7x10^9N/m^2*571{,}355mm^4/m)/(1000mm)^4= 5.538kN/m^2$

Top $P = 16.9mm*(3*71.7x10^9N/m^2*571{,}355mm^4/m)/(1000mm)^3= 2.073kN/m$

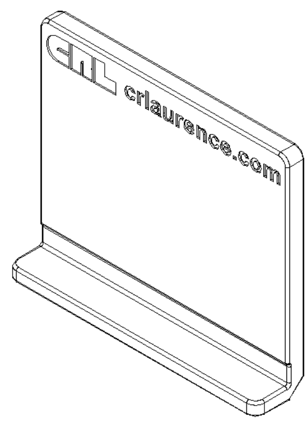
NOTE: FOR THE TAPER-LOC SYSTEM INSTALLED WITHOUT WET GLAZING GLASS LOADS TYPICALLY DO NOT NEED TO BE ADJUSTED FOR STRESS CONCENTRATIONS AS SHOWN LATER IN THIS REPORT.

No adjustment to allowable loads calculated from deflection limits are required.

DRY-GLAZE TAPER-LOC SYSTEM

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

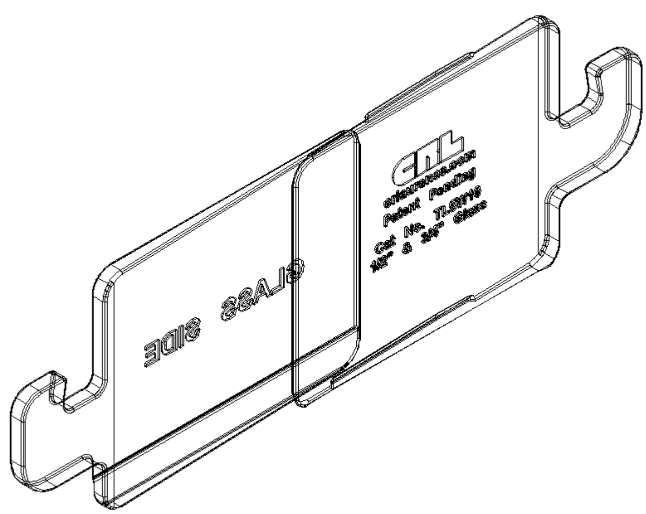
Glass may be extracted by reversing the installation tool to extract tapers.



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

Surface area of the setting plate adhered to the glass:
$A = 50.8mm*88.9 = 4{,}516mm^2$ (2"*3.5" = 7 in^2)
adhesive shear strength $\geq 551.6\ kN/m^2$ (80 psi)
3M™ VHB Tape
$Z = 4{,}516mm^2*551.6\ kN/m^2 = 2.49kN$ (7 in^2*80 = 560# min)

The setting plate locks into place in the base shoe by friction created by the compression generated when the shim plates are locked into place.



Installation force:
$T_{des} = 28.2Nm$ (250#") design installation torque
$T_{max} = 33.9Nm$ (300#") maximum installation torque
Compressive force generated by the installation torque:
$C = (0.2*28.2Nm/25.4mm)/\sin(1.76^\circ)$
$C = 7.24kN$ (1,628#)

Frictional force of shims and setting plate against aluminum base shoe:
coefficient of friction, $\mu = 0.65$
$f = 2*(7.24kN*0.65) = 9.37kN$

Frictional force of shims against glass:
$\mu = 0.20$
$f = 7.24kN*0.20 = 1.448kN$

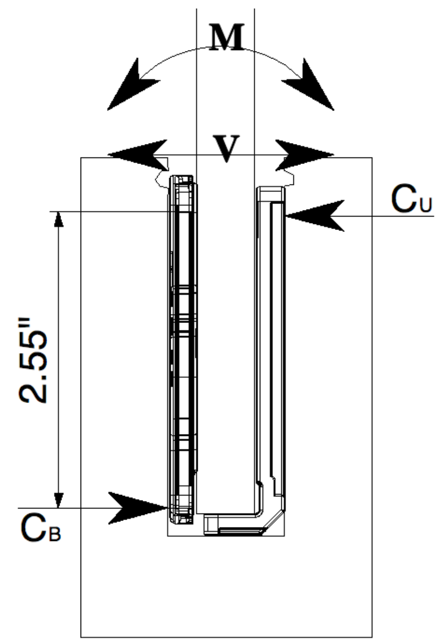
Resistance to glass pull out:

U = 2.491kN+1.448kN = 3.939kN

Safety factor for 890N (200#) pullout resistance = 3.939/0.89 = 4.43
Minimum recommended installation torque:
4/4.43*28.2Nm = 25.5Nm

Extraction force required to remove tapers after installation at design torque:
T = 28.2Nm*(0.7/0.2) = 98.7Nm (875#")

Glass anchorage against overturning:
Determine reactions of Taper-Loc plates on the glass:
Assuming elastic bearing on the nylon parts the reactions will have centroids at approximately 1/6*64.77mm (2.55") from the upper and lower edges of the bearing surfaces:
R_{C_U} @ 1/6*64.77mm = 10.8mm (0.425")



From ∑M about R_{C_U} = 0
0 = M+V*(10.8mm*12.7mm) - R_{C_B} *43.2mm
Where M = V*965.2mm
substitute and simplify:
0 = V*988.7mm - R_{C_B} *43.2mm
Solving for - R_{C_B}
R_{C_B} = V*988.7/43.2 = 22.9V
For C_B = 20.68MPa (3,000 psi):
R_{C_B} = 88.9mm*(64.77mm/2)*20.68MPa/2 = 29.78kN
V_a = 29.78kN/22.9 = 1.3kN
M_a = R_{C_B}*(2/3*64.77mm) = 1.286kNm
R_{C_B} = R_{C_B} +V = 29.78kN+1.299kN = 31.075kN

At maximum allowable moment determine bending in base shoe legs:
M_s = C*(0.188+2.55"/2) + R_{C_B} *(0.188+2.55-0.425) =
M_s = 1,954*(1.463) + 6,986 *(2.313) = 2.149kNm

Base shoe tributary length of leg that resists bending from load:
L = 88.9mm+8*12.7mm+2*(82.55mm) = 355.6mm (3.5"+8*0.5"+2*(3.25") = 14"), This is the maximum allowable spacing of the Taper-Loc system so represents the maximum loading condition.

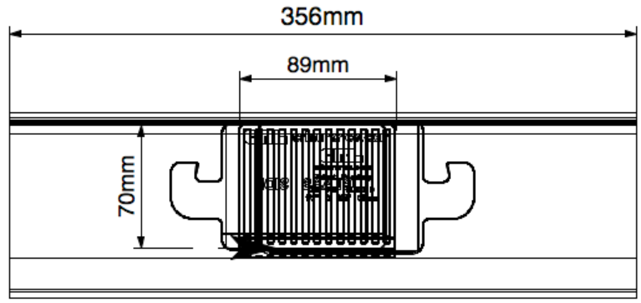
Strength of leg 355.6mm (14") length = 5.212kNm*0.3556 = 1.854kNm

Adjustment to allowable load based on base shoe strength:
M_a = 1.854kNm/2.149kNm*1.286kNm = 1.109kNm (16,406/19,017*11,380 = 9,818#")

Allowable Moment per lineal meter of glass rail:
M_a = 1.109kNm*(1000mm/355.6mm) = 3.118kNm (8,415#"/ft)

GLASS STRESS ADJUSTMENTS FOR THE TAPER-LOC SYSTEM

The Taper-Loc System provides a concentrated support:
Stress concentration factor on glass based on maximum 356mm glass width to each Taper-Loc set.



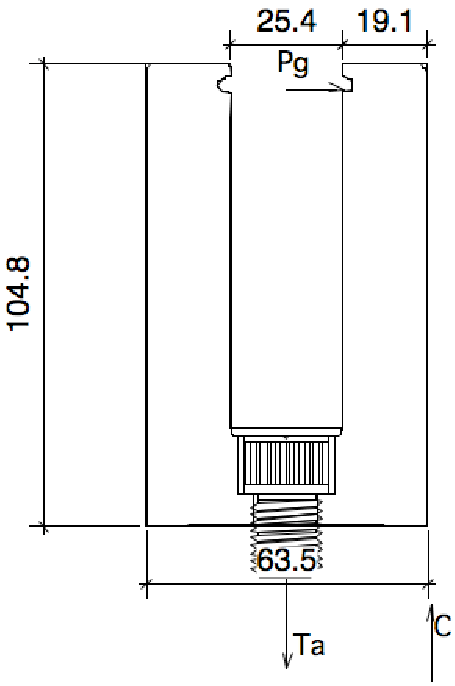
Moment concentration factor
$C_M = [1+(1-a/b)^2(1-c/b)^3(1-t/b)^{1/3}]^{1/2}$
a = 63.5mm (2.75”) (bottom of glass to top of bearing)
b = center to center spacing of supports or width of glass.
c = length of bearing
glass thickness will have less than 1% change in the stress concentration so can be ignored for the three glass thicknesses.
$C_M = [1+(1-63.5/356)^2(1-89/356)^3(1-12.7/356)^{1/3}]^{1/2} = 1.13$
b/h = 356mm/817mm = 0.4375 < 1 based on maximum spacing of 356mm and minimum glass height of 817mm (920mm rail)
$C_{M'} = 1+(C_M - 1)*(b/h)^3 = 1.01$
Since adjustment is typically under 1% it can be ignored when glass height exceeds 21” since $C_{M'} < 1.04$
F_b = 41.37MPa (6,000psi)

Shear concentration factor:
$C_V = 356/89*(2-89/356) = 7.0$
F_{Va} = 20.68MPa (3,000 psi) maximum allowable shear stress

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

Maximum edge distance for edge of glass to centerline of Taper-Loc plates:
e_{des} = 356/2 = 178mm for design conditions (no reduction in allowable),
C_M = 1.0436 for cantilever moment.
$e_{max} = e + e_{des}/2$: limited by added glass stress from cantilever bending of glass
$e_{max} = e + e_{des}/2$:
$(e)+1.25*(1100mm)/2 = 1.0436*993N\text{-}m/1200N/m^2 = 863.6mm$:
solve for e: e = 177
e_{max} = 178mm/2 + 177 = 266mm (to CL of Taper-Loc plates)

B5S 105mm x 63mm GLASS BALUSTRADE BASE SHOE



6063-T52 Aluminum extrusion

Fully tempered glass glazed in place with Taper-Loc® dry-glaze.

Shoe strength – Vertical legs:
Glass reaction by bearing on legs to form couple.
Allowable moment on legs:
$M_a = S_l*F_t$ or F_c
$F_t = F_c = 86.18$MPa (12.5 ksi) (ADM Table 2-23, Sec 3.4.4)
$S_l = 1000mm*(19.1mm)^2/6= 60{,}802mm^3$

$M_a = 60{,}802mm^3*86.18MPa = 5.24$kNm/m

Leg shear strength @ bottom
$t_{min} = 19.1$mm (0.75")
$F_v= 58.6$ MPa 8.5 ksi (ADM Table 2-24, Sec 3.4.20
$V_{all} = 19.1mm*1{,}000*58.6$ MPa = 1,119kN/m

Base shoe anchorage:
Typical rail section: 1,100mm high

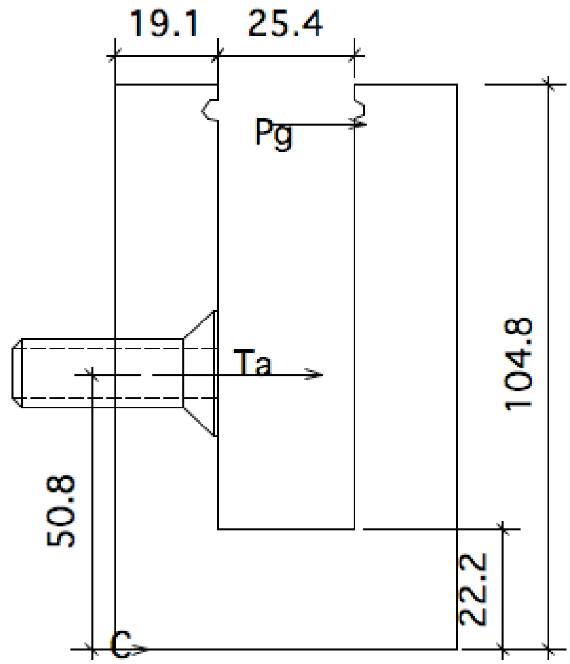
$M_p = 1.1m*P$ kN; P = concentrated load on top rail
$M_t = 1.1m*U$ kN/m; U = uniform load along top rail
$M_w = 1.1^2m/2*W$ kN/m^2; W = Wind load on uniform load on glass

Typical Anchor load – 300mm o.c. –

$T_a = (M_{Nm/m})*.30m/0.03175m = 9.45*M$ (N)

For 12mm 304 SS ASTM E593 Condition AF cap screw to tapped steel
$T_n = A_{sn}*t_c*0.6*F_{tu}$
where t_c = 6.7mm ; A_{sn} =26.117mm and F_{tu} = 400MPa (58 ksi) (A36 steel plate)
Plate thread stripping: T_n =26.117mm*6.7mm*0.6*400MPa = 42.0kN
for screw thread stripping: A_{ss} = 17.064mm and F_{tu} = 571MPa
T_n =17.064mm*6.7mm*0.6*571MPa = 39.17kN
Bolt tension strength = 465.4MPa*84.267mm^2= 39.2kN bolt strength controls
Maximum service load: 0.75*39.2/1.6 = 18.375kN
Maximum allowable moment for 300mm on center spacing and direct bearing of base shoe on steel:
M_a = 18.375kN*[31.75mm-0.5*18.375kN/(206.8MPa*300mm)]= 580.6Nm per anchor
M/m = 580.6Nm*1/.3 = 1,935.6Nm/m
ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT
P_a = 1,935.6Nm/1.1m = 1.76kN/m of glass
U_a = 1,935.6Nm/m/1.1m = 1.76kN/m
W_a = 2*1,935.6Nm/m/(1.1m)^2 = 3.2kN/m^2

Side mounted base shoe:



Verify Anchor Pull through

For counter sunk screw
M12, 12mm dia
from ADM 5.4.2.2
t_1 > 6mm so check with Eq 5.4.2.2-1 only
$P_{nov} = Ct_1F_{tu1}(D_{ws}-D_h)$
P_{nov} = 1.0*15.1mm*205Mpa(22mm-12mm) = 30.955kN
T_a = 30,955/3 = 10,318N

For inset bolt
t_{min} = 6.35mm
$P_{nov} = F_{tu}/\sqrt{3}*(A_v)$
A_v = 6.35mm*π*19.05mm = 380mm^2

P_{nov} = 205MPa/√3*(380mm^2) = 45kN

Screw or bolt strength = 39.2kN

For standard installation, 1,100mm guard height measured from top of base shoe:
Moment calculated about bottom of base shoe, H = 1,100mm+105mm =1,205mm

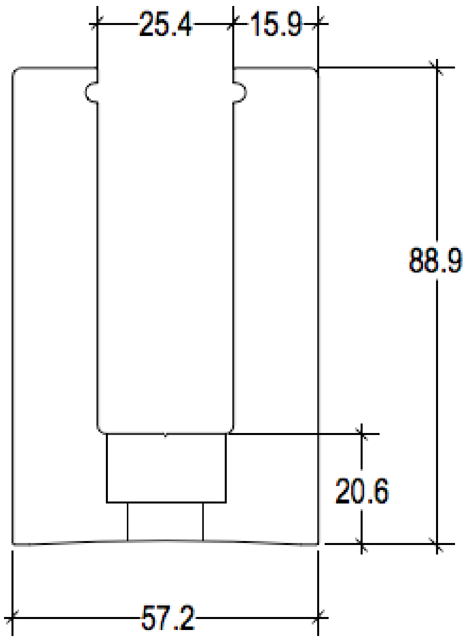
M_p = 1.205m*P kN; P = concentrated load on top rail
M_t = 1.205m*U kN/m; U = uniform load along top rail
M_w = 1.205^{2}m/2*W = 0.726*W kN/m^2; W = Wind load on uniform load on glass

Typical Anchor load – 300mm o.c. –
T_a = ($M_{Nm/m}$)*.30m/0.050m = 6*M (N)

M_a = 10,318N*[50.8mm-0.5*10,318N/(205MPa*300mm)]= 588Nm per anchor
M/m = 588Nm*1/.3 = 1,960Nm/m
ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT
P_a = 1,960Nm/1.205m = 1.627kN/m of glass
U_a = 1,960Nm/m/1.205m = 1.627kN/m
W_a = 2*1,960Nm/m/(1.205m)^2 = 2.7kN/m^2

B5L Low Profile Base Shoe 57mm x 89mm

6063-T52 Aluminum extrusion



Fully tempered glass glazed in place with Taper-Loc® dry-glaze.

Shoe strength – Vertical legs:
Glass reaction by bearing on legs to form couple.
Allowable moment on legs:
$M_a = S_l F_y$
$F_t = F_c = 86.18MPa$ (ADM Table 2-23, Sec 3.4.4)
$S_l = 1000mm*(15.9mm)^2/6= 42,135mm^3$

$M_a = 42,135mm^3*86.18MPa = 3.63kNm/m$

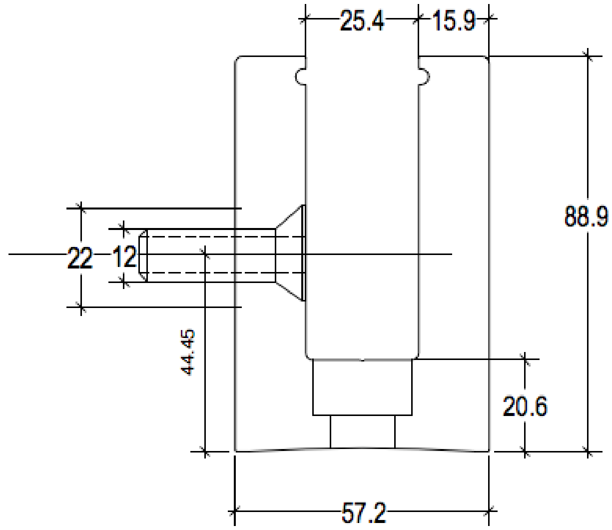
Leg shear strength @ bottom
$t_{min} = 15.9mm$
$F_v= 58.6$ MPa (ADM Table 2-24, Sec 3.4.20
$V_{all} = 15.9mm*1,000*58.6$ MPa = 931.7kN/m

Base shoe anchorage:
Typical rail section: 1,100mm high

$M_p = 1.1m*P$ kN;	P = concentrated load on top rail
$M_t = 1.1m*U$ kN/m;	U = uniform load along top rail
$M_w = 1.1^2m/2*W$ kN/m^2;	W = Wind load on uniform load on glass

Anchor 12mm Cap screws – 304 SS
Maximum allowable moment for 300mm on center spacing and direct bearing of base shoe on steel:
M = 18.375kN*[28.6mm-0.5*18.375kN/(206.8MPa*300mm)] = 525.5Nm per anchor
M/m = 525.5Nm*1/.3 = 1,751.7Nm/m
ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT
P_a = 1,751.7Nm/1.1m = 1.59N/m of glass
U_a = 1,751.7Nm/m/1.1m = 1.59kN/m
$W_a = 2*1,751.7Nm/m/(1.1m)^2 = 2.9kN/m^2$

Side mounted base shoe:



Verify Anchor Pull through

For counter sunk screw
M12, 12mm dia
from ADM 5.4.2.2
t_1 > 6mm so check with Eq 5.4.2.2-1 only
$P_{nov} = Ct_1F_{tu1}(D_{ws}-D_h)$
P_{nov} = 1.0*15.1mm*205Mpa(22mm-12mm) = 30.955kN
T_a = 30,955/3 = 10,318N

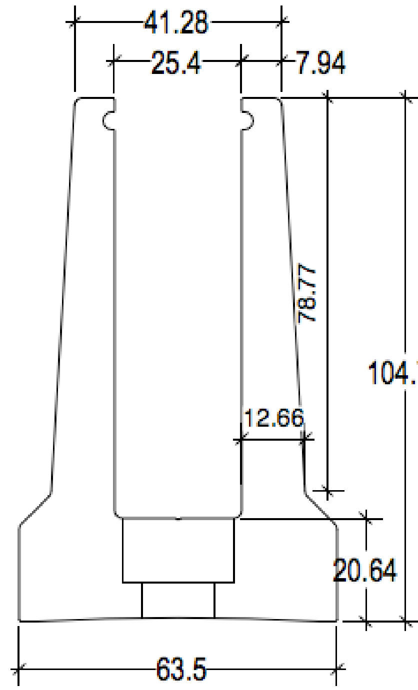
Screw or bolt strength = 39.2kN

For standard installation, 1,100mm guard height measured from top of base shoe:
Moment calculated about bottom of base shoe, H = 1,100mm+89mm =1,189mm

M_p = 1.189m*P kN; P = concentrated load on top rail
M_t = 1.189m*U kN/m; U = uniform load along top rail
M_w = 1.189^2m/2*W = 0.707*W kN/m^2; W = Wind load on uniform load on glass

Typical Anchor load – 300mm o.c. –
T_a = ($M_{Nm/m}$)*.30m/0.044m = 6.82*M (N)

M_a = 10,318N*[44.45mm-0.5*10,318N/(205MPa*300mm)]= 458.6Nm per anchor
M/m = 458.6Nm*1/.3 = 1,529Nm/m
ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT
P_a = 1,529Nm/1.189m = 1.286kN/m of glass
U_a = 1,529Nm/m/1.189m = 1.286kN/m
W_a = 2*1,529Nm/m/$(1.189m)^2$ = 2.16kN/m^2



B5T Tapered Base Shoe
6063-T52 Aluminum
Shoe strength – Vertical legs:
Glass reaction by bearing on legs to form couple.
Allowable moment on legs:
$M_a = S_l F_y$
F_y = 86.18 MPa (ADM Table 2-23, Sec 3.4.4)
S_l = 1,000mm*12.66mm^2*/6 = 26,712.6 mm^3/m
M_a = 86.18 MPa*26,712.6 mm^3/m = 2.3kNm/m

Leg shear strength @ base
t_{min} = 12.66mm
F_v= 37.92 MPa (ADM Table 2-24, Sec 3.4.20
V_{all} = 37.92MPa*12.66mm*1,000mm/m = 33 k/ft
480kN/m
Can be anchored down same as the standard base shoe. The anchorage will have the same strength and loading characteristics. Determine allowable moment on base shoe based on anchorage strength:

Base shoe anchorage:
Typical rail section: 1,100mm high

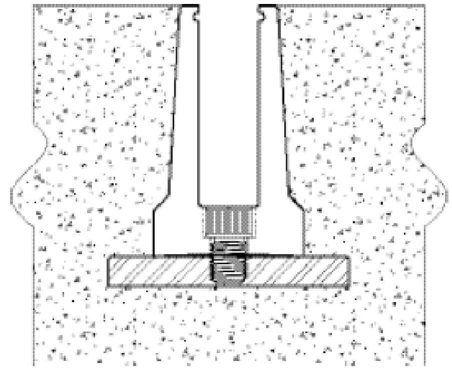
M_p = 1.1m*P kN;	P = concentrated load on top rail
M_t = 1.1m*U kN/m;	U = uniform load along top rail
M_w = 1.1^{2}m/2*W kN/m^2;	W = Wind load on uniform load on glass

Anchor 12mm Cap screws – 304 SS
Maximum allowable moment for 300mm on center spacing and direct bearing of base shoe on steel:
M = 18.375kN*[31.75mm-0.5*18.375kN/(206.8MPa*300mm)] = 580.7Nm per anchor
M/m = 580.7Nm*1/.3 = 1,935.6Nm/m

ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT
P_a = 1,935.6Nm/1.1m = 1.76N/m of glass
U_a = 1,935.6Nm/m/1.1m = 1.76kN/m
W_a = 2*1,935.6Nm/m/(1.1m)^2 = 3.2kN/m^2

Tapered base shoe cannot be side mounted.

Embedded Base Shoe Option (All base shoe types can be used). Check based on tapered base:



Strength of embed in concrete will be dependent on side cover, embed depth and concrete strength. Attachment to substrate is only required to secure the base shoe during concrete placement. When concrete strength is inadequate or side cover is too thin the base shoe anchorage shall be based on attachment to the substrate.

Example of checking base shoe embedment:

1.) Calculate reaction on concrete:
Compression on top edge:

$$0.85*f'_c*a = M/(h-a/2)$$

Solve for a

$1/2a^2-0.85f'_ch_a – M = 0$

Where:

M = guard moment at the top of the base shoe

h_a = lesser of bas shoe height or embedment depth

f'_c = concrete compressive strength

example:

M = 10,000#"/ft, h = 4.125", f'_c = 2,500 psi

$1/2a^2-0.85*f'_c*h_a*a – M = 0$

using the quadratic equation to solve for a:

$[f'_c*h_a+/- \sqrt{[(f'_c*h_a)^2+4*0.5*M)]}/(2*0.5) = a$

if $a < 1/3*h_a$ the concrete strength and embed depth is adequate.

if $a > 1/3*h_a$ the concrete strength or (and) embed depth strength must be increased.

Check side cover for shear

$1.6M \leq 0.85*0.1f'_c*1.0*d^2/6$

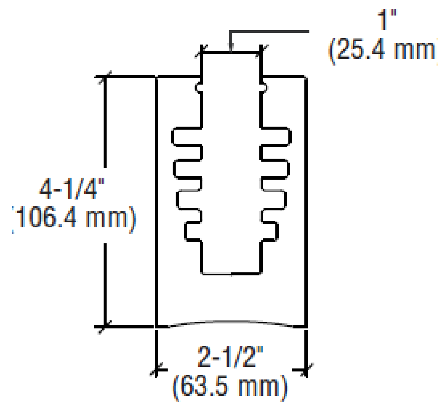
$M \leq 0.00885* f'_c*d^2$

where d = side cover (meters)

When side cover is greater than $2*h_a$ it will not control allowable moment.

Side cover strength can be increased by using steel reinforcement bars.

B5A SurfaceMate Square Base Shoe 63.5mm X 106mm

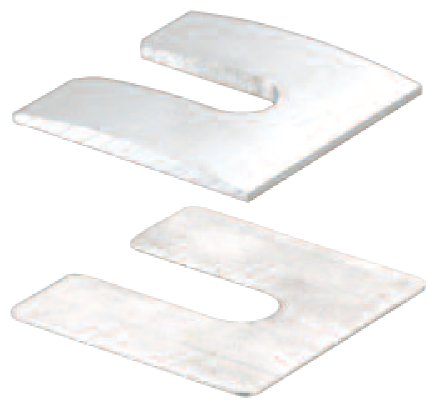


B5A Shoe is designed to be interchangeable with the B5S shoe. The B5A base shoe allowable loads are the same as for the B5S shoes for all anchor types and configurations.
Refer to the B5S base shoe calculations for allowable loads for the anchor time.

<u>Not to be used on wood substrates.</u>

SurfaceMate Angle Adjust Curved Blocks

Used at each anchor bolt to allow adjustment of the B5A base shoe to plumb on an out of level or uneven substrate.



When used on a steel substrate there is no reduction in the allowable loads.

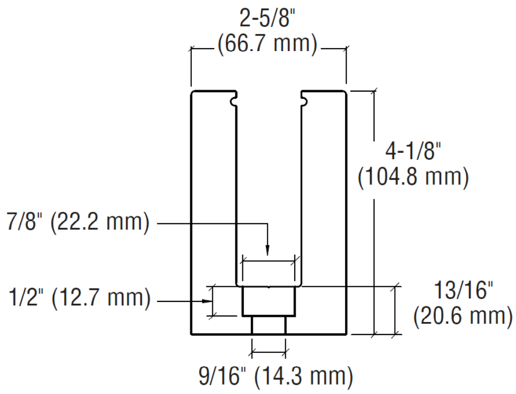
When installed on a concrete substrate grout shall be packed solid under the base shoe or a continuous shim strip used in order to develop the full allowable loads.

When installed on concrete substrate without grouting or continuous shim the allowable loads are adjusted to:
For 86mm anchor edge distance
M_a = 9.39kN*[31.9mm-0.5*9.39kN/(2*0.85*20,684.3kN/m^2*57.5mm)] = 277.7 kN-mm
Maximum allowable wind loads for 300mm spacing:
920mm height: w = (277.7*2/920^2)/0.3 = 2.188kN/m^2
1,100mm height: w = (277.7*2/1100^2)/0.3= 1.53kN/m^2

For minimum edge distance = 60mm
$øM_n$ = 7.64kN*[31.9mm-0.5*7.64kN/(2*0.85*20,684.3kN/m^2*57.5mm)] = 229.3kN-mm
Anchor spacing must be decreased for 1100mm guard height when 1.5kN-m live load applies.
S_{50-42} = 229.3kN-mm/(1100*1.5kN-m)*1000 = 139mm o.c
Maximum allowable wind loads (300mm o.c. spacing):
920mm height: w = (229.3*2/920^2)/0.3 = 1.8kN/m^2
1,100mm height: w = (229.3*2/1100^2)/0.3= 1.26kN/m^2

<u>Not to be used on wood substrates.</u>

B6S 2 5/8" X 4 1/8" GLASS BALUSTRADE BASE SHOE



Heavy Duty Square Base Shoe

6063-T52 Aluminum extrusion

Fully tempered glass glazed in place, either wet glazing cement or GlassWedges®.

Shoe strength – Vertical legs:
Glass reaction by bearing on legs to form couple. Allowable moment on legs:
$M_a = S_l F_y$
$F_t = F_c$ = 86.18 MPa (ADM Table 2-23, Sec 3.4.4)
S_l = 1,000mm*19.16mm^2*/6 = 61152mm^3/m
M_a = 86.18MPa*61152mm^3/m = 5.27 kN-m/m

Leg shear strength @ groove
t_{min} = 8.76mm
F_v= 37.92MPa (ADM Table 2-24, Sec 3.4.20
V_{all} = 8.76mm*1000*37.92MPa = 332.2 kN/m

Base shoe anchorage:
Typical rail section: 1100mm high 0.75kN/m top rail load or 1.0kN/m^2 panel load
M_t = 1100*0.75 = 825kN-mm/m
M_w = 1.0kN/m^2*1.1m*1100mm/2 = 605kN-mm/m

Typical Anchor load – 300mm o.c. – T_a = 825kN-mm/m /33.46mm*0.3m = 7.40

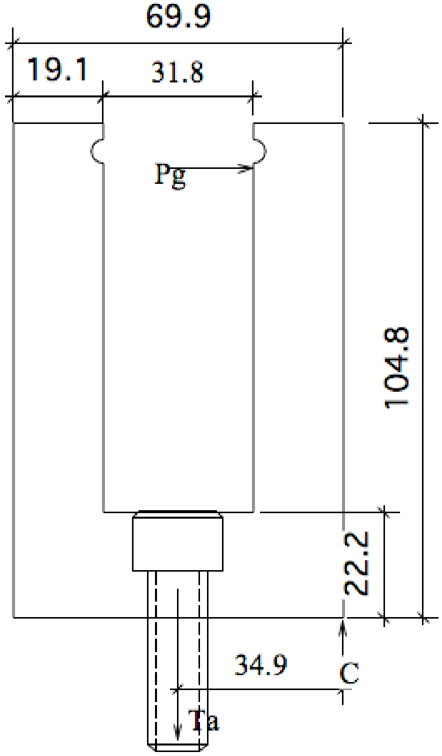
Maximum allowable moment for 12mm cap screws (T_a = 18.375kN) 300mm on center spacing and direct bearing of base shoe on steel:
M_a = 18.375kN*[33.46mm-0.5*18.375kN/(206.8MP*300mm)]/.3m = 2.04kN-mm/m

ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT
P_a = 2,040Nm/1.1m = 1.85kN/m of glass
U_a = 2,040Nm/m/1.1m = 1.85kN/m
W_a = 2*2,040Nm/m/(1.1m)^2 = 3.37kN/m^2

For anchor into concrete:
Hilti HSL-3 M8 x 3-3/4" anchor in accordance with ESR-1545.

FASCIA (SIDE) MOUNTED BASE SHOE
For side mounted base the allowable loads are the same as for the B5S base shoe. Alternative anchors will provide the same allowable loads as for the B5S base shoe to steel, concrete or wood.

B7S 70mm X 105 GLASS BALUSTRADE BASE SHOE



Heavy Duty Square Base Shoe

6063-T52 Aluminum extrusion

Fully tempered glass glazed in place with Taper-Loc® dry-glaze.

Shoe strength – Vertical legs:
Glass reaction by bearing on legs to form couple.
Allowable moment on legs:
$M_a = S_l F_y$
$F_t = F_c = 86.18$MPa (ADM Table 2-23, Sec 3.4.4)
$S_l = 1000\text{mm}*(19.1\text{mm})^2/6 = 60{,}802\text{mm}^3$

$M_a = 60{,}802\text{mm}^3*86.18\text{MPa} = 5.24\text{kNm/m}$

Leg shear strength @ bottom
$t_{min} = 19.1$mm
$F_v = 58.6$ MPa (ADM Table 2-24, Sec 3.4.20
$V_{all} = 19.1\text{mm}*1{,}000*58.6\text{ MPa} = 1{,}119\text{kN/m}$

Base shoe anchorage:
Typical rail section: 1,100mm high

$M_p = 1.1\text{m}*P$ kN;	P = concentrated load on top rail
$M_t = 1.1\text{m}*U$ kN/m;	U = uniform load along top rail
$M_w = 1.1^2\text{m}/2*W$ kN/m^2;	W = Wind load on uniform load on glass

Anchor 12mm Cap screws – 304 SS
Maximum allowable moment for 300mm on center spacing and direct bearing of base shoe on steel:
M = 18.375kN*[34.9mm-0.5*18.375kN/(206.8MPa*300mm)] = 638.6Nm per anchor
M/m = 638.6Nm*1/.3 = 2,128.7Nm/m
ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT
P_a = 2,128.7Nm/1.1m = 1.94kN/m of glass
U_a = 2,128.7Nm/m/1.1m = 1.94kN/m
$W_a = 2*2{,}128.7\text{Nm/m}//(1.1\text{m})^2 = 3.52\text{kN/m}^2$

For side mounted base the allowable loads are the same as for the B5S base shoe.

Standard Concrete Anchor:
Hilti HSL-3 Heavy Duty Sleeve Anchor
Zinc –plated carbon steel.
Try M8 size for clearance requirements in base shoe.
Design values from ESR-1545
Complies with ICC-AC193

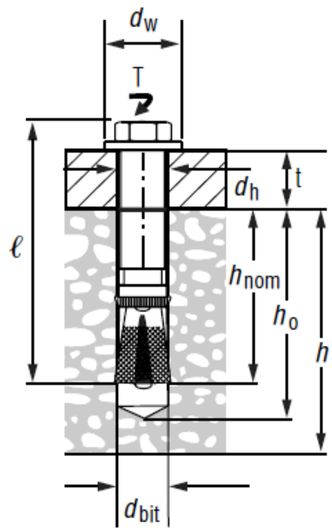
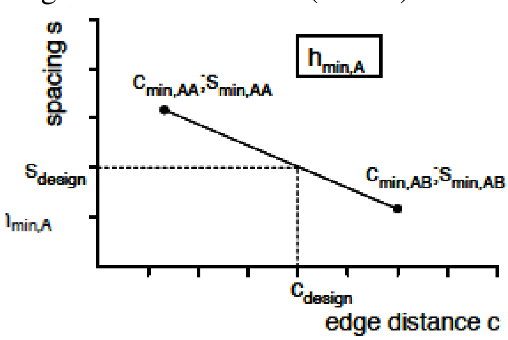


Table 1 — HSL-3 Specifications

Details			M8	
nominal drill bit diameter[1]	d_{bit}	mm	12	
Hilti matched-tolerance carbide-tipped drill bit	-	-	TE-CX 12/22 TE-YX 12/35	
minimum base material thickness (to obtain smallest critical edge distance)	h	mm (in.)	110 (120) 4 3/8 (4-3/4)	
minimum hole depth	h_o	mm (in.)	80 (3-1/8)	
effective embedment depth	$h_{ef,min}$	mm (in.)	60 (2-3/8)	
minimum clearance hole diameter in part being fastened	d_h	mm (in.)	14 (1/2)	
max. cumulative gap between part(s) being fastened and concrete surface	-	mm (in.)	4 (1/8)	
maximum thickness of part fastened HSL-3, HSL-3-B	t	mm (in.)	20 (3/4)	40 (1-1/2)
overall length of anchor HSL-3, HSL-3-B	-	mm (in.)	98 (3-7/8)	118 (4-5/8)
maximum thickness of part fastened HSL-3-G	t	mm (in.)	20 (3/4)	
overall length of anchor HSL-3-G	-	mm (in.)	102 (4)	
washer diameter	d_w	mm (in.)	20 (3/4)	
installation torque HSL-3	T_{inst}	Nm (ft-lb)	25 (18)	
installation torque HSL-3-G	T_{inst}	Nm (ft-lb)	20 (15)	
wrench size HSL-3, HSL-3-G	-	mm	13	
wrench size HSL-3-B	-	mm		

1 Use metric bits only.

Allowable tension load for f'_c = 13.8 MPa (2,000 psi) concrete, uncracked, case B:
T = 7.767 kN (1,746#)
Anchor spacing = 300mm
Edge distance > 60mm (2-3/8")



B	Minimum concrete thickness	$h_{min,B}$[4]	in. (mm)	4-3/8 (110)
B	Critical edge distance[2]	$c_{cr,B}$	in. (mm)	5-7/8 (150)
B	Minimum edge distance[3]	$c_{min,BA}$	in. (mm)	2-3/8 (60)
B	Minimum anchor spacing[3]	$s_{min,BA}$	in. (mm)	7 (180)
B	Minimum edge distance[3]	$c_{min,BB}$	in. (mm)	4 (100)
B	Minimum anchor spacing[3]	$s_{min,BB}$	in. (mm)	2-3/8 (60)

Will plot above and to right of line therefore can use full allowable tension load.

Table 5—HSL-3 Allowable Static Tension (ASD), Normal Weight Uncracked Concrete (pounds)[1,3]

Nominal Anchor Diameter	Embedment Depth h_{ef}		Concrete Compressive Strength[2]							
			f'c = 2,000 psi		f'c = 3,000 psi		f'c = 4,000 psi		f'c = 6,000 psi	
	mm	in.	Condition A	Condition B	Condition A	Condition B	Condition A	Condition B	Condition A	Condition B
M8	60	2.36	1,746	1,746	2,139	2,139	2,470	2,470	3,025	3,025
M10	70	2.76	2,631	2,280	3,222	2,792	3,720	3,224	4,556	3,949
M12	80	3.15	3,214	2,785	3,936	3,411	4,545	3,939	5,567	4,825
M16	100	3.94	4,492	3,893	5,501	4,768	6,352	5,505	7,780	6,743
M20	125	4.92	6,277	5,440	7,688	6,663	8,877	7,694	10,873	9,423
M24	150	5.91	8,252	7,152	10,106	8,759	11,670	10,114	14,292	12,387

For SI: 1 lbf = 4.45 N, 1 psi = 0.006895 MPa For pound-inch units: 1 mm = 0.03937 inches

[1]Values are for single anchors with no edge distance or spacing reduction. For other cases, see Section 4.2 Eq. (5).
[2]Values are for normal weight concrete. For sand-lightweight concrete, multiply values by 0.85. For all-lightweight concrete, multiply values by 0.75. See ACI 318-02 D.3.4.
[3] Condition A applies where the potential concrete failure surfaces are crossed by supplementary reinforcement proportioned to tie the potential concrete failure prism into the structural member. Condition B applies where such supplementary reinforcement is not provided, or where pullout or pryout strength governs.

Table 6—HSL-3 Allowable Static Tension (ASD,) Normal Weight Cracked Concrete (pounds)[1,3]

Nominal Anchor Diameter	Embedment Depth h_{ef}		Concrete Compressive Strength[2]							
			f'c = 2,000 psi		f'c = 3,000 psi		f'c = 4,000 psi		f'c = 6,000 psi	
	mm	in.	Condition A	Condition B	Condition A	Condition B	Condition A	Condition B	Condition A	Condition B
M8	60	2.36	1,167	1,167	1,429	1,429	1,650	1,650	2,021	2,021
M10	70	2.76	1,867	1,867	2,286	2,286	2,640	2,640	3,233	3,233
M12	80	3.15	3,214	2,785	3,936	3,411	4,545	3,939	5,567	4,825
M16	100	3.94	4,492	3,893	5,501	4,768	6,352	5,505	7,780	6,743
M20	125	4.92	6,277	5,440	7,688	6,663	8,877	7,694	10,873	9,423
M24	150	5.91	8,252	7,152	10,106	8,759	11,670	10,114	14,292	12,387

For SI: 1 lbf = 4.45 N, 1 psi = 0.006895 MPa For pound-inch units: 1 mm = 0.03937 inches

[1]Values are for single anchors with no edge distance or spacing reduction. For other cases, see Section 4.2 Eq. (5).
[2]Values are for normal weight concrete. For sand-lightweight concrete, multiply values by 0.85. For all-lightweight concrete, multiply values by 0.75. See ACI 318-02 D.3.4.
[3] Condition A applies where the potential concrete failure surfaces are crossed by supplementary reinforcement proportioned to tie the potential concrete failure prism into the structural member. Condition B applies where such supplementary reinforcement is not provided, or where pullout or pryout strength governs.

Conclusion:
Hilti HSL-3 Heavy Duty Sleeve Anchor will work to anchor the base shoe to concrete in uncracked concrete with a minimum strength of 13.8 MPa (2,000 psi) and cracked concrete with a minimum strength of 27.6 MPa (4,000 psi).

SPECIAL INSPECTION IS REQUIRED.

Allowable base shoe moment:
Standard and Tapered shoes:
a = 7,767N/(.3*0.85*2*13,800,000Pa) = 0.0011m
M_a = [7,767N*(d-a)/2]*(1/0.3) = 12,945N(d-a)
For standard base shoe d = 63.5mm
M_a = 12,945N(0.0635-0.0011) = 807.8Nm/m

ALLOWABLE LOADS USING HILTI HSL-3 M8 ANCHORS AT 300MM ON CENTER

Standard base shoe 64mm x105mm continued

ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT

P_a = 807.8Nm/1.1m = 0.73kN/m of glass

U_a = 807.8Nm/m/1.1m = 0.73kN/m

$W_a = 2*807.8Nm/m/(1.1m)^2 = 1.335kN/m^2$

Same allowable loads are applicable to the **tapered base shoe**

Heavy base shoe 70mm x105mm

d = 69.9mm

M_a = 12,945N(0.069-0.0011) = 879.0Nm/m

ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT

P_a = 879.0Nm/1.1m = 0.799kN/m of glass

U_a = 879.0Nm/m/1.1m = 0.799kN/m

$W_a = 2*879.0Nm/m/(1.1m)^2 = 1.453kN/m^2$

Low Profile Base Shoe 57mm x 89mm

For standard base shoe d = 57.2mm

M_a = 12,945N(0.0572-0.0011) = 726.2Nm/m

ALLOWABLE LOADS FOR 1,100 mm RAIL HEIGHT

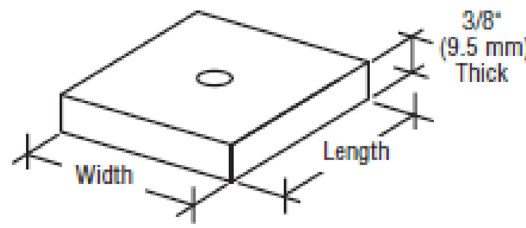
P_a = 726.2Nm/1.1m = 0.66kN/m of glass

U_a = 726.2Nm/m/1.1m = 0.66kN/m

$W_a = 2*726.2Nm/m/(1.1m)^2 = 1.2kN/m^2$

Drain Blocks

Drain blocks may be used under the base shoe to provide a water drainage path on exterior decks.



When used on steel substrate there is no reduction in the allowable loads.

<u>Not to be used on wood substrate.</u>

When used on concrete the allowable loads are reduced as follows:

B5S, B5T and B5A base shoes: 64mmx 57mm

For 96mm anchor edge distance

M_a = 9.39kN*[31.92-0.5*9.39kN/(2*0.85*20.68MPa*57.5)]/0.3m = 926.4N-m/m

Maximum allowable loads for 300mm spacing:

P_a = 926.4Nm/1.1m = 0.84kN/m of glass

U_a = 926.4Nm/m/1.1m = 0.84kN/m

W_a = 2*926.4Nm/m/(1.1m)^2 = 1.53kN/m^2

For minimum edge distance is 60mm

øM_n = 7.638kN*[31.92-0.5*7.638kN/(2*0.85*20.68MPa*57.5)]/0.3m = 764.6N-m/m

Maximum allowable loads for 300mm spacing:

P_a = 764.6Nm/1.1m = 0.695kN/m of glass

U_a = 764.6Nm/m/1.1m = 0.695kN/m

W_a = 2*764.6Nm/m/(1.1m)^2 = 1.264kN/m^2

Anchor spacing must be decreased for 1100mm guard height when 0.74kN/m live load applies.

S_{50-42} = 300mm*0.695/0.74 = 280mm o.c. (use 11 anchors for 3m section)

B5L base shoe: 57mm x 64mm

For 96mm anchor edge distance

M_a = 9.39kN*[28.73-0.5*9.39/(2*0.85*20.68MPa*63.85)]/.3 = 833.8N-m/m

Maximum allowable loads for 300mm spacing:

P_a = 833.8Nm/1.1m = 0.758kN/m of glass

U_a = 833.8Nm/m/1.1m = 0.758kN/m

W_a = 2*833.8Nm/m/(1.1m)^2 = 1.378kN/m^2

For minimum edge distance is 60mm

øM_n = 7.638kN*[28.73-0.5*7.638kN/(2*0.85*20.68MPa*63.85)]/0.3m = 688.1N-m/m

Maximum allowable loads for 300mm spacing:

P_a = 688.1Nm/1.1m = 0.626kN/m of glass

U_a = 688.1Nm/m/1.1m = 0.626kN/m

W_a = 2*688.1Nm/m/(1.1m)^2 = 1.137kN/m^2

B5L base shoe: 57mm x 64mm (cont)
Anchor spacing must be decreased for 1100mm guard height when 0.74kN/m live load applies.
$S_{50\text{-}42}$ = 300mm*0.626/0.74 = 253mm o.c. (use 12 anchors for 3m section)

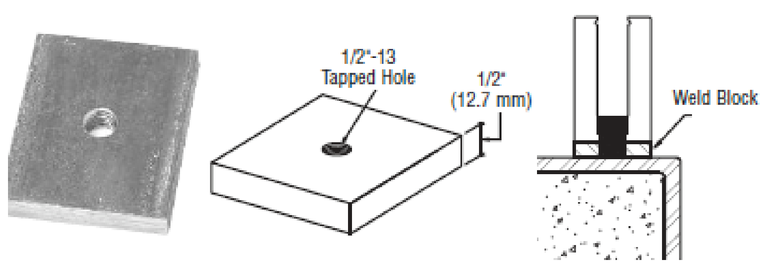
B6S base shoe: 67mm x 73.4mm
For 96mm anchor edge distance
M_a = 9.39kN*[33.46-0.5*9.39/(2*0.85*20.68MPa*73.4)]/.3 = 990N-m/m
Maximum allowable loads for 300mm spacing:
P_a = 990Nm/1.1m = 0.9kN/m of glass
U_a = 990Nm/m/1.1m = 0.9kN/m
W_a = 2*990Nm/m/(1.1m)^2 = 1.636kN/m^2

For minimum edge distance is 60mm
M_a = 7.638kN*[33.46-0.5*7.638/(2*0.85*20.68MPa*73.4)]/.3 = 814.2N-m/m
Maximum allowable loads for 300mm spacing:
P_a = 814.2Nm/1.1m = 0.74kN
U_a = 814.2Nm/m/1.1m = 0.74kN/m
W_a = 2*814.2Nm/m/(1.1m)^2 = 1.346kN/m^2

B7S base shoe: 73.4mm x 67mm
For 96mm anchor edge distance
M_a = 9.39kN*[36.7-0.5*9.39/(2*0.85*20.68MPa*67)]/.3 = 1,086N-m/m
Maximum allowable loads for 300mm spacing:
P_a = 1,086Nm/1.1m = 0.988kN/m of glass
U_a = 1,086Nm/m/1.1m = 0.988kN/m
W_a = 2*1,086Nm/m/(1.1m)^2 = 1.795kN/m^2

For minimum edge distance is 60mm
M_a = 7.638kN*[36.7-0.5*7.638/(2*0.85*20.68MPa*67)]/.3 = 893.1N-m/m
Maximum allowable loads for 300mm spacing:
P_a = 893.1Nm/1.1m = 0.812kN
U_a = 893.1Nm/m/1.1m = 0.812kN/m
W_a = 2*893.1Nm/m/(1.1m)^2 = 1.476kN/m^2

WELD BLOCKS:
When attaching the base shoe to the appropriate steel weld blocks the strength shall be the same as for the base shoe attachment to steel substrate.
Weld block size shall be matched to the base shoe width.

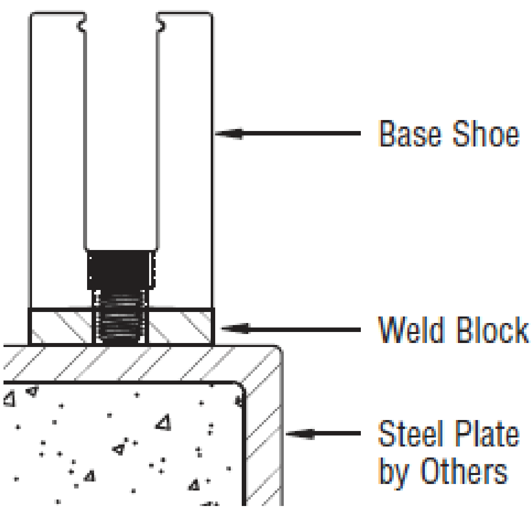


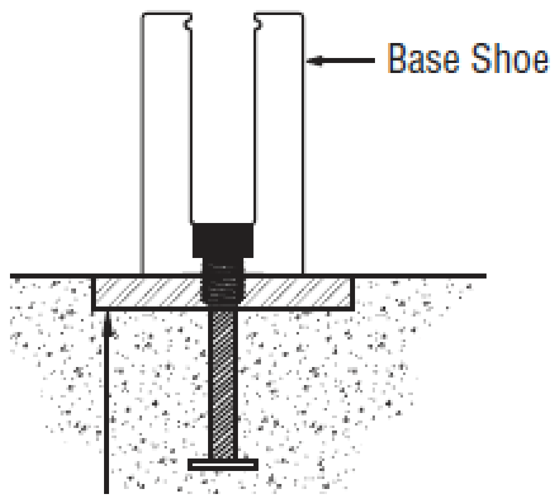
Surface Mounting Base Shoes to Wood Decks:

The base shoe develops a couple between the anchor tension and compression between the base shoe edge and the substrate to resist horizontal loads. Wood doesn't have adequate bearing compressive strength to reliably develop the requisite compressive strength when surface mounted. The shoe may be initially installed tight and appear to perform adequately; but cyclic loading will cause permanent deformation of the wood surface and loss of anchor pretension. This will result in rotation of the base shoe and increased couple forces resulting in excessive guard deflections and possible failure. For this reason the base shoes shall not be surface mounted directly to wood.

It is recommended that whenever possible the base shoe should use the fascia mount when attaching to wood.

When surface mounting to wood a steel or aluminum bar or angle shall be installed on the wood surface first. The bar or angle shall be designed to safely transfer the imposed loads from the base shoe to the wood deck. Attachment to the bar or angle shall be as specified previously.



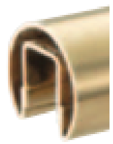


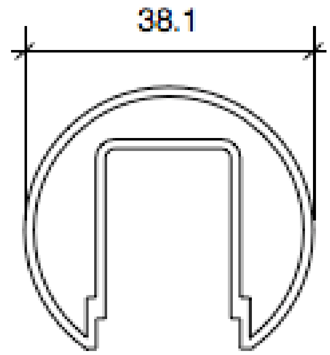
Steel angle or plate bolted to wood deck with base shoe anchored to the plate or angle using 12mm cap screws into threaded weld blocks or tapped holes.

CAP RAILS

Guard applications require a top rail or handrail. The rail shall have adequate strength to support the live load of 200 lb concentrated or 50 plf distributed load assuming the failure of one glass lite at the location of the loading.

GR 15 SERIES CAP RAIL





Area: 213.9 mm^2
I_{xx}: 22,843.8 mm^4
I_{yy}: 30,595.8 mm^4
r_{xx}: 10.33mm
r_{yy}: 11.96mm
C_{xx}: 18.13mm
C_{yy}: 19.05mm
S_{xx}: 1,260 mm^3
S_{yy}: 1,604 mm^3
t = 1.27mm
Allowable stresses:
For stainless steel options: design using SEI/ASCE 8-02
From Table A1, F_y = 344.7MPa for 1/4 hard 304 stainless steel cold formed sheet

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2} \quad \text{(eq 3.3.1.1-9)}$$

η = 0.49 (from table A8a)
$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape
μ = 0.3
E_0 = 186,200 MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$$

$M_n = S_e F_y$ = 1,260 mm^3*344.7MPa = 434.3Nm Vertical loading
1,604 mm^3*344.7MPa = 552.9Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)
Vertical → uniform → w= (434.3Nm• 10/(1.6*(1.5m)^2)) = 1,206 N/m
concentrated →P = 434.3Nm*5/(1.6*1.5m) = 905N

Horizontal → uniform → w= (552.9Nm• 10/(1.6*(1.5m)^2)) = 1,536 N/m
concentrated →P = 552.9Nm*5/(1.6*1.5m) = 1,152N

GR 15 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet

$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$

$k = 3(I_s/I_a)^{1/3}+1<4.0 \;\; = 4.0$ for circular shape

$\mu = 0.34$

$E_0 = 116.5 \text{ x}10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \text{ x}10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

$M_n = S_eF_y = 1{,}260 \text{ mm}^3 * 280.6\text{MPa} = 353.6\text{Nm}$ Vertical loading
$1{,}604 \text{ mm}^3 * 280.6\text{MPa} = 450.1\text{Nm}$ Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → $w= (353.6\text{Nm} \bullet 10/(1.6*(1.5\text{m})^2)) = 982$ N/m
concentrated → $P = 353.6\text{Nm}*5/(1.6*1.5\text{m}) = 736.7\text{N}$

Horizontal → uniform → uniform → $w= (450.1\text{Nm} \bullet 10/(1.6*(1.5\text{m})^2)) = 1{,}250.3$ N/m
concentrated → $P = 450.1\text{Nm}*5/(1.6*1.5\text{m}) = 937.7\text{N}$

Connector Sleeves

The sleeves fit tight (radial compression required) inside the rail and are secured with adhesive. The sleeve provides shear transfer between rail sections, vertically and horizontally. The sleeves can be used to connect straight or curved rail sections to corners and other rail sections.

Minimum shear strength of connectors:
For stainless steel:

F_{yv} = 289.6MPa (42 ksi)

t = 1.27mm, h = 74.9mm (for 38mm rail)

$V_n = 4.84 E_o t^3 (G_s/G_o)/h$; $ø = 0.85$

$G_s/G_o = 0.90$; E_o = 165.5GPa (24,000 ksi)

V_n = 4.84*165,500MPa*(1.27mm)^3(0.90)/74.9mm = 19.7kN controls

or V_n = 0.95*(289.6MPa*1.27mm*74.9mm) =26.17kN

$V_s = øV_n/1.6$ = 0.85*19.7kN/1.6 = 10.47kN

For Brass:

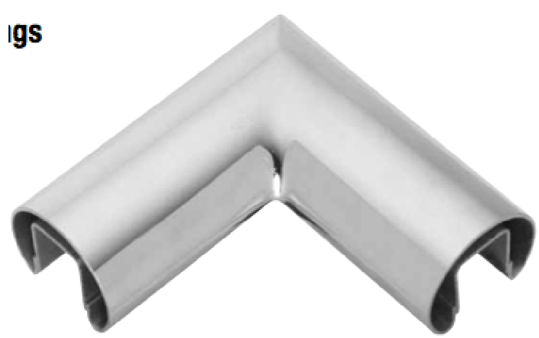
F_{yv} = 172.4MPa (25 ksi)

t = 1.27mm, h = 74.9mm (for 38mm rail)

V_n = 0.95*(172.4MPa*1.27mm*74.9mm) = 15.58kN controls

$V_s = øV_n/1.6$ = 0.85*15.58kN/1.6 = 8.28kN

Welded Corners



Constructed from the standard rail sections. Corners are welded all around full thickness of metal.

Load on corner is limited to shear and tension at corner.

Shear strength is same as the connector sleeve (weld length is same as connector perimeter)

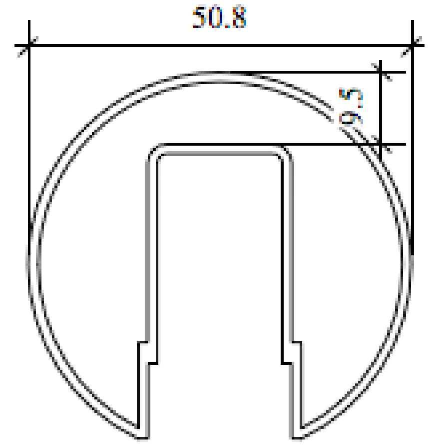
Tension: = 1/0.6*V = 1.667V

T_{ss} = 1.667*10.47kN = 17.45kN

T_{br} = 1.667*8.28kN = 13.80kN

CRL GR 20 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails



Area: 293.9 mm^2
I_{xx}: 62,393.4 mm^4
I_{yy}: 68,860.8 mm^4
r_{xx}: 14.57mm
r_{yy}: 11.96mm
C_{xx}: 24.90mm
C_{yy}: 25.4mm
S_{xx}: 2,505.9 mm^3
S_{yy}: 2,655.3 mm^3
t = 1.27mm

Allowable stresses:

For stainless steel options: design using SEI/ASCE 8-02

From Table A1, 344.7MPa for 1/4 hard A304 stainless steel sheet used to form the rail.

$F_{cr} = \dfrac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$ (eq 3.3.1.1-9)

$\eta = 0.49$ (from table A8a)

$k = 3(I_s/I_a)^{1/3}+1<4.0 = 4.0$ for circular shape

$\mu = 0.3$

$E_0 = 186{,}200$ MPa

$F_{cr} = \dfrac{\pi^2 * 4.0 * 0.49 * 186{,}200MPa}{12(1-0.3^2)(35.6/1.27)^2} = 419.8MPa$ but $\leq F_y$

$M_n = S_eF_y = 2{,}505.9\ mm^3 * 344.7MPa = 863.8Nm$ Vertical loading
$2{,}655.3\ mm^3 * 344.7MPa = 915.3Nm$ Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m

Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → $w = (863.8Nm \bullet 10/(1.6*(1.5m)^2)) = 2{,}399$ N/m
concentrated → $P = 863.8Nm*5/(1.6*1.5m) = 1{,}800N$

Horizontal → uniform → uniform → $w = (915.3Nm \bullet 10/(1.6*(1.5m)^2)) = 2{,}542$ N/m
concentrated → $P = 915.3Nm*5/(1.6*1.5m) = 1{,}907N$

GR 20 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet

$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$

$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape

$\mu = 0.34$

$E_0 = 116.5 \text{ x}10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \text{ x}10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

$M_n = S_e F_y = 2{,}505.9 \text{ mm}^3 * 280.6\text{MPa} = 703.2\text{Nm}$ Vertical loading
$2{,}655.3 \text{ mm}^3 * 280.6\text{MPa} = 745.1\text{Nm}$ Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → $w = (703.2\text{Nm} \bullet 10/(1.6*(1.5\text{m})^2)) = 1{,}953$ N/m
concentrated → $P = 703.2\text{Nm}*5/(1.6*1.5\text{m}) = 1{,}465\text{N}$

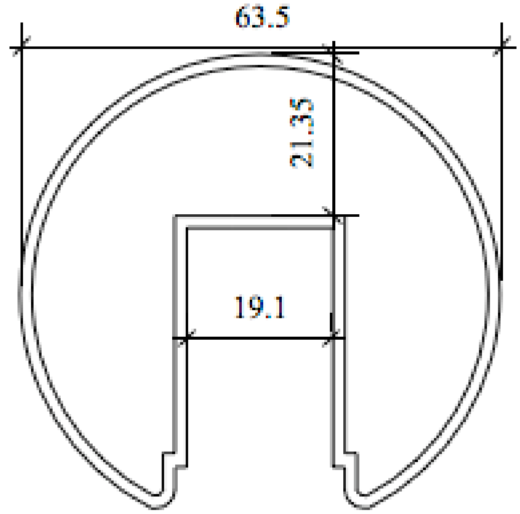
Horizontal → uniform → uniform → $w = (745.1\text{Nm} \bullet 10/(1.6*(1.5\text{m})^2)) = 2{,}069.7$ N/m
concentrated → $P = 745.1\text{Nm}*5/(1.6*1.5\text{m}) = 1{,}552.3\text{N}$

Connector Sleeves
Corners

The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

CRL GR 25 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails



Area: 423.4 mm^2
I_{xx}: 138,449 mm^4
I_{yy}: 161,110.9 mm^4
r_{xx}: 18.08mm
r_{yy}: 19.51mm
C_{xx}: 30.81mm
C_{yy}: 31.75mm
S_{xx}: 4,494.0 mm^3
S_{yy}: 5,073.0 mm^3
t = 1.27mm

Allowable stresses:
For stainless steel options: design using SEI/ASCE 8-02
From Table A1, 344.7MPa for 1/4 hard A304 stainless steel sheet used to form the rail.

$$F_{cr} = \frac{\pi^2 k\eta E_0}{12(1-\mu^2)(w/t)^2} \quad \text{(eq 3.3.1.1-9)}$$

η = 0.49 (from table A8a)
k = $3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape
μ = 0.3
E_0 = 186,200 MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$$

$M_n = S_eF_y$ = 4,494 mm^3*344.7MPa = 1,549Nm Vertical loading
5,073 mm^3*344.7MPa = 1,748.7Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)
Vertical → uniform → w= (1,549Nm• 10/(1.6*$(1.5m)^2$)) = 4,302.8 N/m
concentrated →P = 1,549Nm*5/(1.6*1.5m) = 3,227.1N

Horizontal → uniform → uniform → w= (1,748.7Nm• 10/(1.6*$(1.5m)^2$)) = 4,857.5 N/m
concentrated →P = 1,748.7Nm*5/(1.6*1.5m) = 3,643.1N

GR 25 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet
$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$
$k = 3(I_s/I_a)^{1/3}+1<4.0 = 4.0$ for circular shape
$\mu = 0.34$
$E_0 = 116.5 \text{ x}10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \text{ x}10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

S_{xx}: 4,494.0 mm^3
S_{yy}: 5,073.0 mm^3
$M_n = S_e F_y$ = 4,494.0 mm^3*280.6MPa = 1,261.0Nm Vertical loading
5,073.0 mm^3*280.6MPa = 1,423.5Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

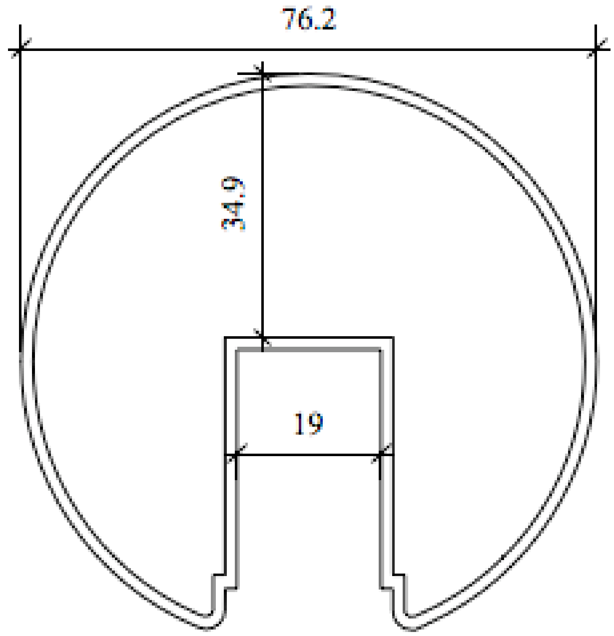
Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)
Vertical → uniform → w= (1,261Nm• 10/(1.6*(1.5m)^2)) = 3,502.8 N/m
concentrated →P = 1,261Nm*5/(1.6*1.5m) = 2,627.1N

Horizontal → uniform → uniform → w= (1,423.5Nm• 10/(1.6*(1.5m)^2)) = 3,954.2 N/m
concentrated →P = 1,423.5Nm*5/(1.6*1.5m) = 2,965.6N

Connector Sleeves
Corners
The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

CRL GR 30 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails



Area: 487.36 mm^2
I_{xx}: 252,988 mm^4
I_{yy}: 271,897 mm^4
r_{xx}: 22.78mm
r_{yy}: 23.62mm
C_{xx}: 39.11mm
C_{yy}: 38.1mm
S_{xx}: 6,468.5 mm^3
S_{yy}: 7,134.4 mm^3
t = 1.27mm

Allowable stresses:
For stainless steel options:
design using SEI/ASCE 8-02
From Table A1, 344.7MPa for 1/4 hard
A304 stainless steel sheet used to form the rail.

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2} \quad \text{(eq 3.3.1.1-9)}$$

η = 0.49 (from table A8a)
$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape
μ = 0.3
E_0 = 186,200 MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$$

$M_n = S_eF_y$ = 6,468.5 mm^3*344.7MPa = 2,229.7Nm Vertical loading
7,134.4 mm^3*344.7MPa = 2,459.2Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)
Vertical → uniform → w= (2,229.7Nm• 10/(1.6*$(1.5m)^2$)) = 6,193.6 N/m
concentrated →P = 2,229.7Nm*5/(1.6*1.5m) = 4,645.2N

Horizontal → uniform → uniform → w= (2,459.2Nm• 10/(1.6*$(1.5m)^2$)) = 6,831.1 N/m
concentrated →P = 2,459.2Nm*5/(1.6*1.5m) = 5,123.3N

GR 30 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet

$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$

$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape

$\mu = 0.34$

$E_0 = 116.5 \text{ x}10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \text{ x}10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

S_{xx}: 6,468.5 mm^3

S_{yy}: 7,134.4 mm^3

$M_n = S_e F_y$ = 6,468.5 mm^3*280.6MPa = 1,815.1Nm Vertical loading
7,134.4 mm^3*280.6MPa = 2,001.9Nm Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → w= (1,815.1Nm• 10/(1.6*(1.5m)^2)) = 5,041.9 N/m
concentrated →P = 1,815.1Nm*5/(1.6*1.5m) = 3,781.5N

Horizontal → uniform → uniform → w= (2,001.9Nm• 10/(1.6*(1.5m)^2)) = 5,560.8N/m
concentrated →P = 2,001.9Nm*5/(1.6*1.5m) = 4,170.7N

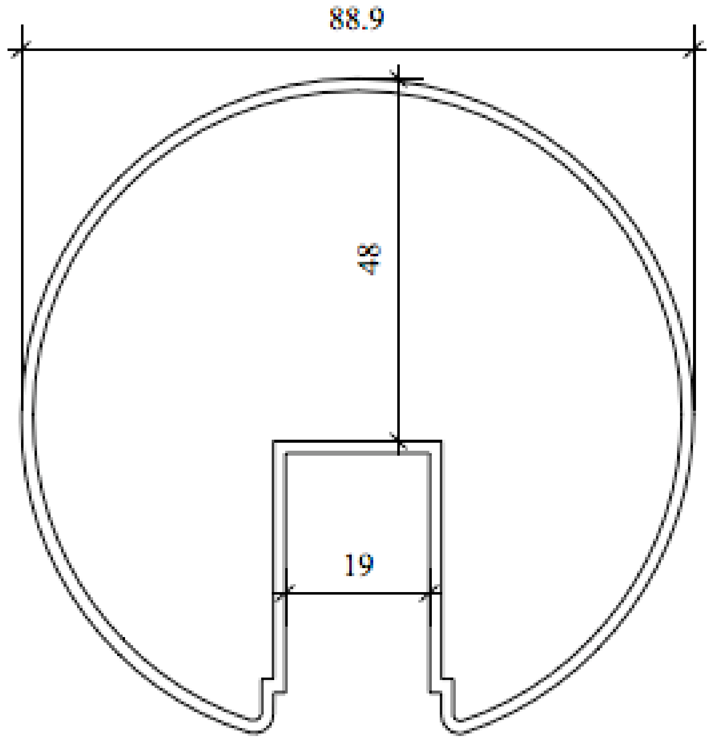
Connector Sleeves

Corners

The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

CRL GR 35 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails



Area: 558.5 mm^2
I_{xx}: 424,766 mm^4
I_{yy}: 437,638 mm^4
r_{xx}: 27.58mm
r_{yy}: 27.99mm
C_{xx}: 47.12mm
C_{yy}: 44.45mm
S_{xx}: 9,014.9 mm^3
S_{yy}: 9,845.6 mm^3
t = 1.27mm

Allowable stresses:

For stainless steel options: design using SEI/ASCE 8-02 From Table A1, 344.7MPa for 1/4 hard A304 stainless steel sheet used to form the rail.

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2} \quad \text{(eq 3.3.1.1-9)}$$

η = 0.49 (from table A8a)
$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape
μ = 0.3
E_0 = 186,200 MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$$

$M_n = S_e F_y$ = 9,014.9 mm^3*344.7MPa = 3,107.4Nm Vertical loading
9,845.6 mm^3*344.7MPa = 3,393.8Nm Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → w= (3,107.4Nm• 10/(1.6*(1.5m)^2)) = 8,631.7 N/m
concentrated →P = 3,107.4Nm*5/(1.6*1.5m) = 6,473.7N

Horizontal → uniform → uniform → w= (3,393.8Nm• 10/(1.6*(1.5m)^2)) = 9,427.2 N/m
concentrated →P = 3,393.8Nm*5/(1.6*1.5m) = 7,070.4N

GR 35 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet

$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$

$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape

$\mu = 0.34$

$E_0 = 116.5 \times 10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \times 10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

S_{xx}: 9,014.9 mm^3

S_{yy}: 9,845.6 mm^3

$M_n = S_e F_y$ = 9,014.9 mm^3*280.6MPa = 2,529.6Nm Vertical loading
9,845.6 mm^3*280.6MPa = 2,762.7Nm Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → w= (2,529.6Nm• 10/(1.6*(1.5m)^2)) = 7,026.7 N/m
concentrated →P = 2,762.7Nm*5/(1.6*1.5m) = 5,755.6N

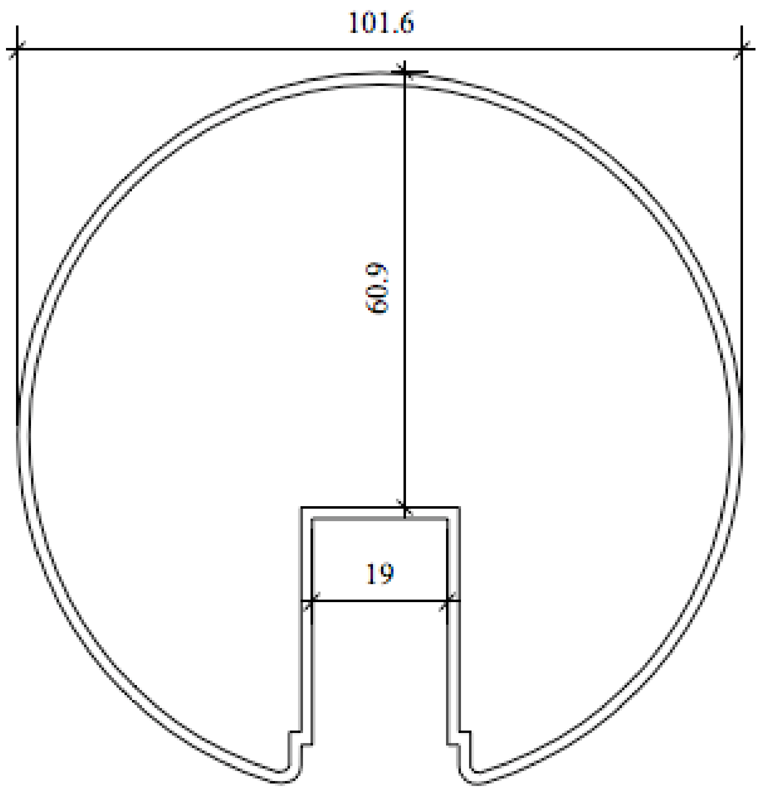
Horizontal → uniform → uniform → w= (2,762.7Nm• 10/(1.6*(1.5m)^2)) = 7,674.2N/m
concentrated →P = 2,762.7Nm*5/(1.6*1.5m) = 5,755.6N

Connector Sleeves
Corners

The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

CRL GR 40 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails



Area: 614.3 mm^2
I_{xx}: 646,553 mm^4
I_{yy}: 636,584 mm^4
r_{xx}: 32.44mm
r_{yy}: 32.19mm
C_{xx}: 54.13mm
C_{yy}: 50.80mm
S_{xx}: 11,944.8 mm^3
S_{yy}: 12,529.6 mm^3
t = 1.27mm

Allowable stresses:
For stainless steel options: design using SEI/ASCE 8-02
From Table A1, 344.7MPa for 1/4 hard A304 stainless steel sheet used to form the rail.

$F_{cr} = \dfrac{\pi^2 k\eta E_0}{12(1-\mu^2)(w/t)^2}$ (eq 3.3.1.1-9)

$\eta = 0.49$ (from table A8a)
$k = 3(I_s/I_a)^{1/3}+1<4.0 = 4.0$ for circular shape
$\mu = 0.3$
$E_0 = 186{,}200$ MPa

$F_{cr} = \dfrac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$

$M_n = S_e F_y = 11{,}944.8\ mm^3 * 344.7\text{MPa} = 4{,}117.4\text{Nm}$ Vertical loading
$12{,}529.6\ mm^3 * 344.7\text{MPa} = 4{,}319.0\text{Nm}$ Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → $w= (4{,}117.4\text{Nm} \bullet 10/(1.6*(1.5m)^2)) = 11{,}437.2$ N/m
concentrated → $P = 4{,}117.4\text{Nm}*5/(1.6*1.5m) = 8{,}577.9$N

Horizontal → uniform → uniform → $w= (4{,}319.0\text{Nm} \bullet 10/(1.6*(1.5m)^2)) = 11{,}997.2$ N/m
concentrated → $P = 4{,}319.0\text{Nm}*5/(1.6*1.5m) = 8{,}997.9$N

GR 40 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet

$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$

$k = 3(I_s/I_a)^{1/3}+1<4.0 = 4.0$ for circular shape

$\mu = 0.34$

$E_0 = 116.5 \times 10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \times 10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

S_{xx}: 11,944.8 mm^3

S_{yy}: 12,529.6 mm^3

$M_n = S_e F_y$ = 11,944.8 mm^3*280.6MPa = 3,351.7Nm Vertical loading
12,529.6 mm^3*280.6MPa = 3,515.8Nm Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → w= (3,351.7Nm• 10/(1.6*$(1.5m)^2$)) = 9,310.3 N/m
concentrated →P = 3,351.7Nm*5/(1.6*1.5m) = 6,982.7N

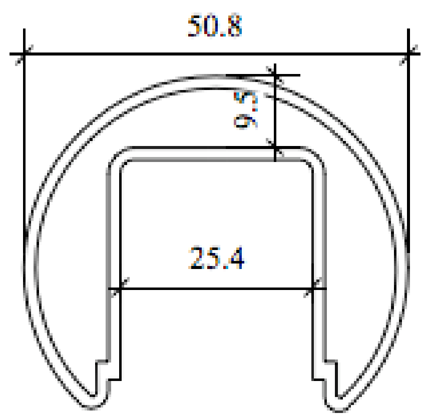
Horizontal → uniform → uniform → w= (3,515.8Nm• 10/(1.6*$(1.5m)^2$)) = 9,766.1N/m
concentrated →P = 3,515.8Nm*5/(1.6*1.5m) = 7,324.6N

Connector Sleeves
Corners

The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

CRL GR 207 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails.
Use with 19mm glass balustrades



Area: 341.28 mm^2
I_{xx}: 58,557 mm^4
I_{yy}: 92,312 mm^4
r_{xx}: 13.10mm
r_{yy}: 16.45mm
C_{xx}: 23.59mm
C_{yy}: 25.40mm
S_{xx}: 2,482.7 mm^3
S_{yy}: 3,634.3 mm^3
t = 1.27mm
Allowable stresses:
For stainless steel options: design using SEI/ASCE 8-02
From Table A1, F_y = 344.7MPa for 1/4 hard 304 stainless steel cold formed sheet

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2} \quad \text{(eq 3.3.1.1-9)}$$

η = 0.49 (from table A8a)
$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape
μ = 0.3
E_0 = 186,200 MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$$

$M_n = S_eF_y$ = 2,482.7 mm^3*344.7MPa = 855.8Nm Vertical loading
3,634.3 mm^3*344.7MPa = 1,252.7Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)
Vertical → uniform → w= (855.8Nm• 10/(1.6*$(1.5m)^2$)) = 2,377.2N/m
concentrated →P = 855.8Nm*5/(1.6*1.5m) = 1,782.9N

Horizontal → uniform → w= (1,252.7Nm• 10/(1.6*$(1.5m)^2$)) = 3,479.7 N/m
concentrated →P = 1,252.7Nm*5/(1.6*1.5m) = 2,609.8N

GR 207 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet

$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$

$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape

$\mu = 0.34$

$E_0 = 116.5 \times 10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \times 10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

S_{xx}: 2,482.7 mm^3
S_{yy}: 3,634.3 mm^3

$M_n = S_eF_y =$ 2,482.7 mm^3*280.6MPa = 696.6Nm Vertical loading
3,634.3 mm^3*280.6MPa =1,019.8Nm Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → w= (696.6Nm• 10/(1.6*(1.5m)^2)) = 1,935 N/m
concentrated →P = 696.6Nm*5/(1.6*1.5m) = 1,451.3N

Horizontal → uniform → uniform → w= (1,019.8Nm• 10/(1.6*(1.5m)^2)) = 2,832.8N/m
concentrated →P = 1,019.8Nm*5/(1.6*1.5m) = 2,124.6N

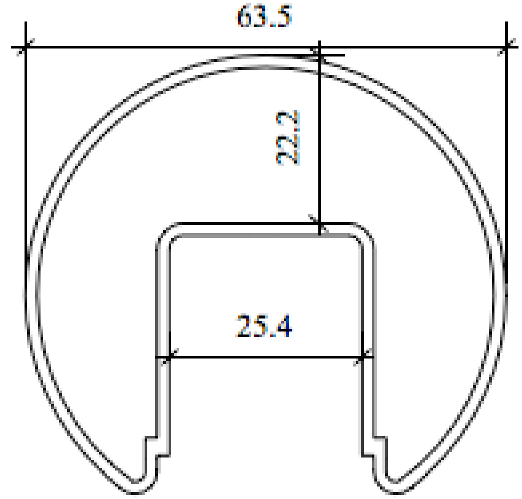
Connector Sleeves

Corners

The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

CRL GR 257 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails



Use with 19mm glass balustrades

Area: 409.2 mm^2
I_{xx}: 122,820 mm^4
I_{yy}: 167,126 mm^4
r_{xx}: 17.33mm
r_{yy}: 20.21mm
C_{xx}: 29.58mm
C_{yy}: 31.75mm
S_{xx}: 4,152.2 mm^3
S_{yy}: 5,263.8 mm^3
t = 1.27mm
Allowable stresses:
For stainless steel options: design using SEI/ASCE 8-02
From Table A1, F_y = 344.7MPa for 1/4 hard 304 stainless steel cold formed sheet

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2} \quad \text{(eq 3.3.1.1-9)}$$

η = 0.49 (from table A8a)
$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape
$\mu = 0.3$
E_0 = 186,200 MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$$

$M_n = S_e F_y$ = 4,152.2 mm^3*344.7MPa = 1,431.3Nm Vertical loading
5,263.8 mm^3*344.7MPa = 1,814.4Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)
Vertical → uniform → w= (1,431.3Nm• 10/(1.6*$(1.5m)^2$)) = 3,975.8N/m
concentrated →P = 1,431.3Nm*5/(1.6*1.5m) = 2,981.9N

Horizontal → uniform → w= (1,814.4Nm• 10/(1.6*$(1.5m)^2$)) = 5,040 N/m
concentrated →P = 1,814.4Nm*5/(1.6*1.5m) = 3,780N

GR 257 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet
$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$
$k = 3(I_s/I_a)^{1/3}+1<4.0 = 4.0$ for circular shape
$\mu = 0.34$
$E_0 = 116.5 \times 10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \times 10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

S_{xx}: 4,152.2 mm^3
S_{yy}: 5,263.8 mm^3

$M_n = S_e F_y =$ 4,152.2 mm^3*280.6MPa = 1,165.1Nm Vertical loading
5,263.8 mm^3*280.6MPa =1,477.0Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

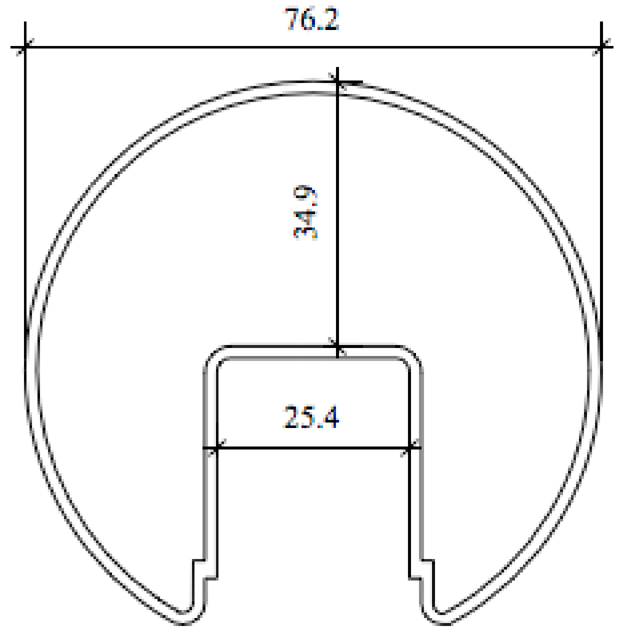
Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)
Vertical → uniform → w= (1,165.1Nm• 10/(1.6*(1.5m)^2)) = 3,236.4 N/m
concentrated →P = 1,165.1Nm*5/(1.6*1.5m) = 2,427.3N

Horizontal → uniform → uniform → w= (1,477.0Nm• 10/(1.6*(1.5m)^2)) = 4,102.8N/m
concentrated →P = 1,477.0Nm*5/(1.6*1.5m) = 3,077.1N

Connector Sleeves
Corners
The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

CRL GR 307 SERIES CAP RAIL

Used as the top rail on glass balustrade panel guardrails.



Use with 19mm glass balustrades

Area: 479.3 mm^2
I_{xx}: 233,090 mm^4
I_{yy}: 281,765 mm^4
r_{xx}: 22.05mm
r_{yy}: 24.25mm
C_{xx}: 37.94mm
C_{yy}: 38.1mm
S_{xx}: 6,143.3 mm^3
S_{yy}: 7,360.2 mm^3
t = 1.27mm
Allowable stresses:
For stainless steel options: design using SEI/ASCE 8-02
From Table A1, F_y = 344.7MPa for 1/4 hard 304 stainless steel cold formed sheet

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2} \quad \text{(eq 3.3.1.1-9)}$$

η = 0.49 (from table A8a)
$k = 3(I_s/I_a)^{1/3}+1<4.0$ = 4.0 for circular shape
μ = 0.3
E_0 = 186,200 MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 186{,}200\text{MPa}}{12(1-0.3^2)(35.6/1.27)^2} = 419.8\text{MPa but} \le F_y$$

$M_n = S_eF_y$ = 6,143.3 mm^3*344.7MPa = 2,117.6Nm Vertical loading
7,360.2 mm^3*344.7MPa = 2,537.1Nm Horizontal load
Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$) or Pl/5
Vertical → uniform → w= (2,117.6Nm• 10/(1.6*(1.5m)^2)) = 5,882.2N/m
concentrated →P = 2,117.6Nm*5/(1.6*1.5m) = 4,411.7N

Horizontal → uniform → w= (2,537.1Nm• 10/(1.6*(1.5m)^2)) = 7,047.5N/m
concentrated →P = 2,537.1Nm*5/(1.6*1.5m) = 5,285.6N

GR 307 SERIES CAP RAIL For Brass:
Alloy C26000, Cartridge Brass, 70% Cu, 30% Zn
Cap rail fabricated from cold rolled sheet

$F_{yu} \geq 296.5$ MPa

$$F_{cr} = \frac{\pi^2 k \eta E_0}{12(1-\mu^2)(w/t)^2}$$

$\eta = 0.49$

$k = 3(I_s/I_a)^{1/3}+1<4.0 = 4.0$ for circular shape

$\mu = 0.34$

$E_0 = 116.5 \text{ x}10^3$ MPa

$$F_{cr} = \frac{\pi^2 * 4.0 * 0.49 * 116.5 \text{ x}10^3 \text{ MPa}}{12(1-0.34^2)(35.6/1.27)^2} = 280.6 \text{ MPa (40.7 ksi) but} \leq F_y$$

S_{xx}: 6,143.3 mm^3
S_{yy}: 7,360.2 mm^3

$M_n = S_eF_y =$ 6,143.3 mm^3*280.6MPa = 1,723.8Nm Vertical loading
7,360.2 mm^3*280.6MPa = 2,065.3Nm Horizontal load

Use load factor of 1.6 and resistance factor of 1.0 (round shape using section modulus)

Determine allowable rail loads (ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$)

Vertical → uniform → w= (1,723.8Nm• 10/(1.6*(1.5m)^2)) = 4,788.3 N/m
concentrated →P = 1,723.8Nm*5/(1.6*1.5m) = 3,591.2N

Horizontal → uniform → uniform → w= (2,065.3Nm• 10/(1.6*(1.5m)^2)) = 5,736.9N/m
concentrated →P = 2,065.3Nm*5/(1.6*1.5m) = 4,302.7N

Connector Sleeves

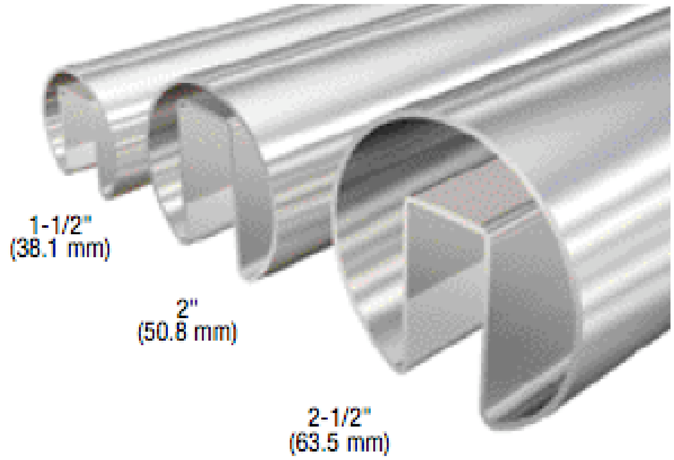
Corners

The connector sleeves and corners are demonstrated as adequate based on strength for the 38mm size.

Roll Formed Cap Rails:
304 Stainless steel
GRRF15 38mm rail is structurally equivalent to GR15 38mm rail.

GRRF20 51mm rail is structurally equivalent to GR20 51mm rail.

GRRF25 63mm rail is structurally equivalent to GR25 63mm rail.



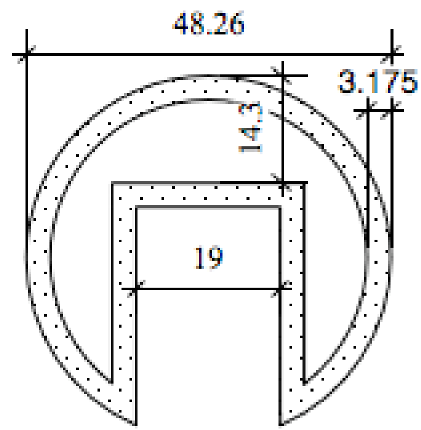
Custom Angle Corners
Corners may be welded at any angle, vertical or horizontal angles.

Compound angles may be used.

The strength of the angle is not decreased below that for the 90˚ angle used for the standard calculation therefore strength adequacy is demonstrated for all angles.

ALUMINUM CAP RAILS

GR19 Aluminum



Area: 623.2 mm^2
I_{xx}: 100,768 mm^4
I_{yy}: 135,542 mm^4
r_{xx}: 12.72mm
r_{yy}: 14.80mm
C_{xx}: 24.08mm
C_{yy}: 24.13mm
S_{xx}: 4,184.6 mm^3 top
S_{xx}: 4,167.4 mm^3 bottom
S_{yy}: 5,658.6 mm^3
t = 3.175mm

Allowable stresses **ADM Table 2-24 6063-T6 Aluminum**

$F_{Cb} \rightarrow R_b/t = \frac{20.95mm}{3.175mm} = 6.6$ line 16.1

$F_{Cb} = 127.55MPa - 4.10(6.6)^{1/2} = 117.0MPa$
$M_{all\ horiz} = 117.0MPa \bullet (5{,}658.6\ mm^3) = 662.1Nm$

For vertical load → bottom in tension top comp.

$F_b = 124.1MPa$
bottom stress: $M_{all\ vert} = (4{,}167.4\ mm^3) \bullet 124.1MPa = 517.2Nm$ or
top stress: $=(4{,}184.6\ mm^3)*117.0MPa = 489.6Nm$ controls

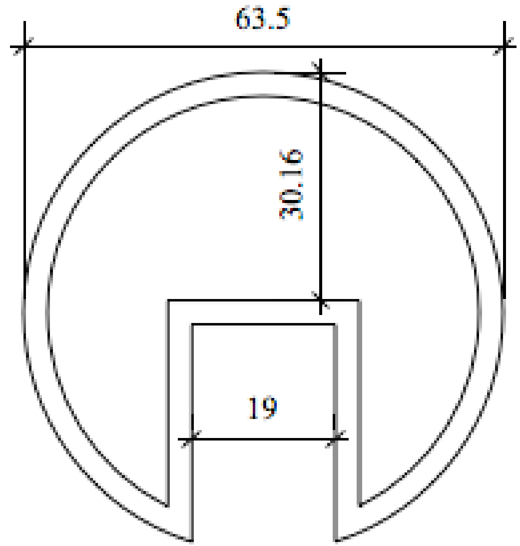
Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$) or Pl/5

Vertical → uniform → $w= (489.6Nm\bullet 10/(1.6*(1.5m)^2)) = 1{,}360N/m$
concentrated →$P = 489.6Nm*5/(1.6*1.5m) = 1{,}020N$

Horizontal → uniform → $w= (662.1Nm\bullet 10/(1.6*(1.5m)^2)) = 1{,}753.6N/m$
concentrated →$P = 662.1Nm*5/(1.6*1.5m) = 1{,}379.4N$

GR25 Aluminum

Area: 777.85 mm^2
I_{xx}: 259,022 mm^4
I_{yy}: 296,181 mm^4
r_{xx}: 18.25mm
r_{yy}: 19.51mm
C_{xx}: 32.23mm
C_{yy}: 31.75mm
S_{xx}: 8,283.4 mm^3 top
S_{xx}: 8,035.7 mm^3 bottom
S_{yy}: 9,328.5 mm^3
t = 3.175mm



Allowable stresses **ADM Table 2-24**
6063-T6 Aluminum

$F_{Cb} \rightarrow R_b/t = \dfrac{28.575mm}{3.175mm} = 9$ line 16.1

F_{Cb} = 127.55MPa– 4.10$(9)^{1/2}$ = 115.25MPa
$M_{all\ horiz}$ = 115.25MPa • (9,328.5mm^3) = 1,075.1Nm

For vertical load → bottom in tension top comp.

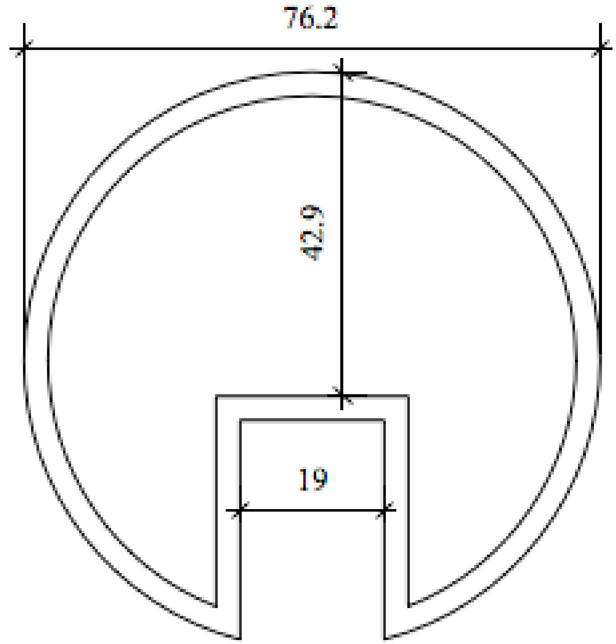
F_b = 124.1MPa
bottom stress: $M_{all\ vert}$ = (8,035.7 mm^3) • 124.1MPa = 997.2Nm or
top stress: =(8,283.4 mm^3)*115.25MPa = 954.7Nm controls

Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights (M = $wl^2/10$) or Pl/5

Vertical → uniform → w= (954.7Nm• 10/(1.6*$(1.5m)^2$)) = 2,651.9N/m
concentrated →P = 954.7Nm*5/(1.6*1.5m) = 1,989N

Horizontal → uniform → w= (1,075.1Nm• 10/(1.6*$(1.5m)^2$)) = 2,986.1N/m
concentrated →P = 1,075.1Nm*5/(1.6*1.5m) = 2,239.8N

GR30 Aluminum



Area: 907.5 mm^2
I_{xx}: 482,853 mm^4
I_{yy}: 508,642 mm^4
r_{xx}: 23.07mm
r_{yy}: 23.67mm
C_{xx}: 39.84mm
C_{yy}: 38.10mm
S_{xx}: 13,279.8 mm^3 top
S_{xx}: 12,119.0 mm^3 bottom
S_{yy}: 13,350.2 mm^3
t = 3.175mm

Allowable stresses **ADM Table 2-24**
6063-T6 Aluminum

$F_{Cb} \rightarrow R_b/t = \frac{36.51mm}{3.175mm} = 11.5$ line 16.1

$F_{Cb} = 127.55MPa - 4.10(11.5)^{1/2} = 113.65MPa$
$M_{all\ horiz} = 113.65MPa \bullet (13{,}350.2mm^3) = 1{,}517.3Nm$

For vertical load → bottom in tension top comp.

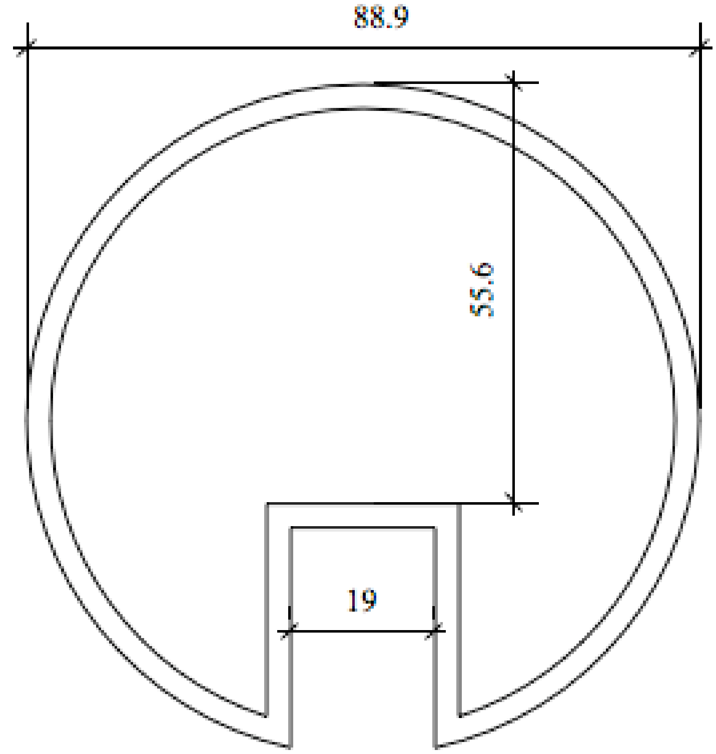
$F_b = 124.1MPa$
bottom stress: $M_{all\ vert} = (12{,}119.0mm^3) \bullet 124.1MPa = 1{,}504.0Nm$ or
top stress: $=(13{,}279.8\ mm^3)*113.65MPa = 1{,}509.2Nm$ controls

Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$) or Pl/5

Vertical → uniform → $w = (1{,}504.0Nm \bullet 10/(1.6*(1.5m)^2)) = 4{,}177.8N/m$
concentrated → $P = 1{,}504.0Nm*5/(1.6*1.5m) = 3{,}133N$

Horizontal → uniform → $w = (1{,}517.3Nm \bullet 10/(1.6*(1.5m)^2)) = 4{,}215.1N/m$
concentrated → $P = 1{,}517.3Nm*5/(1.6*1.5m) = 3{,}161N$

GR35 Aluminum
Area: 1,036.2 mm^2
I_{xx}: 808,339 mm^4
I_{yy}: 808,918 mm^4
r_{xx}: 27.93mm
r_{yy}: 27.94mm
C_{xx}: 47.15mm
C_{yy}: 44.45mm
S_{xx}: 19,361.4 mm^3 top
S_{xx}: 17,144.1 mm^3 bottom
S_{yy}: 18,198.4 mm^3
t = 3.175mm



Allowable stresses **ADM Table 2-24 6063-T6 Aluminum**
line 16.1
$F_{Cb} \rightarrow R_b/t = \dfrac{42.86mm}{3.175mm} = 13.5$

$F_{Cb} = 127.55MPa - 4.10(13.5)^{1/2}$
= 112.49MPa
$M_{all\ horiz}$ = 112.49MPa • (18,198.4mm^3) = 2,047.1Nm

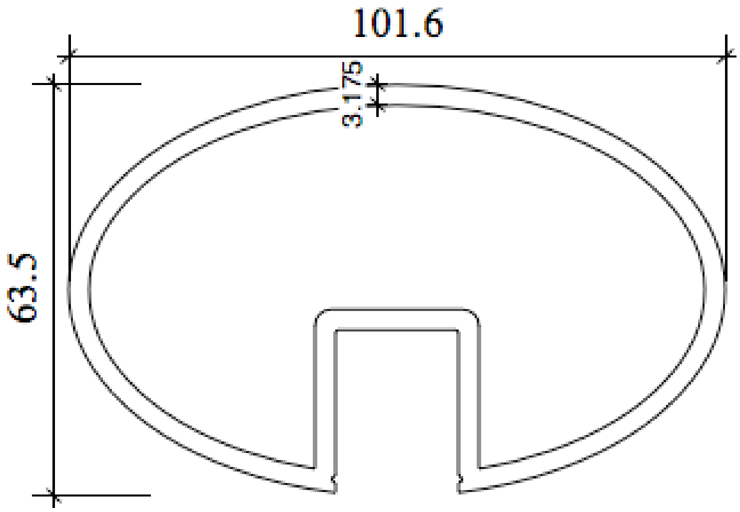
For vertical load → bottom in tension top comp.
F_b = 124.1MPa
bottom stress: $M_{all\ vert}$ = (17,144.1mm^3) • 124.1MPa = 2,127.6Nm or
top stress: =(19,361.4 mm^3)*112.49MPa = 2,178.0Nm controls

Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$) or Pl/5
Vertical → uniform → w= (2,127.6Nm• 10/(1.6*$(1.5m)^2$)) = 5,910N/m
concentrated →P = 2,127.6Nm*5/(1.6*1.5m) = 4,432.5N

Horizontal → uniform → w= (2,047.1Nm• 10/(1.6*$(1.5m)^2$)) = 5,686.4N/m
concentrated →P = 2,047.1Nm*5/(1.6*1.5m) = 4,264.8N

GROV4Aluminum

Area: 946.1 mm^2
I_{xx}: 395,502 mm^4
I_{yy}: 864.942 mm^4
r_{xx}: 20.45mm
r_{yy}: 30.24mm
C_{xx}: 32.65mm
C_{yy}: 50.80mm
S_{xx}: 12,820.2 mm^3 top
S_{xx}: 12,112.6 mm^3 bottom
S_{yy}: 17,026.1 mm^3
t = 3.175mm



Allowable stresses **ADM Table 2-24 6063-T6 Aluminum**
line 16.1

$F_{Cb} \rightarrow R_b/t = \frac{49.21mm}{3.175mm} = 15.5$ top of rail

F_{Cb} = 127.55MPa– 4.10$(15.5)^{1/2}$ = 111.41MPa Compression on top of rail

$F_{Cb} \rightarrow R_b/t = \frac{17.41mm}{3.175mm} = 5.48$ top of rail

F_{Cb} = 127.55MPa– 4.10$(5.48)^{1/2}$ = 117.95MPa Compression on top of rail

$M_{all\ horiz}$ = 117.95MPa • (17,026.1mm^3) = 2,008.2Nm

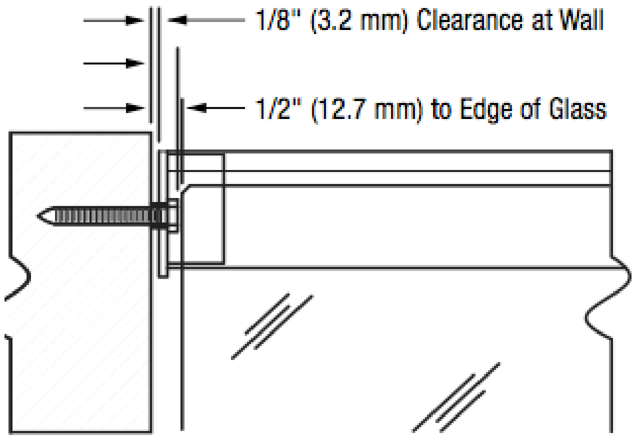
For vertical load → bottom in tension top comp.
F_b = 124.1MPa
bottom stress: $M_{all\ vert}$ = (12,112.6mm^3) • 124.1MPa = 1,503.2Nm or
top stress: =(12,820.2 mm^3)*111.41MPa = 1,428.3Nm controls

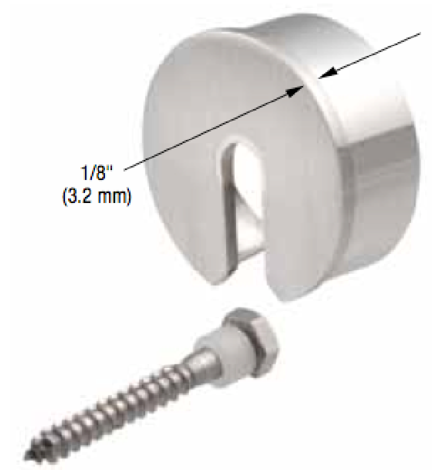
Determine allowable rail loads(ignoring deflection) for a maximum span of 1.5m
Rail is continuous over multiple glass lights ($M = wl^2/10$) or Pl/5
Vertical → uniform → w= (1,428.3Nm• 10/(1.6*$(1.5m)^2$)) = 3,967.5N/m
concentrated →P = 1,428.3Nm*5/(1.6*1.5m) = 2,975.6N

Horizontal → uniform → w= (2,008.2Nm• 10/(1.6*$(1.5m)^2$)) = 5,578.3N/m
concentrated →P = 2,008.2Nm*5/(1.6*1.5m) = 4,183.7N

Stabilizing End Cap

Used to attach cap rail to wall or post to provide one anchor point.





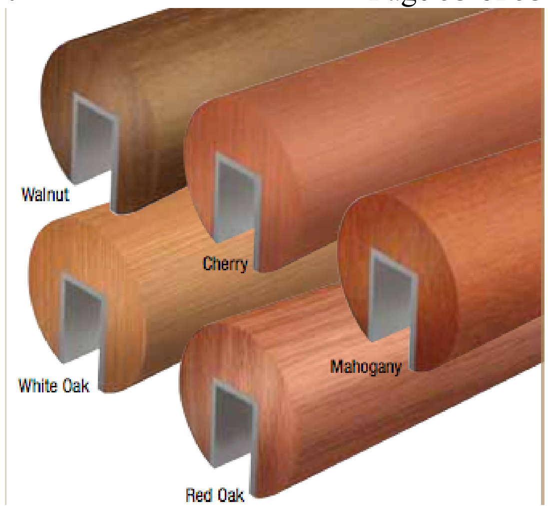
End cap sized to match rail:
Maximum load to End Cap:
P = Full concentrated load or
For distributed load P = U*L/2 (from broken end lite) where
U = distributed load and L = lite length
Cap thickness is 3.175mm
Anchor size is 6mm
Bearing pressure on end cap:
$F_B = P/(6*3.175) = P/19.05mm^2$
Allowable bearing stresses for all material types used:

304 SS = 2*0.65*517.1MPa/1.6 = 420.1MPa
6063 T6 AL = 213.7MPa
Brass = 2*0.65*296.5/1.6 = 240.9MPa

Maximum allowable load based on anchor bearing:
$P_{max} = 19.05*213.7MPa = 4kN$

Anchor strength will control most applications:
Anchor to be designed for P as calculated above.

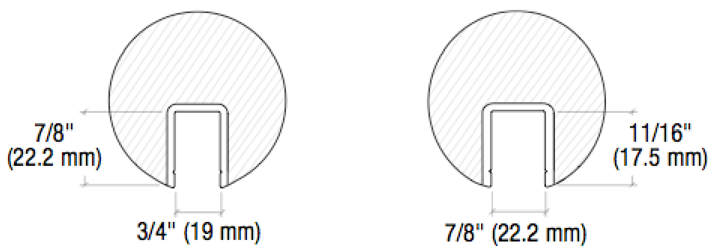
Wood Cap Rails



Composite rail made of select clear wood bonded with aluminum channel.

Determine equivalent section:
$n = E_a/E_w$
$n = 69.6GPa/6.65GPa = 7.2$

for aluminum channel thickness = 2.54mm
equivalent wood = 7.2*2*2.54 = 36.6mm
maxim notch width
= 22.2mm+2*2.54mm = 27.28mm< 36.6mm
therefore can assume that section is equivalent to a solid round .
Wood stress from National Design Specification for Wood Construction Supplement, 2001 edition.
$F_b = 7.6MPa*1.33*1.5*1.15 = 17.4MPa$



Three rail sizes:
50.8mm (2") dia: $S = \pi 50.8^3/32 = 12{,}870mm^3$
$M_a = 12{,}870mm^3 * 17.4MPa = 223.9Nm$
Determine maximum allowable load for 1.5m maximum light length
uniform → $w = (223.9Nm \bullet 10/(1.5m)^2)) = 995.1N/m$
concentrated → $P = 223.9Nm*5/(1.5m) = 746N$

63.5mm (2.5") dia: $S = \pi 63.5^3/32 = 25{,}137mm^3$
$M_a = 25{,}137mm^3 * 17.4MPa = 437.4Nm$
Determine maximum allowable load for 1.5m maximum light length
uniform → $w = (437.4Nm \bullet 10/(1.5m)^2)) = 1{,}944N/m$
concentrated → $P = 437.4Nm*5/(1.5m) = 1{,}458N$

76.2mm (3.0") dia: $S = \pi 76.2^3/32 = 43{,}437\ mm^3$
$M_a = 43{,}437mm^3 * 17.4MPa = 755.8Nm$
Determine maximum allowable load for 1.5m maximum light length
uniform → $w = (755.8Nm \bullet 10/(1.5m)^2)) = 3{,}359N/m$
concentrated → $P = 755.8Nm*5/(1.5m) = 2{,}519N$