MORSE INDUSTRIES

Working Solutions in Aluminum, Plastics and Stainless Steel

ANALYSIS OF GLASS RAIL BASE MOLDING ATTACHMENT

WJE **Wiss, Janny, Elstner Associates, Inc.** 330 Pfingsten Rd., Northbrook Illinois 60062	Made by: NSA	Sheet # 1/21
Morse Industries Kent, Washington	Checked by: MJS	Project # 970798
Glass Rail Base Molding Attachment Analysis	Date: 07/22/97	

Design Criteria

The purpose of these calculations is to check the adequacy of the connection of the Morse Industries glass hand railing base shoe molding (two types - see fig. 1) to either a concrete or steel substrate. The analysis considers the adequacy of the connection when when the standard height railing (42 in.) is subjected to live loads required by model building codes. The analysis is limited to the base shoe to substrate connection. Analysis of stresses in the glass, top rail, and base shoe molding are beyond the scope of these calculations.

Analysis of glass railing base shoe connections (4 types considered)

Case 1: Concrete surface mounted (see fig. 2)
Case 2: Concrete flush mounted (see fig. 3)
Case 3: Steel fascia mounted (see fig. 4)
Case 4: Steel fascia mounted (see fig. 5)

Model Code regulations require a uniform loading of 50 lbs per lineal foot (plf) or a 200-lb concentrated load to be resisted at the top rail, whichever creates the most severe stresses.

For the base shoe connection, the 200-lb load applied in a horizontal direction at the top handrail causes the maximum stresses in the connections.

The analysis considered shear and moment due to the 200 lb load being resisted by 3 - SAE Grade 5, 1/2" diameter cap screws (F_u =120,000 psi and F_y= 92,000 psi) and 2 - ASTM A307, 3/8" diameter T-bolts (F_u = 60,000 psi)

Reference Standards

- The Aluminum Associations (AA), *Aluminum Design Manual*, Specifications & Guidelines for Aluminum Structures, October, 1994.
- American Architectural Manufacturers Association AAMA), *Metal Curtain Wall Fasteners* (AAMA TIR-A9-1991), 1991
- American Concrete Institute (ACI), *Building Code Requirements for Structural Concrete* (ACI 318-95), 1995.
- American Institute of Steel Construction (AISC), *Manual of Steel Construction* (Allowable Stress Design), 9th Edition, 1989.
- Industrial Fasteners Institute (IFI), *Fastener Standards*, 6th Edition, 1988
- International Conference of Building Officials (ICBO), *Uniform Building Code* (UBC), Structural Engineering Design Provisions, Volume 2, 1997.
- Precast/Prestressed Concrete Institute (PCI), *PSI Design Handbook*, MNL 120, 4th Edition, 1992.

Note: Relevant reference to these documents in the calculations is made with [ ] (square brackets).

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Glass Rail Base Molding Attachment Analysis	*Date:* 07/22/97	

Figure 1 - 6063-T6 Aluminum Base Shoe Moldings

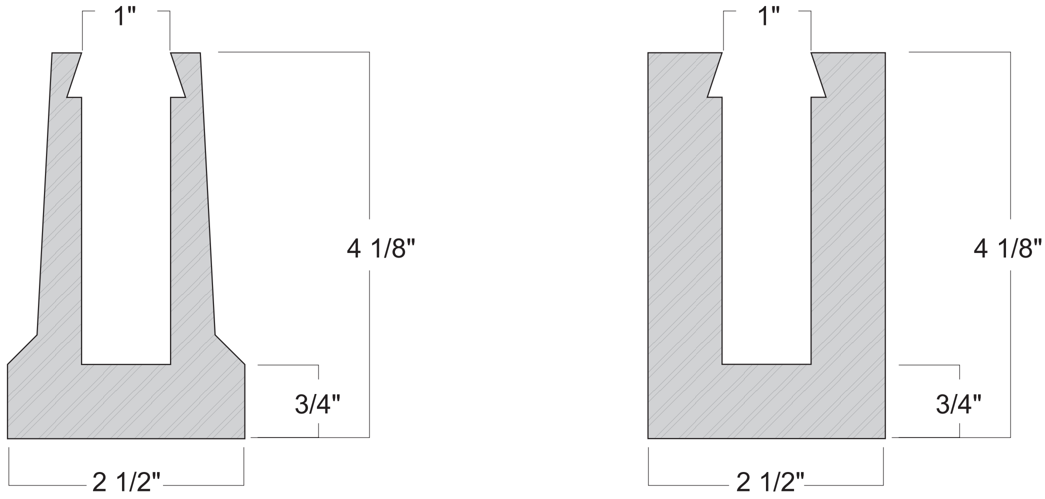

Figure 2 - Surface Mounted Base Shoe Molding

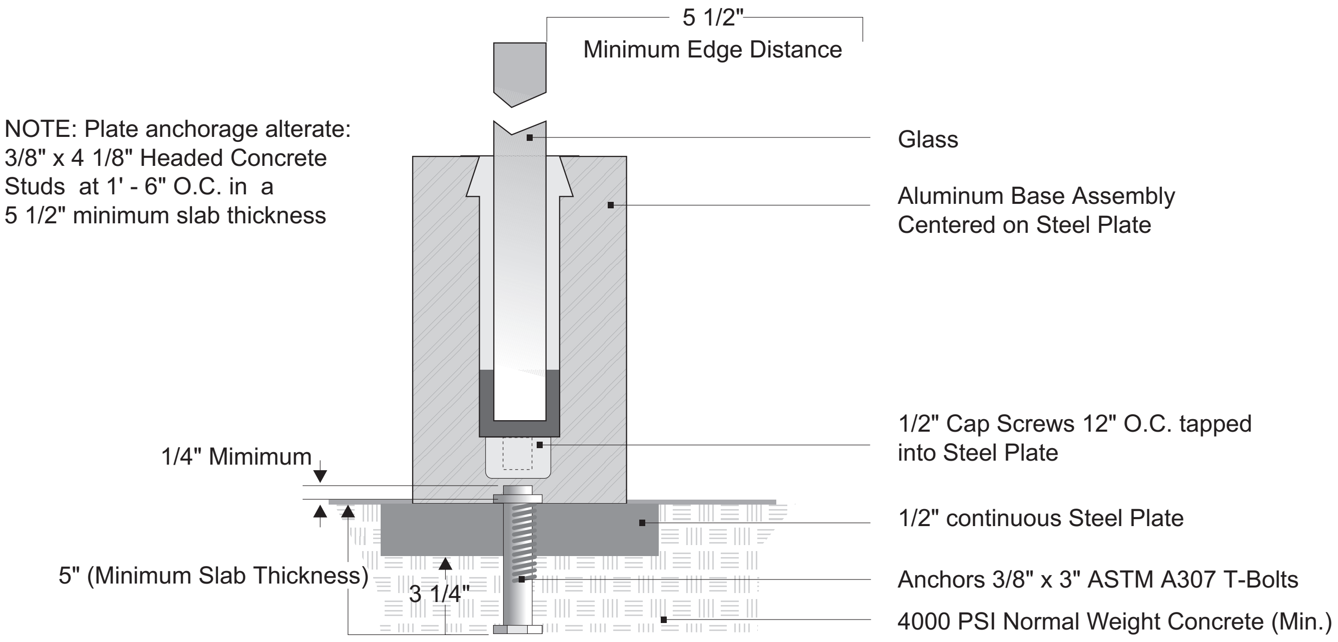

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Figure 3 - Flush Mounted Base Shoe Molding (recessed in concrete)

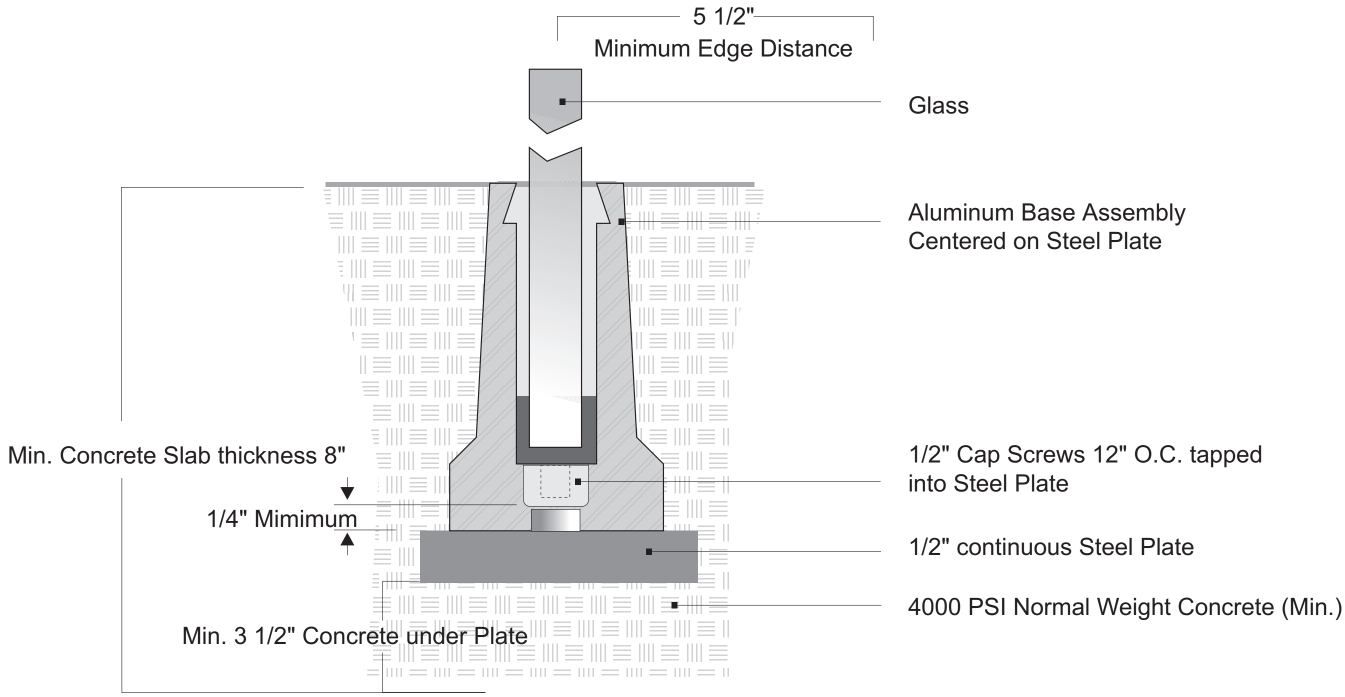
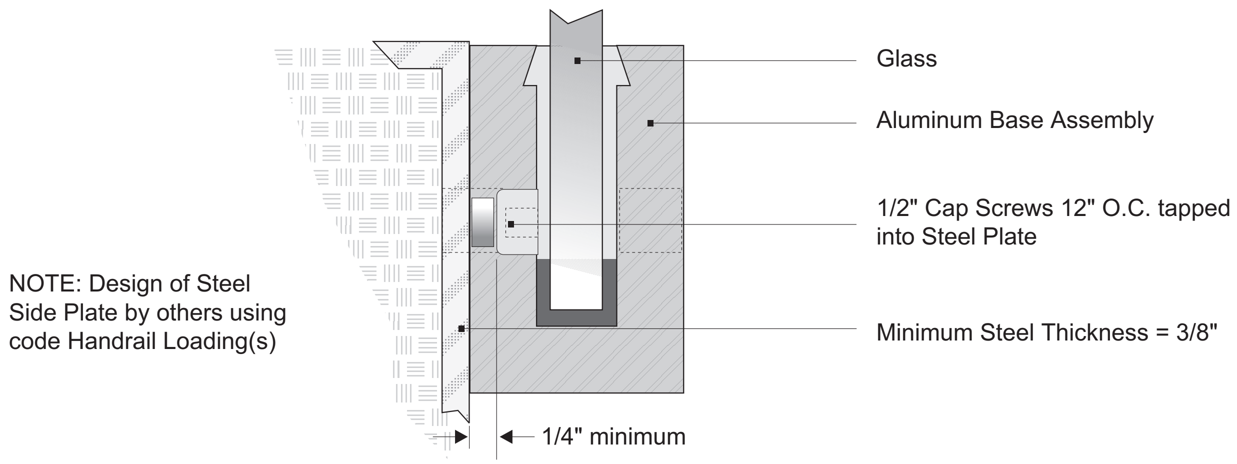


Figure 4 - Fascia Mounted Base Shoe Molding



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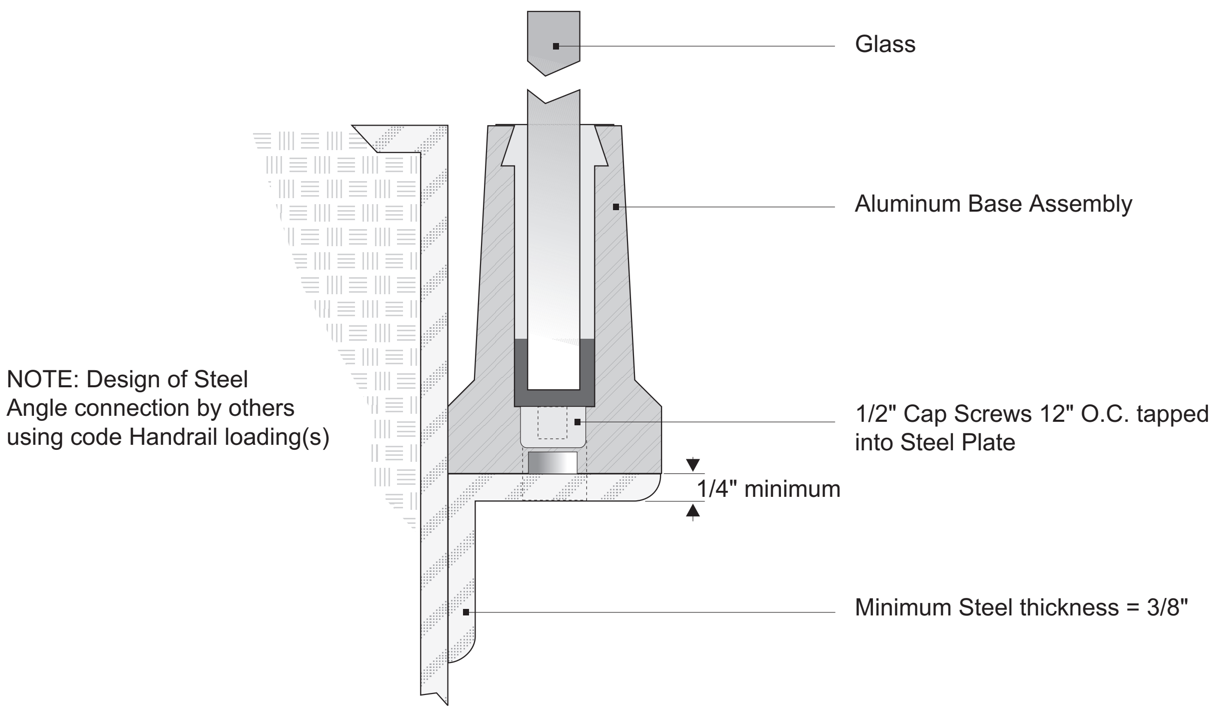
		Date: 07/22/97	

Figure 5 - Fascia Mounted Base Shoe Molding



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		Date: 07/22/97	

Analysis of Glass Railing Base Shoe Connections

Railing Load

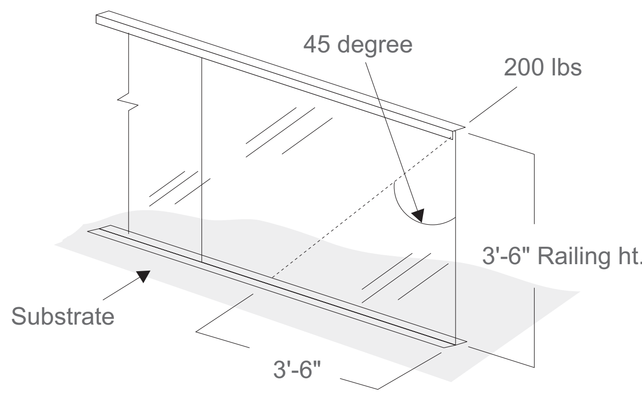
(Ref: 1997 UBC)

per Table 16-B:

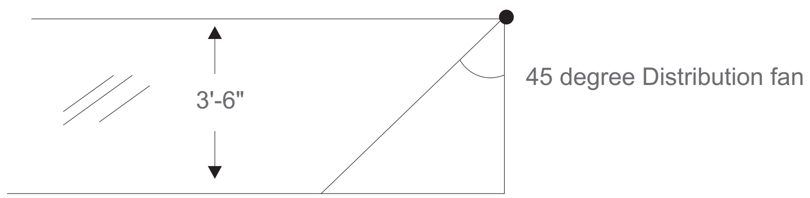
Lateral Load 50 lbs/ft

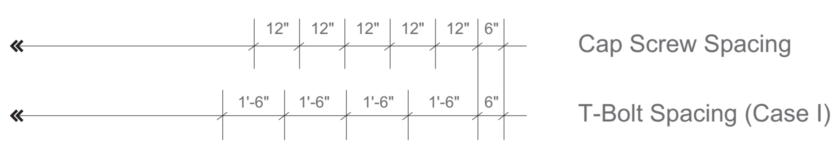
Concentrated Load 200 lbs.
(not acting cumulatively with the above load)

Application



200 lbs at end of railing
(into page - see above)





Maximum end distance assumed

ANALYSIS OF GLASS RAIL BASE MOLDING ATTACHMENT

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Morse Industries Kent, Washington Glass Rail Base Molding Attachment Analysis	Checked by: MJS Date: 07/22/97	Project # 970798

Material Assumptions

- Cap Screws
  SAE Grade 5, 1/2" ⌀ Screws — F_u= 120 ksi (ultimate); F_y= 92 ksi (yield)
- T-Bolts
  ASTM A307, 3/8" ⌀ — F_u= 60 ksi (ultimate)
- Aluminum Base Shoe Molding
  Alloy 6063 -T6
- Concrete (Substrate)
  F_c= 4000 psi (minimum)
- Steel (Substrate)
  ASTM A36 F_y= 36 ksi (minimum)

Base Shoe Connection Types

- Case 1 Concrete surface mounted (recessed molding)
- Case 2 Concrete flush mounted (vertically attached)
- Caes 3 Steel facia mounted (horizontally attached)
- Case 4 Steel facia mounted

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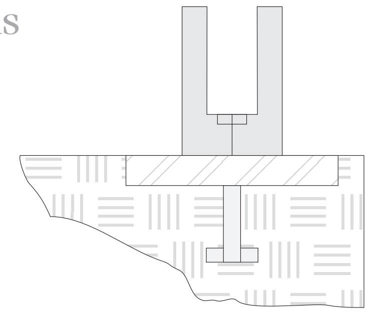
Morse Industries Kent, Washington **Glass Rail Base Molding Attachment Analysis**	*Checked by:* MJS *Date:* 07/22/97	*Project #* 970798

Caes 1 Analysis

Configuration



1/2" ⌀ Cap Screws, 1'-0" o.c.

3/8" Cap Bolts, 1'-6" o.c.

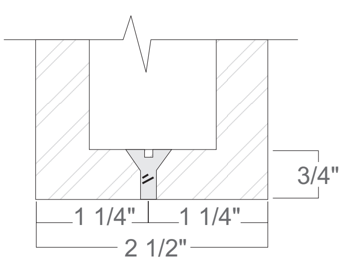
Applied Loads (Service)

Maximum at base: Shear V = 200 lbs →

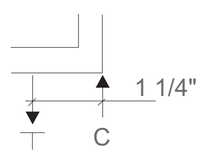
Moment M = (200 lbs)(42") = 8400 in-lbs

These loads act over a 3'-6" horizontal width, assuming a 45 degree distribution of load (page 1).

Cap Screw Connection (Screw & Aluminum checks)



Free Body Diagram



Molding assumed to be Relatively stiff

∴ Arm = 1-14"

Tensile Load on One Cap Screw

M = 1.25 T

T = M/1.25 = 8400/1.25 = 6720 lbs

Conservatively, assume 3 cap screws are effective (pg 1)

6720/3 = 2240 lbs

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Tensile Allowable

F_t = 0.33 F_u (AISC Manual of Steel Construction)

= 0.33(120 ksi) = 40 ksi

Area = $\pi d^2/4 = \pi(.5)^2/4$ = 0.196 sq. in.

T allow = $F_t A$ = (40 ksi)(0.196in) = 7.84 kips = 7840 lbs

7840 # >2240 lbs ok

Shear Load on Cap Screw

V = 200/3 = 66.7 lbs

Shear Allowable

F_v = 0.17 F_u (AISC Manual - threads included)

= 0.17 (120) = 20.4 ksi

V allow = $F_v A$ = (20.4 ksi)(0.96 in^2) = 3.99 kips = 4000 lbs

4000 >66.7 ok

Combined

By observation → ok

Check Screw Bearing on Aluminum

Screw shank length brg on AL: 3/4" - 0.21 = 0.54 in ← Countersunk Head
(Ref. IFI Stds) 3/4" - 0.5in = 0. 25 in ← Socket Head

Bearing Area = (.5)(.25 in) = 0.125 in^2

Allowable bearing stress on aluminum (Aluminum Spec. '94)

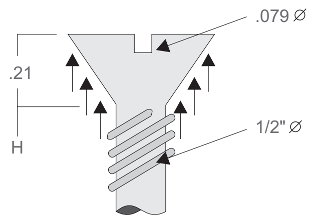
Table 2-23 F_p = 24 ksi

V allow = $F_p A_{brg}$ = (24 ksi)(0.125 in) = 3.0 kips

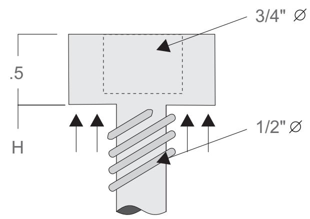
3000 lbs >66.7 lbs ok

Check Screw Pullout in Aluminum

Countersunk Head



Socket Head



Countersunk Head:

$A_p = \pi/4\,(.79^2 - .5^2)$

$= 0.294\ in^2$

$A_v = \pi dh$

$= \pi(.79")(3/4" - .21)$

$= 1.34\ in^2$

Socket Head:

$A_p = \pi/4\,(.75^2 - .5^2)$

$= 0.245\ in^2$

$A_v = \pi dh$

$= \pi(.75")(.25)$

$= 0.589\ in^2$ ← critical

~ Bearing Under Head

F_p = 16 ksi (conservative) on Flat surfaces ~ brg.

T allow = $F_p A_p$ = (16 ksi)(.245 in^2) = 3.92 kips = 3920 lbs

>2240 lbs ok

~ Shear Plug

F_v = 8.5 ksi (Aluminum Spec '94)

V allow = $F_u A_u$ = (8.5 ksi)(.589 in^2) = 5 kips

>2240 lbs ok

ANALYSIS OF GLASS RAIL BASE MOLDING ATTACHMENT

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Morse Industries Kent, Washington Glass Rail Base Molding Attachment Analysis	Checked by: MJS Date: 07/22/97	Project # 970798

Cap Screw into Steel Plate

1/2" thick Steel Plate

(Ref: "Metal Curtain Wall Fasteners", from AAMA)

Table 4 Thread Stripping Area - Internal (sq. in. / thread)

1/2"∅ TSA(I) = 0.036

Number of Threads / Inch N = 13 (UNC)

$$\text{Min. PL - Thickness to achieve Tension Force} = \frac{\text{Allowable Tension}}{\text{Allow. Shear Stress} \bullet \text{TSA(I)} \bullet \text{(N)}} + \frac{1}{N}$$

$$MT = \frac{7840 \text{ lbs}}{(.4)(36{,}000)(0.86)(13)} + \frac{1}{13}$$

$F_V = .4F_y$

$$\frac{7840}{16099} + \frac{1}{13} = 0.56 \text{ in}$$ 1/2" PL provided

Reduction Factor = .5/.56 = 0.88

Tallow = (7840 lbs)(.88) = 6900 lbs

>2240 lbs ok

Anchor in Concrete (Steel check)

3/8" ∅ A307 bolts assumed to act as studs.

Bolt Tension

4 in wide plate assume Arm = 4/2 = 2 in

On page 1, 2 stud bolts assumed effective

$$T = \frac{M}{\text{Arm}} = \frac{8400 \text{ in lbs}}{(2 \text{ in})(2 \text{ bolts})} = 2100 \text{ lbs/bolt}$$

ANALYSIS OF GLASS RAIL BASE MOLDING ATTACHMENT

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Morse Industries Kent, Washington Glass Rail Base Molding Attachment Analysis	Checked by: MJS Date: 07/22/97	Project # 970798

Allowable Tension

(Ref: AISC Manual) F_t = 20 ksi

Area = $\pi(3/8")^2$ /4 = 0.11 in^2

T allow = (20 ksi)(.11 in^2) = 2.2 kips = 2200 lbs

>2100 lbs ok

Shear in Bolt

200 lbs / 2 bolts = 100 lbs →

Allowable Shear

F_v = 10 ksi (Ref. AISC MAnual)

V allow = (10 ksi)(.11) = 1100 lbs

>100 lbs ok

Check Interaction

(AISC Table J3.3) F_t = 26 -1.8 F_v <20

actual

F_v = 100/.11 = 909 psi

F_t = 2100/.11 = 19,090 psi = 19.1 ksi

Allowable

$\therefore F_t$ = 26-1.8(0.91 ksi) = 24.36 ksi use 20 ksi as default

$F_t > f_t$ ok

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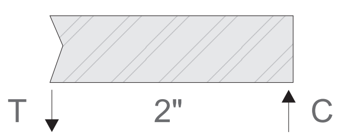
Glass Rail Base Molding Attachment Analysis	*Date:* 07/22/97	

Check Steel Plate

1/2" thick PL , studs at 18in oc.
Assume 6" of plate is tributary to resist bending

$$s = \frac{bd^2}{6} = \frac{(6")(.5)^2}{6} = 0.25 \text{ in}^3$$

$$M = (2100 \text{ lbs})(2") = 4200 \text{ in lbs}$$



$$Fb = \frac{m}{s} = \frac{(4.2 \text{ in kips})}{.25 \text{ in}^3} = 16.8 \text{ ksi}$$

= 2100 lbs

Fb = 0.75 Fy = 0.75 (36) = 27 kis ok

Check Stud in Concrete

(Ref: PCI Design Handbook, 4th edition, Chapter 6)

Factored Loads (refer to pages 6& 7)

V = (100 lbs)(1.7) = 170 lbs
T = (2100 lbs)(1.7) = 3570 lbs

Bolt Geometry

As a practical minimum, select a 3" long bolt
(AISC Manual) 3/8" hex head bolty F = 9/16" (dist. across flats)

Pull - Out Cone (Tension)

$\ell e = 3$ in $Ao = \sqrt{2}\, \ell e\, \pi (\ell e = d_h)$

$d_h = 9/16$ in $= \sqrt{2}(3)(\pi)\, [3.5625"] = 47.5 \text{ in}^2$

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F'c = 4000 psi (mimimum)

ℓpc = ℓAo (2.8 x $\sqrt{F'c}$)

= (0.85) (47.5) (2.8) $\sqrt{4000}$

= 7150 lbs >3570 obs ok

Shear

Min. edge distance = 15Db = 15 (3/8") = 5.625 in

ℓVc = ℓ628db^2 $\lambda \sqrt{f'c}$ η where η = number of studs

= (.85) (628) (.375)^2 (1.0) $\sqrt{4000}$ (1.0)

= 4750 lbs > 170 lbs ok

Examine Shear Parameters

Bolt length + PL Thickness = 3" + 1/2" = 3 1/2"
Say practical min. edge dist. = 1.5 (3.5) = 5 1/4" = de

ℓVc = ℓ12.5 de$^{1.5}$ $\lambda \sqrt{fc}$

= (.85)(12.5)(5.25)$^{1.5}$ (1.0) $\sqrt{4000}$ = 8085 lbs

* Width Effect Cw = 1.0 (only one stud in group)
* Thickness Effect = $Ct = \dfrac{h}{1.3de} \leq 1.0$

Only becomes a factor when h<1.3(5 1/4) = 6 7/8"
Select h = 5 in $Ct = \dfrac{5}{6.875} = 0.73$

* Corner Effect Cc = 1.0

→ Keep edge distance ≥5 1/4" in both directions.

$\ell V_c = \ell V'_c \, C_w C_t \, C_c$

= (8085 lbs.) (1.0) (0.73) (1.0)

= 5092 lbs

Other egn still governs

(Note: A 5" min. slab thickness is a practical minimum for this ℞ & bolt combination)

Check Combined

Pc = 7150/ .85 = 8412 lbs

Vc = 4750/ .85 = 5588 lbs

$$\frac{1}{\ell}\left[\left(\frac{Pu}{Pc}\right)^2 + \left(\frac{Vu}{Vc}\right)^2\right] \le 1.0$$

$$\frac{1}{.85}\left[\left(\frac{3750}{8412}\right)^2 + \left(\frac{170}{5588}\right)^2\right] \le 1.0$$

$$\frac{1}{.85}\left[.18 + .001\right] \le 1.0$$

$0.2 \le 1.0$ ok

Weld bolt to plate

3/8" Ø Length = $2\pi_V$ = (3/8") (π) = 1.178

T = 2100 lbs 2.1 kips
V = 100 lbs = 0.1 kips

E70 electodes Fv = (.3) (70 ksi) = 21 ksi

3/16" weld Rw (3/16") (.707) (21 ksi) (1.178")
= 3.3 kips ok

No need to check interaction as tension dominates

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330 Pfingsten Rd., Northbrook Illinois 60062

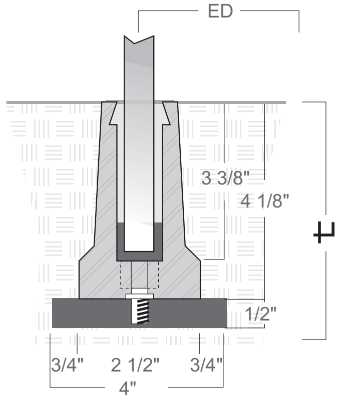
Morse Industries
Kent, Washington

Glass Rail Base Molding Attachment Analysis

Made by:	Checked by:	Date:	Sheet #	Project #
NSA	MJS	07/22/97	15/21	970798

Case 2 Analysis

Configuration



200 lbs over 42" width

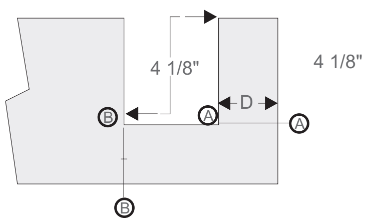
M = (200) (42) = 8400 in lbs
= 8.4 in kips
(at finish floor elev.)

M = (200) (42" + 4 1/8")
= 9225 in lbs
Mu = 1.7 (9.23)
= 15.7 in kips

Vu 1.7 (0.2) = 0.34 kips

Evaluate a Resisting Couple in the Molding

FBD



$N \approx \frac{M}{4\ 1/8"}$ = 15.7 / 4.125 = 3.81 kips

or

MA = N(4 1/8") = 15.7 in kips

Section A-A

Analyze as a plain concrete section
(Ref: ACI 318-95)
Section 9.3.5 ℓ = 0.65 Stregth reduction factor
Chapter 22 ~ Structural Plain Concrete

Mu = ℓ Mn = ℓ 5 $\sqrt{f'c}$ S [Eq'n 22-2]

Determine req'd section modulus ~ S

$$Mu = \ell 5 \sqrt{f'c}\ S$$

$$S = \frac{Mu}{\ell 5 \sqrt{f'c}} = \frac{15{,}700 \text{ in lbs}}{(.65)\ (5)\ \sqrt{4000}}$$

Determine min. width req'd

$$5 = bd^2/6 \quad d = \sqrt{\frac{65}{b}} = \sqrt{\frac{6(76.4)}{42"}} = 3.3 \text{ in}$$

where b = 42" (effective width resisting the load, p.1)

From center of railing to edge

ED = 4/2 + 3.3 = 5.3 in say 5 1/2" min.

~Shear across interface

$$\ell Vn = \ell (4/3)\ \sqrt{Fc}\ b_h \quad [\text{Eq'n } 22\text{-}8]$$

$$= (6.5)\ (4/3)\ \sqrt{4000}\ (42")\ (3.5)\ (1/1000)$$

$$= 8.1 \text{ kips} \quad \text{ok}$$

Section B-B

Slight increase in moment; the depth at B-B will be at least 3 1/2"

Arm = (42" + 4 5/8" + 3.5/2) = 48.375
Mu = (1.7) (48.375) (0.2 kips) = 16.45 in kips

~Check 3 1/2 in of concrete below PL

$$S = \frac{bd^2}{6} = \frac{(42")\ (3.5)^2}{6} = 85.75 \text{ in}^3$$

$$\ell Mn = \ell 5 \sqrt{f'c}\ S = (.65)5\ \sqrt{4000}\ (85.75)\ (1/1000)$$

$$= 17.63 \text{ in kips} \quad > 16.45 \text{ in kips} \quad \text{ok}$$

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~ Shear across section

Glass weighs 15 psf/lin thickness

3/4" thick glass ~ w = 11.3 psf

1 ft width:

w = (11.3 psf) (4 ft) = 45.2 lbs/ft.

Where 4 ft height includes top hardrail wt. (approv)

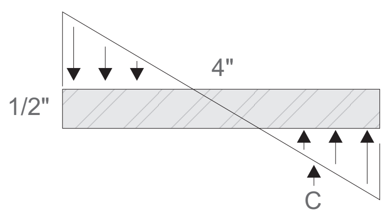
Wu = (1.4) (45.2/ft.) + (1.7) (50) = 148 lbs over 1 ft

Effective Width = 3.5 ft

Wu (148 lbs/ft) (3.5 ft) = 520 lbs <<8.1 kips ok

Evaluate a Resisting Couple in the Steel Plate

FBD



M = 15.7 in. kips

Arms = 2/3 (4") = 2.667"

$C \approx \frac{15.7}{2.667} = 5.9$ kips

By inspection, the concrete section (3 1/2" min.) below this has the necessary capacity to resist the moment & shear (C force) at the previously identified section B-B.

At the top, the upward reacting C force acts over an area:

A = (3/4") (42") = 31.5 sq. in.

Check concrete bearing

$Fp = \frac{5900 lbs}{31.5 in^2} = 187$ psi

Allowable [ACI 22.5.5]

Fp = ℓ0.85fc = (.65) (.85) (4000psi) = 2210 psi ok

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Morse Industries Kent, Washington	*Checked by:* MJS	*Project #* 970798
Glass Rail Base Molding Attachment Analysis	*Date:* 07/22/97	

Evaluate Cap Screw Fastener

Moment slightly higher   M = 9225 in lbs (see page 11)
T = M/1.25" = 9225/1.5 = 7380 lbs
3 cap screws effective   7380/3 = 2460 lbs

Allowables
(page 4) screw tensile allowable = 7840 lbs   ok
(page 5) tensile brg under head = 3920 lbs → ok
→

: screw connection remains ok

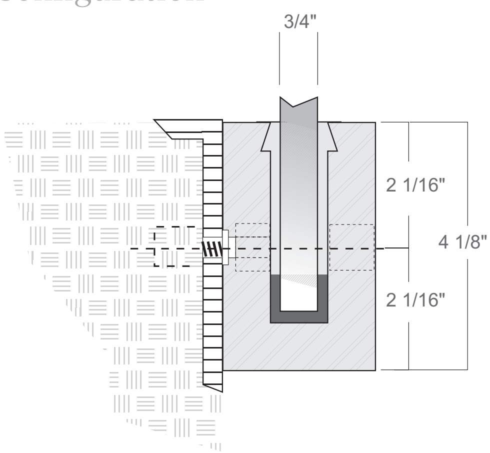
Working Solutions in Aluminum, Plastics and Stainless Steel

ANALYSIS OF GLASS RAIL BASE MOLDING ATTACHMENT

WJE **Wiss, Janny, Elstner Associates, Inc.**
330 Pfingsten Rd., Northbrook Illinois 60062

Morse Industries Kent, Washington **Glass Rail Base Molding Attachment Analysis**	*Made by:* NSA *Checked by:* MJS *Date:* 07/22/97	*Sheet #* 19/21 *Project #* 970798

Case 3 Analysis: Configuration



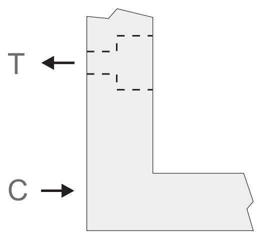
(from page 11 & 13)
conservatively say

M = 9225 in lbs
N = 200 lbs →
P = glass wt.
= (3.5') (45 lbs/ft)
= 158 lbs ↓

Cap Screw Connection

Tensile Load on One Cap Screw

Again, conservatively assume that 3 screws are effective



Arm = 2 1/16"

$$T = \frac{M}{Arm} = \frac{9225 \text{ in lbs}}{(2\ 1/16)\ (3 \text{ screws})} = 1491 \text{ lbs}$$

(page 4) T allow = 7840 lbs ok

Shear Load on Cap Screw

V = 520/3 = 173 lbs

(page 4) V allow = 4000 lbs ok

(page 5) Brg. on aluminum with 1/4" min.
V allow = 3000 lbs

ok

(page 5) Brg. on aluminum under head for tensile load
T allow = 3920 lbs ok

Check Allowable Tensile Capacity into ℙ or <

(page 6) Min. Steel Thickness (MT) = 0.56"

for 1/2" Reduction = .5/.56 = 0.88
T allow = (7840 =) (.88) = 6900 lbs ok

for 3/8" Reduction = .375/.56 = 0.67
T allow = (7840") (.67) = 5250 lbs ok

: As a practical mimimum, use 3/8" thick steel

Check screw bearing in Steel Angle

Say t = 3/8" screw ∅ = 1/2"
A36 steel Fu = 58 ksi (Ref: AISC Manual)

$V_{brg\text{-}allow}$ = (3/8") (1/2") (1.2) (58 ksi)
= 13 kips ok (does not control)

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ANALYSIS OF GLASS RAIL BASE MOLDING ATTACHMENT

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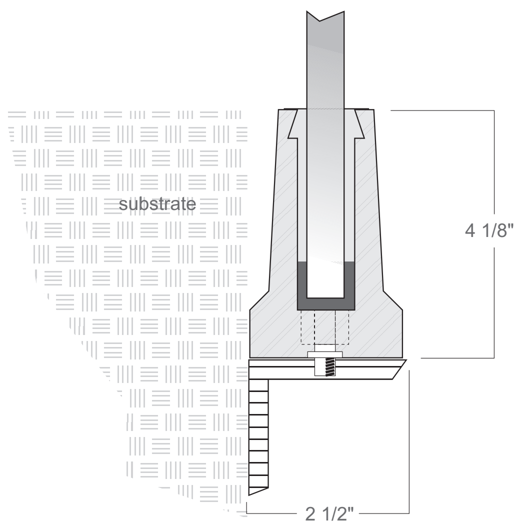
Morse Industries Kent, Washington	*Checked by:* MJS	*Project #* 970798
Glass Rail Base Molding Attachment Analysis	*Date:* 07/22/97	

Case 4 Analysis: Configuration



(from page 11 & 13)
M = 9225 in lbs
N = 200 lbs →
DL
P = (3.5') (45)
= 158 lbs ↓

Cap Screw Connection

Arm = (2 1/2) (1/2) = 1 1/4"   Again, 3 screws effective

$$T = \frac{M}{Arm} + \frac{9225}{(3)(1.25)} = 2460 \text{ lbs}$$

(page 4)   T allow = 7840 lbs   ok

(page 5)   T allow = 3920 lbs   ok   (brg under head)

(page 16)   T allow = 5250 lbs   ok   (3/8" PL grip)