WEAVER CONSTRUCTION MANAGEMENT, INC.
3679 S. Huron St., Suite 404
Englewood, CO 80110
Phone: (303) 789-4111 FAX: (303) 789-4310

S U B M I T T A L   T R A N S M I T A L

November 17, 2011
Submittal No: 05500-001.B

PROJECT: Harold Thompson Regional WRF
Birdsall Rd.
Fountain, CO 80817
Job No. 2908

ENGINEER: GMS, Inc.
611 No. Weber St., #300
Colorado Springs, CO 80903
719-475-2935 Roger Sams

OWNER: Lower Fountain Metropolitan
Sewage Disposal District
901 S. Santa Fe Ave.
Fountain, CO 80817
719-382-5303 James Heckman

CONTRACTOR: Rocky Mountain Railings
11839 E. 51st Ave.
Denver, CO 80239

SUBJECT: Re-submittal of Handrail for the Headworks Building

SPEC SECTION: 05500 – Metal Fabrications

PREVIOUS SUBMISSION DATES: 10/17/11

DEVIATIONS FROM SPEC: ____ YES _X_ NO

CONTRACTOR'S STAMP: This submittal has been reviewed by Weaver General Construction and approved with respect to the means, methods, techniques, & safety precautions & programs incidental thereto. Weaver General Construction also warrants that this submittal complies with contracted documents and comprises on deviations thereto:

Contractor's Stamp:	Engineer's Stamp:
Date: 11/17/11 Reviewed by: H.C. Myers (X) Reviewed Without Comments ( ) Reviewed With Comments	

ENGINEER'S
COMMENTS:____

ROCKY MOUNTAIN RAILINGS

November 17, 2011

Weaver Construction
3679 S. Huron St. Suite 404
Englewood, CO. 80110

Re: Harold D. Thompson R.W.R.F. & Lower Fountain Metro. S.D.D
Subject: Response Letter

This is Rocky Mountain Railings response to GSM. Incôs review comments,

Comment #1
A certification from ATEC Associates, Inc. was provided for load testing of the aluminum handrail titled, TABCO 2500 CONSTRUCITON. The testing data was provided on February 7, 1986. We question whether the certification provided is applicable to this handrail and if there is data more current than 25-year old data. Several pages following the certification is a letter provided by Rocky Mountain Railings, Inc. stating as of January 1, 2007, they have changed the aluminum alloy being used for the Schedule 40 pipe. Since this change was instituted in January 2007, we question the validity of the certification letter prepared in 1986

Response #1
Attached is test data that was done on 8/12/2009 for another project that we worked on. The loads required per the specification are congruent.

Comment #2
Reference is made to Marson stainless rivets in the shop submittal. No rivets are to be used in the fabrication and installation of the handrail system proposed for use at the LFMSDD HDTRWRF.

Response #2
No reference was made to said specific company and the mention of a blind rivet has been removed from the submittals.

Comment #3
H.B. Tenmecol: No Exception Taken

Response #3
Acknowledged

Comment #4
Aluminum Railing Design Calculations: We take no exception to the design analysis provided. However, we note the following:

a. Guardrail ñAò Analysis allows for a 5ô0ò max. post spacing
b. Guardrail ñBò Analysis allows for a 5ô0ò max. post spacing
c. Guardrail ñCò Analysis allows for a 5ô0ò max. post spacing
d. Guardrail ñDò Analysis allows for a 5ô0ò max. post spacing
e. Guardrail ñKò Analysis allows for a 4ô5ò max. post spacing

f. GMS, Inc. Construction Drawings indicate post spacing to be at a maximum of 6ô0ö. We request clarification on how the post spacing will be accomplished in the field. General notes No. 13) on Drawing No. D-1 indicates the maximum post spacing will be 6ô0ö. Please reconcile the differences between the design analysis provided, the shop drawings and the Construction Drawings.

Response #4
Attached are standard calculations that were done on 3/8/2011 that adhere to similar loads per this job specification. Rail sections pertaining to this job can be maxed out at 6ô0òmax post spacing per sheet B1 (13 of 64), C1 (19 of 64), and E1 (37 of 64).

Comment #5
Hilti HIT-RE 500 Epoxy Adhesive Anchoring Systems: No Exception Taken

Response #5
Acknowledged

Comment #6
Rocky Mountain Railings, Drawing D-1:

a. General Note No. 5) references blind rivets. Based on our cursory review, we see no reference on the drawings indicating where riveting is proposed for use and installation. Per Comment No. 2 above, no rivets are to be used.
b. Detail 80KD-7A: In Weaver Construction Management, Inc. (WCMI) correspondence issued on October 13, 2011 under additional comments, there was question whether Detail 80KD-7A is acceptable at the top of the stairs of the west side of the chain opening. We take no exception to the LEVEL P-END being used at this location.

Response #6

- All reference to blind rivets and rivets of any kind have been removed from this submittal.

- Acknowledged

Comment #7
We take no exception to the remainder of Rocky Mountain Railings drawings and details provided. The Contractor will be responsible for the cutting and placement of the appropriate lengths as indicated on the Construction Drawings on to meet field conditions.

Response #7
Acknowledged

Sincerely,
Danny Brown
Rocky Mountain Railings
dbrown@rockymountainrailings.com

11939 E. 51st Ave. Denver, CO. 80239. Phone (303) 432-0003. Fax (303) 432-2038

R0001 – RMR Standard Calculations

Aluminum Railing Design Calculations – R11-02-15H

Colorado

Prepared for

Rocky Mountain Railings

Denver, CO

Design Criteria:

Date: 3/8/11

1. Railing live loads per **International Building Code 2009**:

    Guardrails

    50 plf uniform load in any direction on top rail
    200 pound concentrated load in any direction on top rail
    50 pound concentrated load over 1 ft^2 of infill area
    Concentrated load and uniform loads need not be assumed to act concurrently

    Railing deflections per ASTM E985

    Members designed per Aluminum Association Inc, "Aluminum Design Manual"

2. Aluminum member sizes shall be as recommended in the calculation booklet
3. Aluminum alloys shall be as recommended in the calculation booklet
4. Stainless steel fasteners to be minimum **Condition "CW", Fy= 65 ksi**
5. Aluminum welds to be **filler alloy 5356**, unless noted otherwise
6. Concrete strength is assumed to be **F'c= 4,000 psi, normal weight**
7. Additional RISA Finite Element Analysis model data available upon request.

This Certification is limited to the structural design of structural components of this handrail or divider system.
It does NOT include responsibility for:

- Structural design of misc. hardware (latches, hinges, etc.).
- Structural design of concrete slabs and other masonry units
- Structural design of wood blocking or wood framing
- Structural design of all other anchorage substrates
- The manufacture, assembly, or installation of the system.
- Quantities of materials or dimensional accuracy of drawings

Engineers Design Approval Stamp:

COLORADO LICENSED L. DAVID RICE 40031 PROFESSIONAL ENGINEER

MAR 08 2011

Sheet Number	Description	Date	Revision
PL	Project Location & Specs	2/23/11	
A	Guardrail "A"	2/23/11	
A1-A1B	Guardrail "A" Analysis	2/23/11	
A2	2-Bolt Base Plate	2/23/11	
A3	Corner Base Plate	2/23/11	
A3.1	RISA Data	2/23/11	
A3.2	RISA Data	2/23/11	
B	Guardrail "B"	2/23/11	
B1-B1B	Guardrail "B" Analysis	2/23/11	
B2	Surface Mount Anchorage	2/23/11	
B3	Hilti Adhesive	2/23/11	
C	Guardrail "C"	2/23/11	
C1-C1B	Guardrail "C" Analysis	2/23/11	
C2	Side Mount Anchorage	2/23/11	
C3	Hilti Adhesive	2/23/11	
C4	Corner Side Mount Anchorage	2/23/11	
C4.1	RISA Data	2/23/11	
C4.2	RISA Data	2/23/11	
C5	Hilti Adhesive	2/23/11	
C6	Side Mount Anchorage	2/23/11	
C7	Hilti Adhesive	2/23/11	
D	Guardrail "D"	2/23/11	
D1-D1B	Guardrail "D" Analysis	2/23/11	
D2	Side Mount Anchorage	2/23/11	
D3	Side Mount Anchorage	2/23/11	
E	Guardrail "E"	2/23/11	
E1-E1B	Guardrail "E" Analysis	2/23/11	
E2	Side Mount Anchorage	2/23/11	
E3	Side Mount Anchorage	2/23/11	
F	Guardrail "F"	2/23/11	
F1-F1B	Guardrail "F" Analysis	2/23/11	
F2	Post Embedment in Grout	2/23/11	
M1	Miscellaneous Connections	2/23/11	
M1A	RISA Data	2/23/11	
M2	Wall Rail Post Bracket	2/23/11	
M2A	RISA Data	2/23/11	
M2B	RISA Data	2/23/11	
M3-M3A	Wall or Grab Rail Analysis	2/23/11	
M4	Grab Rail Bracket Analysis	2/23/11	
M5	Wall Rail Bracket Analysis	2/23/11	
M6	Offset Rail Connections	2/23/11	
M7	Wall Mount End Cap	2/23/11	
M8	2-Bolt Raked Base Plate	2/23/11	
	Algor Base Plate Models	2/23/11	
S1	Fastener Spec. Sheet	2/23/11	

Sheet Number	Description	Date

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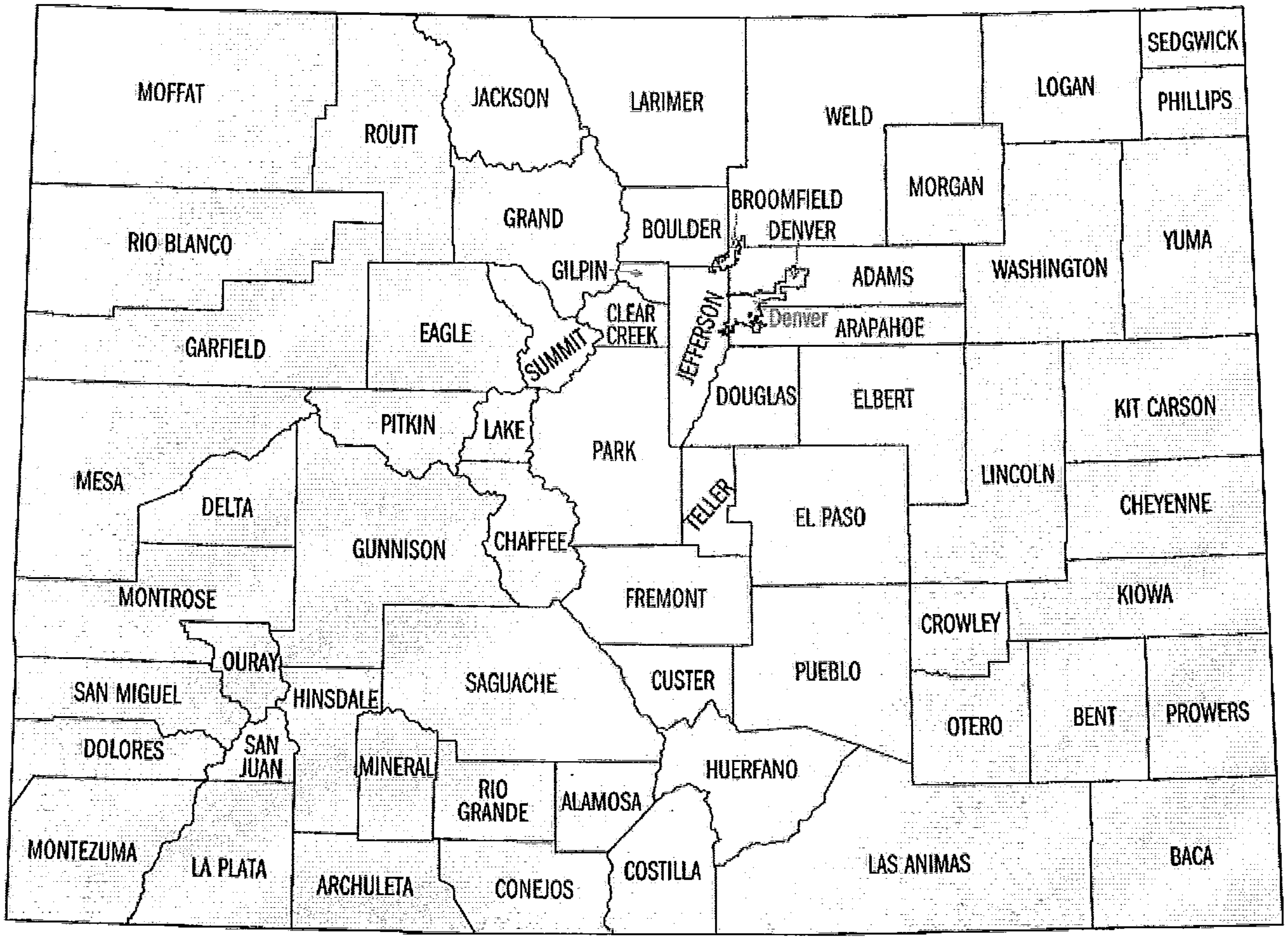
- Structural design of wood blocking or wood framing
- Structural design of all other anchorage substrates
- The manufacture, assembly, or installation of the system.
- Quantities of materials or dimensional accuracy of drawings

Engineers Design Approval Stamp:

COLORADO LICENSED
L. DAVID RICE
0031
PROFESSIONAL ENGINEER

MAR 0 8 2011

Project Location & Specifications	SHT PL



Project Location: Colorado

- Design Loads per IBC 2009

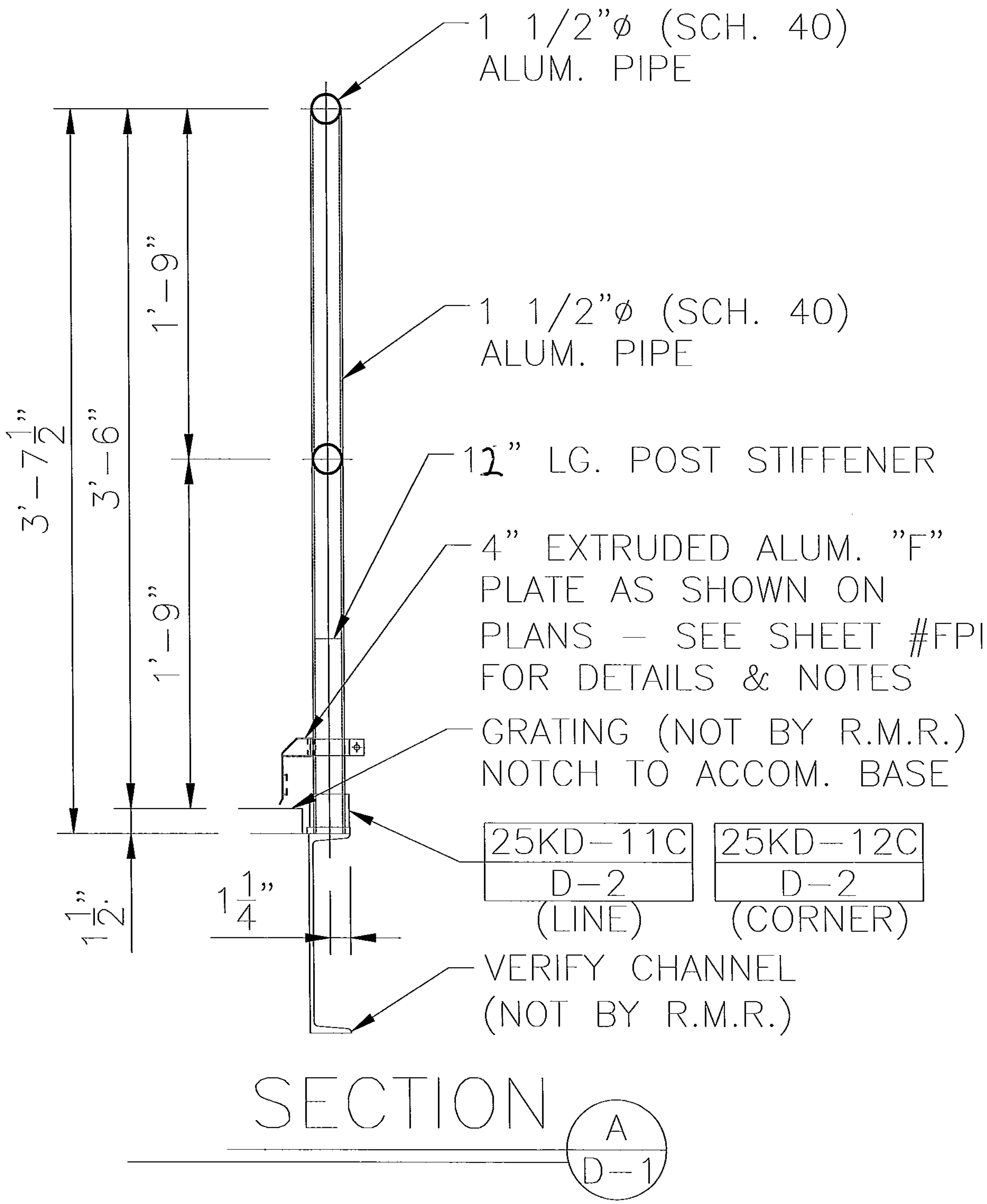
    50 plf uniform load in any direction on top rail

    200# concentrated load in any direction on top rail

    50# concentrated load applied to 1 square foot of infill

RICE ENGINEERING Template: REI-MC-2002	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
			Engineer: JDB	Sheet No: PL
			Date: 2/23/11	Rev:
			Chk By:	Date:

Guardrail "A"	SHT A



Note: *Structural steel, Concrete, CMU and all other anchorage substrates designed by others*

ROCKY MOUNTAIN RAILINGS

RICE ENGINEERING	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
Template: REI-MC-5707			Engineer: JDB	Sheet No: A
			Date: 2/23/11	Rev:
			Chk By:	Date:

Pipe Railing & Post

These calculations are based on emperical test data performed by Julius Blum & Co., Inc.

Guardrail "A" Analysis	SHT A1

Input Variables:

$F_H := 50$ plf Load Case 1 (Uniform Load)

$F_V := 0$ plf Simultaneous Vertical Uniform Load

$P := 200$ lb Load Case 2 (Point Load)

$L_{bp} := 21$ in Unbraced Length of Post

$h := 41$ in Railing Height Above Base Flange

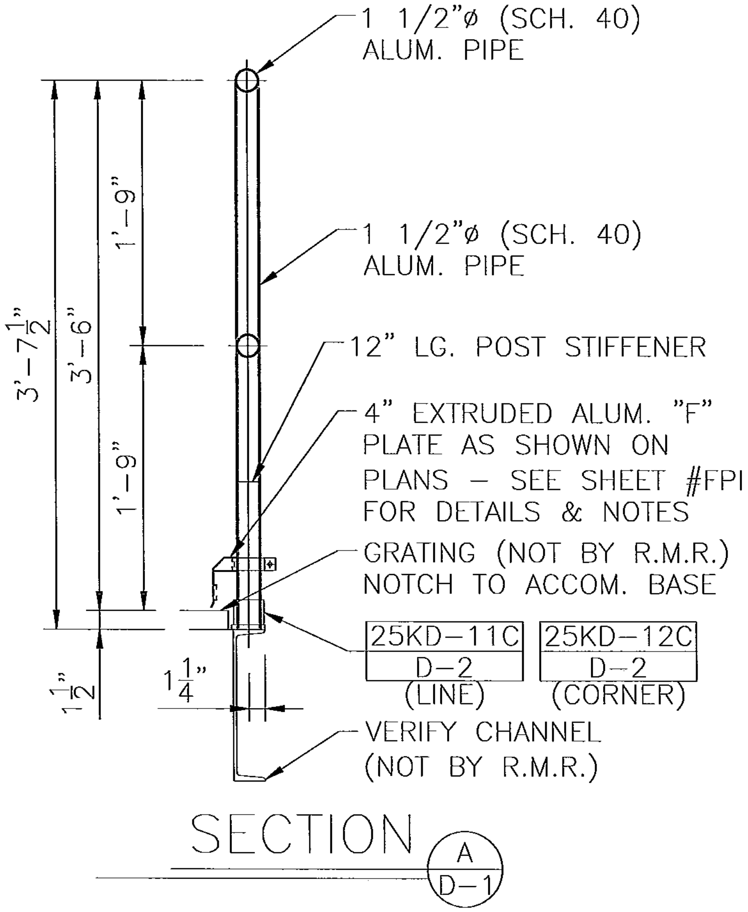
$L := 58$ in **4'-10" MAX POST SPACING**

Number of Railing Spans: *Note: Post Spacing (Anchor limits the span length)

1 span ☑

2 span ☑

3 or more spans ☑



Railing Section:	***Post Section:***
☐ 1 1/4" Schd. 40	☐ 1 1/4" Schd. 40
☐ 1 1/4" Schd. 80	☐ 1 1/4" Schd. 80
☑ 1 1/2" Schd. 40	☑ 1 1/2" Schd. 40
☐ 1 1/2" Schd. 80	☐ 1 1/2" Schd. 80
☐ 1 1/2" tube	☐ 1 1/2" tube
☐ 2" Schd. 40	☐ 2" Schd. 40
☐ 2" Schd. 80	☐ 2" Schd. 80

Railing Temper:	***Post Temper:***
☐ 6063-T5	☐ 6063-T6
☐ 6063-T6	☐ 6005-T5
☑ 6061-T6 or 6105-T5	☑ 6061-T6 or 6105-T5
☐ *4/3 increase allowed*	☐ Post Welded to Base Plate

All calculations below this line are automatic

Railing Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

Post Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

$S_{R1} := \frac{R_r}{t_r}$ $S_{R1} = 6.55$

$S_{R3} := \frac{R_p}{t_p}$ $S_{R3} = 6.55$

Computational Factors

$K_1 := (8 \cdot q1) + (8 \cdot q2) + (9.5 \cdot q3)$ $K_1 = 8$

$K_2 := (4 \cdot q1) + (5 \cdot q2) + (5 \cdot q3)$ $K_2 = 5$

$K_3 := (48 \cdot q1) + (66 \cdot q2) + (87 \cdot q3)$ $K_3 = 66$

$E_r := 10100000$ psi

$I_{xtotr} := I_{xr}$ $I_{xtotr} = 0.31$ in^4 $I_{xtotp} := I_{xp}$ $I_{xtotp} = 0.31$ in^4

$I_{ytotr} := I_{yr}$ $I_{ytotr} = 0.31$ in^4 $I_{ytotp} := I_{yp}$ $I_{ytotp} = 0.31$ in^4

12" Min. Length AL. Ribbed Tube Stub

$I_{st} := 0.174$ in^4 $L_{st} := 9.5$ in

$S_{st} := 0.224$ in^3 $F_{bst} := 25000$ psi

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			Engineer: JDB	Sheet No: A1
			Date: 2/23/11	Rev:
			Chk By:	Date:

Railing Analysis:

$W_h := \frac{F_H}{12}$ $W_v := \frac{F_V}{12}$

Guardrail "A" Analysis	SHT A1 A

Case 1 Uniform Load:

$\Delta_{yr1} := \frac{5 \cdot W_h \cdot L^4}{384 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr1} = 0.196$ in Modeled as a simple span

$\Delta_{xr1} := \frac{5 \cdot W_v \cdot L^4}{384 \cdot E_r \cdot I_{xtotr}}$ $\Delta_{xr1} = 0$ in

$\Delta_{allr} := \frac{L}{96}$ $\Delta_{allr} = 0.6$ in Per ASTM Specification E985

$M_{yrmax} := \frac{W_h \cdot L^2}{K_1}$ $M_{yrmax} = 1752$ lb·in

$M_{xrmax} := \frac{W_v \cdot L^2}{K_1}$ $M_{xrmax} = 0$ lb·in

---

$f_{bry1} := \frac{M_{yrmax}}{S_{yr}}$ $f_{bry1} = 5374$ psi

$f_{brx1} := \frac{M_{xrmax}}{S_{xr}}$ $f_{brx1} = 0$ psi

Case 2 - Point Load:

$\Delta_{yr2} := \frac{P \cdot L^3}{K_3 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr2} = 0.189$ in

$M_{yrmax2} := \frac{P \cdot L}{K_2}$ $M_{yrmax2} = 2320$ lb·in

$f_{bry2} := \frac{M_{yrmax2}}{S_{yr}}$ $f_{bry2} = 7117$ psi

$F_{bry} := \begin{cases} (F_{bry1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bry1} & \text{otherwise} \end{cases}$ $\boxed{F_{bry} = 25000}$ psi

Calculation Results:

$Int_{r1} := \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right)$ $Int_{r1} = 0.21$

$Int_{r2} := \frac{f_{bry2}}{F_{bry}}$ $Int_{r2} = 0.28$

$RAILS := \begin{cases} \text{"OK"} & \text{if } \frac{\max(\Delta_{yr1}, \Delta_{xr1}, \Delta_{yr2})}{\Delta_{allr}} \le 1 \land \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right) \le 1 \land \frac{f_{bry2}}{F_{bry}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ $\boxed{RAILS = \text{"OK"}}$

Post Analysis:

$E_p := E_r$

Guardrail "A" Analysis	SHT A1 B

$\Delta_{xp1} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$ — $\Delta_{xp1} = 0.804$ in

$\Delta_{xp2} := \frac{P \cdot 0.85 \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$ — $\Delta_{xp2} = 0.566$ in

Max Deflection:

$\Delta_{tot} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot I_{xp}} + \frac{W_h \cdot L \cdot \left[h^3 - (h - L_{st})^3\right]}{3 \cdot \left[(E_p \cdot I_{xp}) + (E_p \cdot I_{st})\right]}$ — $\boxed{\Delta_{tot} = 1.425}$ in

$\Delta_{allp} := \frac{h}{12}$ — $\boxed{\Delta_{allp} = 3.42}$ in *Per ASTM E985*

Case 1 - Uniform Load:

$M_{xp} := (W_h \cdot L \cdot h) + W_v \cdot L \cdot \Delta_{tot}$ $\quad M_{xpmax} := 0.5 \cdot M_{xp} \cdot q1 + M_{xp}q2 + M_{xp} \cdot q3$ — $M_{xpmax} = 9908$ lb·in

$M_{xp2} := W_h \cdot L \cdot (h - L_{st}) + W_v \cdot L \cdot \Delta_{xp1}$ $\quad M_{xpmax2} := 0.5 \cdot M_{xp2} \cdot q1 + M_{xp2}q2 + M_{xp2} \cdot q3$ — $M_{xpmax2} = 7613$ lb·in

Case 2 - Point Load:

$M_{xpmax4} := P \cdot (h - L_{st}) \cdot 0.85$ — $M_{xpmax4} = 5355$ lb·in

$M_{xpmax3} := (P \cdot h \cdot 0.85)$ — $M_{xpmax3} = 6970$ lb·in

Max Post Stress:

$f_{bpx} := \frac{\max(M_{xpmax2}, M_{xpmax4})}{S_{xp}}$ — $\boxed{f_{bpx} = 23351}$ psi

$F_{bpx} := \begin{cases} (F_{bpx1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bpx1} & \text{otherwise} \end{cases}$ — $\boxed{F_{bpx} = 25000}$ psi

Max Post/Stub Combined Stress:

$f_{bpx2} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{xp}}{(I_{xp} + I_{st}) \cdot S_{xp}}$ — $\boxed{f_{bpx2} = 19467}$ psi

$\boxed{F_{bpx} = 25000}$ psi

Max Stub Stress:

$f_{bst} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{st}}{(I_{xp} + I_{st}) \cdot S_{st}}$ — $\boxed{f_{bst} = 15902}$ psi

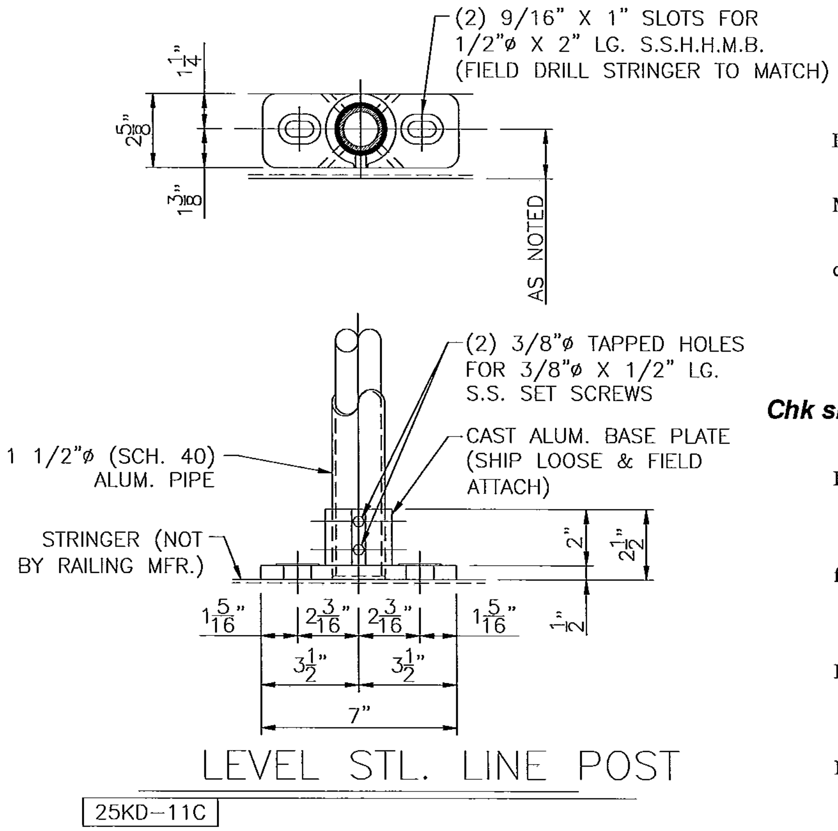
$\boxed{F_{bst} = 25000}$ psi

Calculation Results:

$Int_{p1} := \max\left(\frac{f_{bpx}}{F_{bpx}}, \frac{f_{bpx2}}{F_{bpx}}, \frac{f_{bst}}{F_{bst}}\right)$ — $Int_{p1} = 0.93$

$POSTS := \begin{cases} \text{"OK"} & \text{if } Int_{p1} \le 1 \wedge \frac{\max(\Delta_{xp1}, \Delta_{xp2}, \Delta_{tot})}{\Delta_{allp}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ — $\boxed{POSTS = \text{"OK"}}$

2-Bolt Base Plate	SHT A2



$R_{max} := 242$ lb

$M_{max} := 9908 + R_{max} \cdot 2.5 = 10513$ lb·in

$d := 2.5$ in (sleeve dia.)

Chk shear on shoe wall:

$P := \frac{M_{max}}{0.85 \cdot (2.375)}$ $P = 5208$ lb

$f_v := \frac{(P + R_{max})}{2 \cdot (0.315) \cdot (2)}$ $f_v = 4325$ psi

$F_v := \frac{0.57 \cdot (18000)}{1.65}$ $F_v = 6218$ psi

$I := \frac{f_v}{F_v}$ $I = 0.7$ Shear Stress "OK"

Note: 4'10" ℄ Post spacing @ 3'7½" rail height (as shown)

if rail height was 3'6" then ℄ Post Spacing could be 5'0"

Chk Aluminum Base Plate:

$L1 := 7$ in $D1 := 1.3125$ in

$L2 := 2.625$ in $D2 := 1.25$ in

$t := 0.563$ in

$L := L1 - (2 \cdot D1)$ $L = 4.38$ in

$P := \frac{M_{max}}{d}$ $P = 4205$ lb

$M_{p1} := 0.5 \cdot P \cdot 0.9375$ $M_{p1} = 1971$ in·lb

$F_y := \frac{1.3 \cdot (18000)}{1.65}$ $F_y = 14182$ psi

$t_{req1} := \sqrt{\frac{M_{p1} \cdot 6}{F_y \cdot L2}}$ $t_{req1} = 0.564$ in

$I_2 := \frac{t_{req1}}{t}$ $I_2 = 1$

Chk Bolts to Steel Stringer:

$V_b := \frac{R_{max}}{2}$ $V_b = 121$ lb

$T_b := \frac{M_{max}}{2 \cdot 1.25}$ $T_b = 4205$ lb

$V_{all} := 0.196 \cdot 23094$ $V_{all} = 4526$ lb

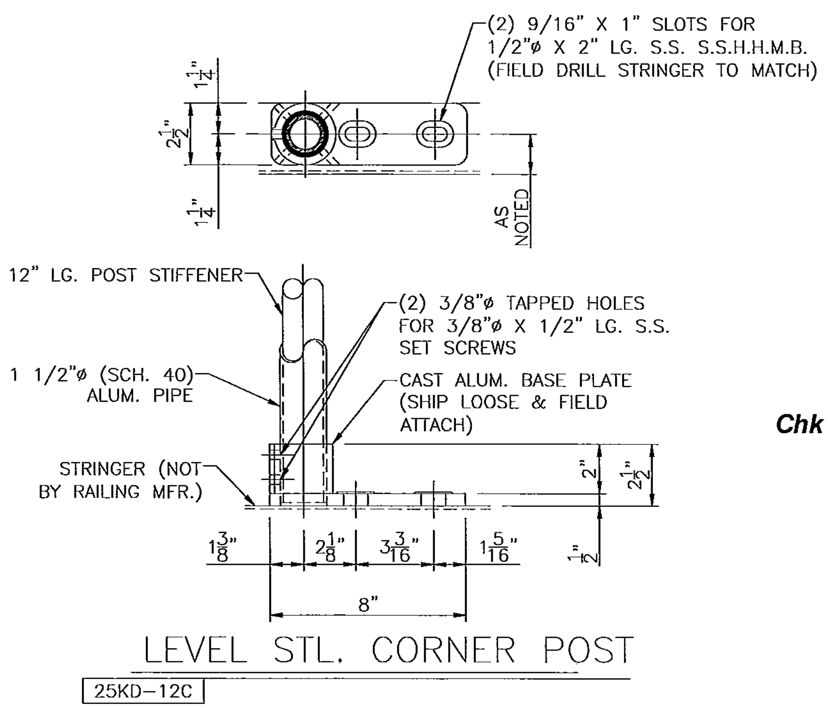
$T_{all} := 0.142 \cdot 40000$ $T_{all} = 5680$ lb

$I_3 := \left(\frac{V_b}{V_{all}}\right)^2 + \left(\frac{T_b}{T_{all}}\right)^2$ $I_3 = 0.55$

Use (2) - 1/2" Dia. S.S. Thru-Bolts
Condition "CW" - Fy = 65 ksi

Use Cast Aluminum Base, as shown
535 casting alloy, Fu= 35 ksi min.

Corner Base Plate	SHT A3



$R_{max} := 101$ lb — *Reactions from RISA Model*

$M_{max} := 0$ lb·in — *(Corner Post Modeled as a Pin Connection)*

$d := 2.5$ in (sleeve dia.)

Chk shear on shoe wall:

$P := \frac{M_{max}}{0.85\cdot(2.375)}$ $P = 0$ lb

$f_v := \frac{(P + R_{max})}{2\cdot(0.315)\cdot(2)}$ $f_v = 80$ psi

$F_v := \frac{0.57\cdot(18000)}{1.65}$ $F_v = 6218$ psi

$I := \frac{f_v}{F_v}$ $I = 0.01$ Shear Stress "OK"

Chk Aluminum Base Plate:

$L1 := 7$ in $D1 := 1.3125$ in

$L2 := 2.625$ in $D2 := 1.25$ in

$t := 0.563$ in

$L := L1 - (2\cdot D1)$ $L = 4.38$ in

$P := \frac{M_{max}}{d}$ $P = 0$ lb

$M_{p1} := P\cdot 0.9375$ $M_{p1} = 0$ in·lb

$F_y := \frac{1.3\cdot(18000)}{1.65}$ $F_y = 14182$ psi

$t_{req1} := \sqrt{\frac{M_{p1}\cdot 6}{F_y\cdot L2}}$ $t_{req1} = 0$ in

$I_2 := \frac{t_{req1}}{t}$ $I_2 = 0$

Use Cast Aluminum Base, as shown
535 casting alloy, Fu= 35 ksi min.

Chk Bolts to Steel Stringer:

$V_b := \frac{R_{max}}{2}$ $V_b = 50.5$ lb

$T_b := \frac{M_{max}}{2\cdot 1.25}$ $T_b = 0$ lb

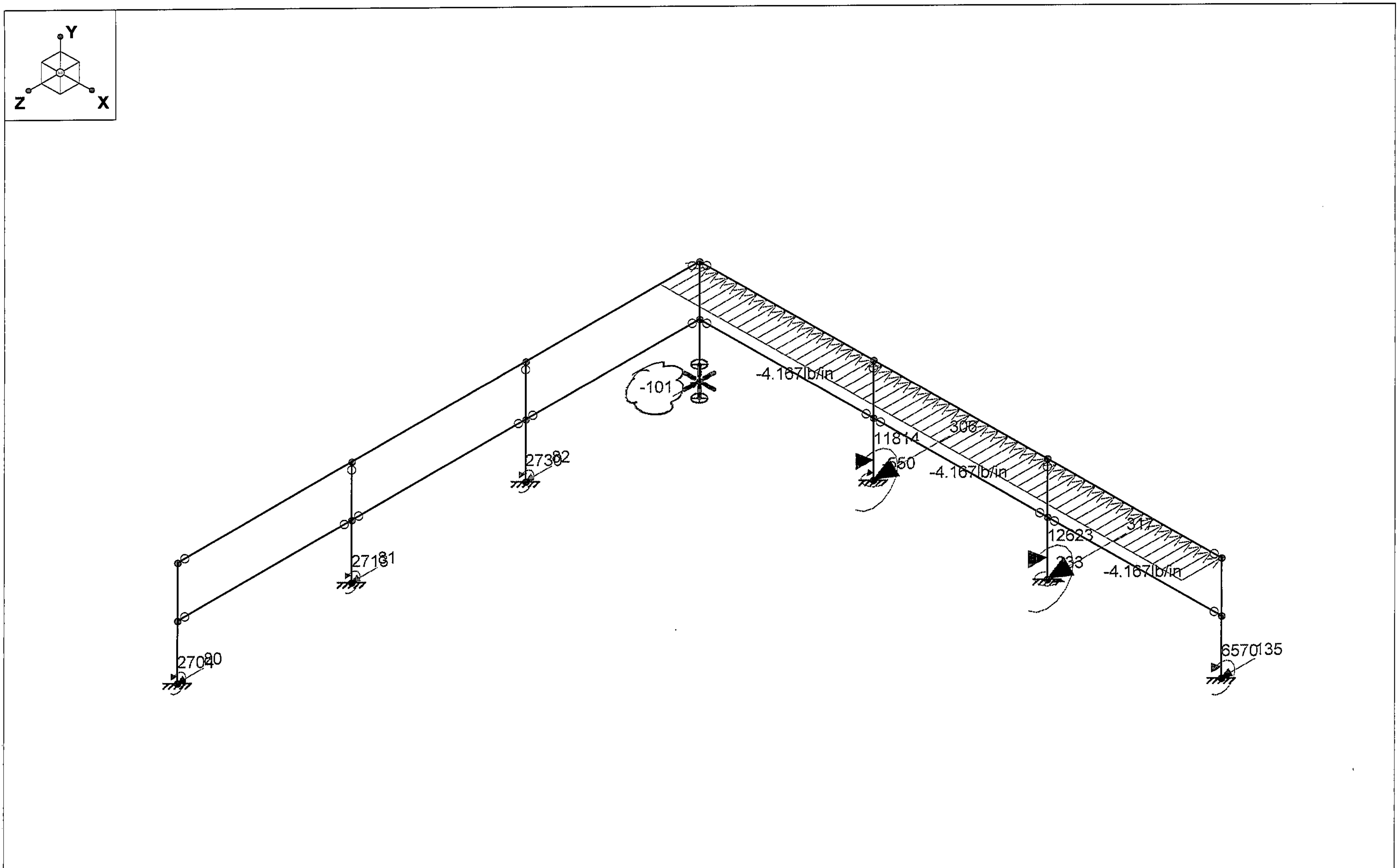
$V_{all} := 0.196\cdot 23094$ $V_{all} = 4526$ lb

$T_{all} := 0.142\cdot 40000\cdot\frac{0.1875}{0.456}$ $T_{all} = 2336$ lb

$I_3 := \left(\frac{V_b}{V_{all}}\right)^2 + \left(\frac{T_b}{T_{all}}\right)^2$ $I_3 = 0$

Use (2) - 1/2" Dia. S.S. Thru-Bolts
or Drill & Tap - 3/16" Min. Thread Engagement
Condition "CW" - Fy = 65 ksi

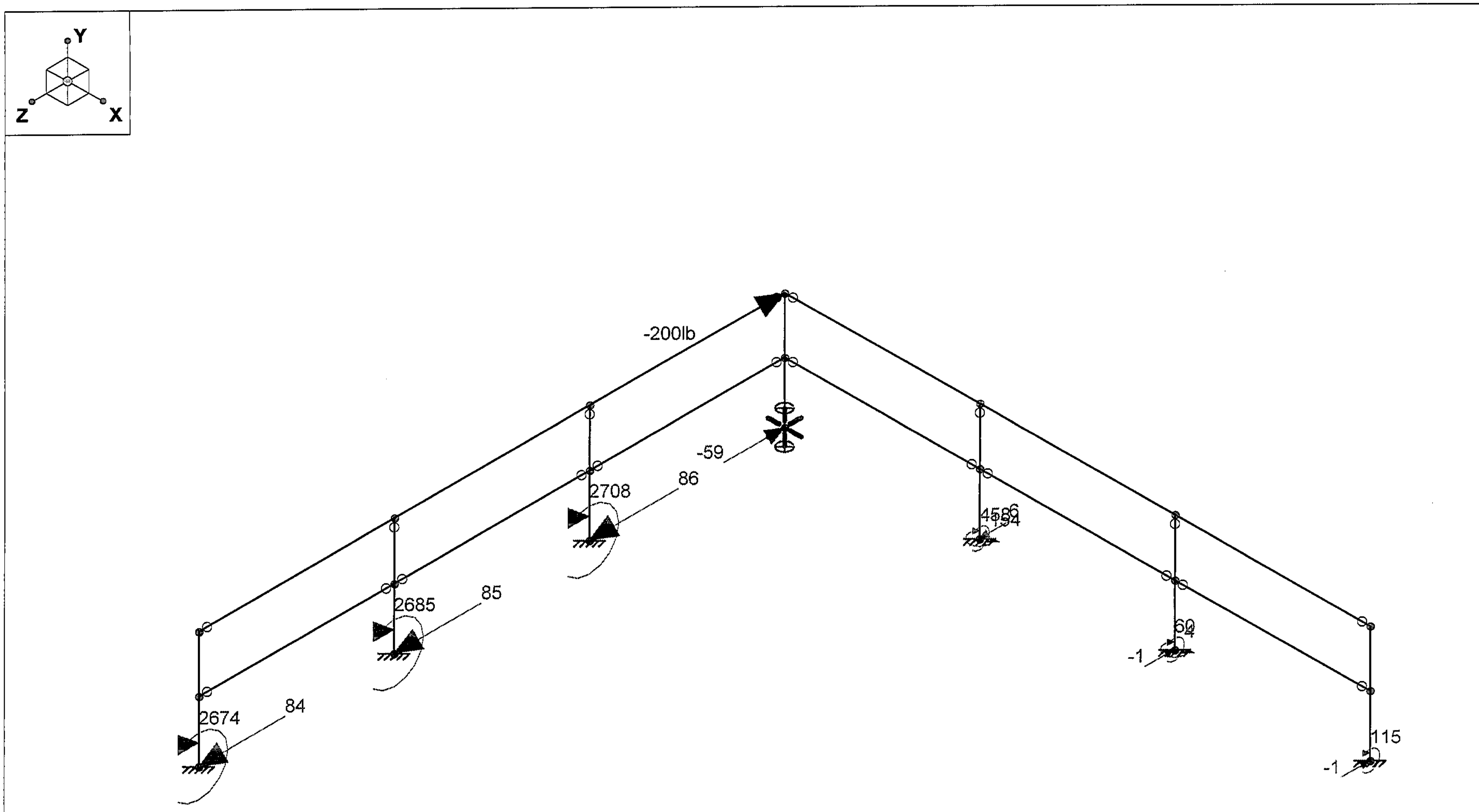
RICE ENGINEERING Template:	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
			Engineer: JDB	Sheet No: A3
			Date: 2/23/11	Rev:
			Chk By:	Date:



Loads: BLC 1,
Results for LC 1, Dist 1
Z-moment Reaction units are lb and lb-in

Rice Engineering	R0001 - RMR Standard Calcs	SK - 1
Joe Bauer		Feb 23, 2011 at 5:24 PM
R11-02-15H		Corner Bracket A.r3d

A3.1

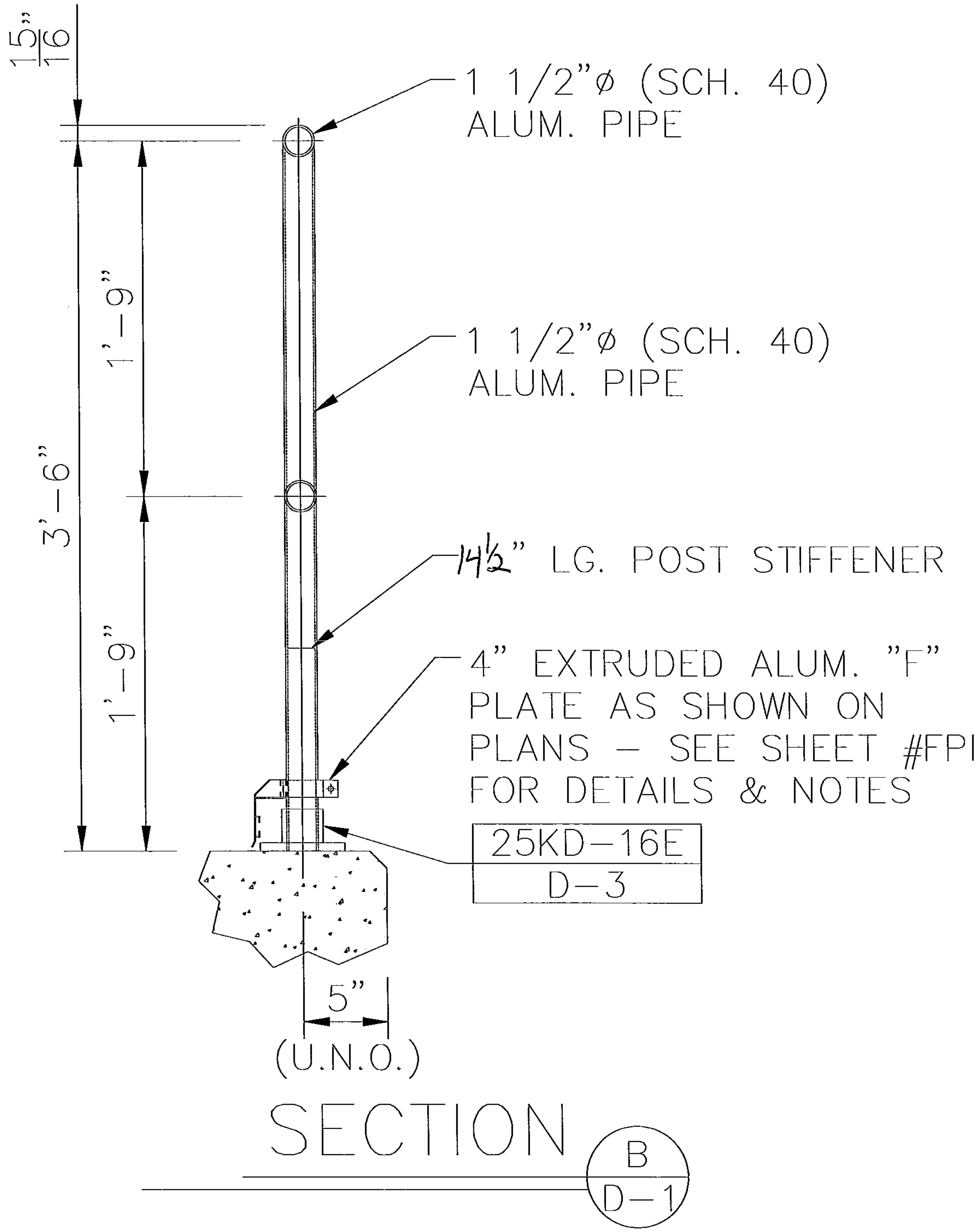


Loads: BLC 2,
Results for LC 2, Point
Z-moment Reaction units are lb and lb-in

Rice Engineering	R0001 - RMR Standard Calcs	SK - 2
Joe Bauer		Feb 23, 2011 at 5:24 PM
R11-02-15H		Corner Bracket A.r3d

A3.2

Guardrail "B"	SHT B



Note: *Structural steel, Concrete, CMU and all other anchorage substrates designed by others*

ROCKY MOUNTAIN RAILINGS

RICE ENGINEERING Template: REI-MC-5707	105 School Creek Trail, Luxemburg, WI 54217, Phone: (920)845-1042, Fax: (920)845-1048, www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
			Engineer: JDB	Sheet No: B
			Date: 2/23/11	Rev:
			Chk By:	Date:

Pipe Railing & Post

These calculations are based on emperical test data performed by Julius Blum & Co., Inc.

Guardrail "B" Analysis	SHT B1

Input Variables:

$F_H := 50$ plf — Load Case 1 (Uniform Load)

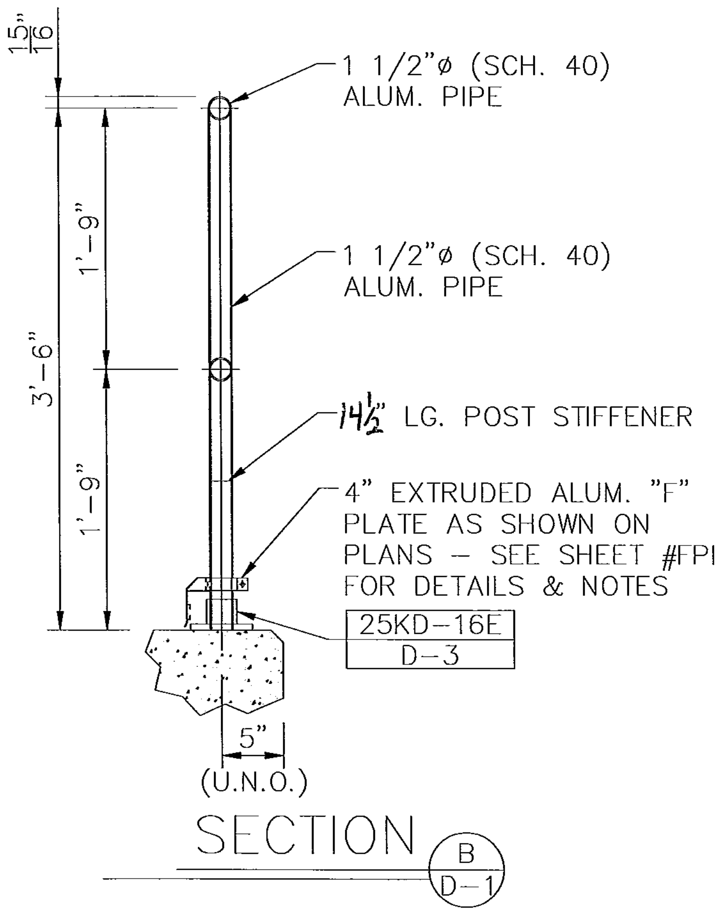
$F_V := 0$ plf — Simultaneous Vertical Uniform Load

$P := 200$ lb — Load Case 2 (Point Load)

$L_{bp} := 21$ in — Unbraced Length of Post

$h := 39.5$ in — Railing Height Above Base Flange

$L := 72$ in — ***6'-0" MAX POST SPACING***



Number of Railing Spans:

- [x] 1 span
- [x] 2 span
- [x] 3 or more spans

Railing Section:	*Post Section:*
[ ] 1 1/4" Schd. 40	[ ] 1 1/4" Schd. 40
[ ] 1 1/4" Schd. 80	[ ] 1 1/4" Schd. 80
[x] 1 1/2" Schd. 40	[x] 1 1/2" Schd. 40
[ ] 1 1/2" Schd. 80	[ ] 1 1/2" Schd. 80
[ ] 1 1/2" tube	[ ] 1 1/2" tube
[ ] 2" Schd. 40	[ ] 2" Schd. 40
[ ] 2" Schd. 80	[ ] 2" Schd. 80

Railing Temper:	*Post Temper:*
[ ] 6063-T5	[ ] 6063-T6
[ ] 6063-T6	[ ] 6005-T5
[x] 6061-T6 or 6105-T5	[x] 6061-T6 or 6105-T5
[ ] *4/3 increase allowed*	[ ] Post Welded to Base Plate

All calculations below this line are automatic

Railing Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

Post Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

$S_{R1} := \frac{R_r}{t_r}$ $\quad S_{R1} = 6.55$

$S_{R3} := \frac{R_p}{t_p}$ $\quad S_{R3} = 6.55$

Computational Factors

$K_1 := (8 \cdot q1) + (8 \cdot q2) + (9.5 \cdot q3)$ $\quad K_1 = 8$

$K_2 := (4 \cdot q1) + (5 \cdot q2) + (5 \cdot q3)$ $\quad K_2 = 5$

$K_3 := (48 \cdot q1) + (66 \cdot q2) + (87 \cdot q3)$ $\quad K_3 = 66$

$E_r := 10100000$ psi

$I_{xtotr} := I_{xr}$ $\quad I_{xtotr} = 0.31$ in^4 $\qquad I_{xtotp} := I_{xp}$ $\quad I_{xtotp} = 0.31$ in^4

$I_{ytotr} := I_{yr}$ $\quad I_{ytotr} = 0.31$ in^4 $\qquad I_{ytotp} := I_{yp}$ $\quad I_{ytotp} = 0.31$ in^4

14.5" Min. Length AL. Ribbed Tube Stub

$I_{st} := 0.174$ in^4 $\qquad L_{st} := 12$ in

$S_{st} := 0.224$ in^3 $\qquad F_{bst} := 25000$ psi

Railing Analysis:

$W_h := \frac{F_H}{12}$ $W_v := \frac{F_V}{12}$

Guardrail "B" Analysis	SHT B1 A

Case 1 Uniform Load:

$\Delta_{yr1} := \frac{5 \cdot W_h \cdot L^4}{384 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr1} = 0.466$ in Modeled as a simple span

$\Delta_{xr1} := \frac{5 \cdot W_v \cdot L^4}{384 \cdot E_r \cdot I_{xtotr}}$ $\Delta_{xr1} = 0.47$ in

$\Delta_{allr} := \frac{L}{96}$ $\Delta_{allr} = 0.75$ in Per ASTM Specification E985

$M_{yrmax} := \frac{W_h \cdot L^2}{K_1}$ $M_{yrmax} = 2700$ lb·in

$M_{xrmax} := \frac{W_v \cdot L^2}{K_1}$ $M_{xrmax} = 2700$ lb·in

---

$f_{bry1} := \frac{M_{yrmax}}{S_{yr}}$ $f_{bry1} = 8282$ psi

$f_{brx1} := \frac{M_{xrmax}}{S_{xr}}$ $f_{brx1} = 8282$ psi

Case 2 - Point Load:

$\Delta_{yr2} := \frac{P \cdot L^3}{K_3 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr2} = 0.361$ in

$M_{yrmax2} := \frac{P \cdot L}{K_2}$ $M_{yrmax2} = 2880$ lb·in

$f_{bry2} := \frac{M_{yrmax2}}{S_{yr}}$ $f_{bry2} = 8834$ psi

$F_{bry} := \begin{cases} (F_{bry1} \cdot 1.33) & \text{if IBC} = 1 \\ F_{bry1} & \text{otherwise} \end{cases}$ $F_{bry} = 25000$ psi

Calculation Results:

$Int_{r1} := \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right)$ $Int_{r1} = 0.66$

$Int_{r2} := \frac{f_{bry2}}{F_{bry}}$ $Int_{r2} = 0.35$

$RAILS := \begin{cases} \text{"OK"} & \text{if } \frac{\max(\Delta_{yr1}, \Delta_{xr1}, \Delta_{yr2})}{\Delta_{allr}} \le 1 \wedge \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right) \le 1 \wedge \frac{f_{bry2}}{F_{bry}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ RAILS = "OK"

Post Analysis:

$E_p := E_r$

Guardrail "B" Analysis	SHT B1 B

$$\Delta_{xp1} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp1} = 0.664$ in

$$\Delta_{xp2} := \frac{P \cdot 0.85 \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp2} = 0.376$ in

Max Deflection:

$$\Delta_{tot} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot I_{xp}} + \frac{W_h \cdot L \cdot \left[h^3 - (h - L_{st})^3\right]}{3 \cdot \left[(E_p \cdot I_{xp}) + (E_p \cdot I_{st})\right]}$$ $\boxed{\Delta_{tot} = 1.5}$ in

$$\Delta_{allp} := \frac{h}{12}$$ $\boxed{\Delta_{allp} = 3.29}$ in *Per ASTM E985*

Case 1 - Uniform Load:

$M_{xp} := (W_h \cdot L \cdot h) + W_v \cdot L \cdot \Delta_{tot}$ $M_{xpmax} := 0.5 \cdot M_{xp} \cdot q1 + M_{xp}q2 + M_{xp} \cdot q3$ $M_{xpmax} = 11850$ lb·in

$M_{xp2} := W_h \cdot L \cdot (h - L_{st}) + W_v \cdot L \cdot \Delta_{xp1}$ $M_{xpmax2} := 0.5 \cdot M_{xp2} \cdot q1 + M_{xp2}q2 + M_{xp2} \cdot q3$ $M_{xpmax2} = 8250$ lb·in

Case 2 - Point Load:

$M_{xpmax4} := P \cdot (h - L_{st}) \cdot 0.85$ $M_{xpmax4} = 4675$ lb·in

$M_{xpmax3} := (P \cdot h \cdot 0.85)$ $M_{xpmax3} = 6715$ lb·in

Max Post Stress:

$$f_{bpx} := \frac{\max(M_{xpmax2}, M_{xpmax4})}{S_{xp}}$$ $\boxed{f_{bpx} = 25307}$ psi

$$F_{bpx} := \begin{cases} (F_{bpx1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bpx1} & \text{otherwise} \end{cases}$$ $\boxed{F_{bpx} = 25000}$ psi

Max Post/Stub Combined Stress:

$$f_{bpx2} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{xp}}{(I_{xp} + I_{st}) \cdot S_{xp}}$$ $\boxed{f_{bpx2} = 23282}$ psi

$\boxed{F_{bpx} = 25000}$ psi

Max Stub Stress:

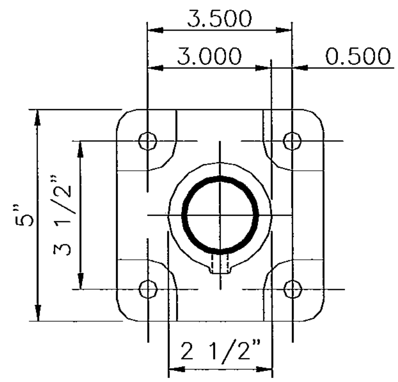
$$f_{bst} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{st}}{(I_{xp} + I_{st}) \cdot S_{st}}$$ $\boxed{f_{bst} = 19018}$ psi

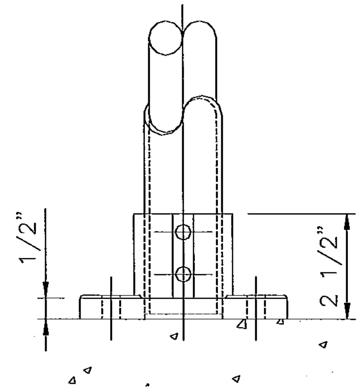
$\boxed{F_{bst} = 25000}$ psi

Calculation Results:

$$Int_{p1} := \max\left(\frac{f_{bpx}}{F_{bpx}}, \frac{f_{bpx2}}{F_{bpx}}, \frac{f_{bst}}{F_{bst}}\right)$$ $Int_{p1} = 1.01$ *1% Over OK*

$$POSTS := \begin{cases} \text{"OK"} & \text{if } Int_{p1} \le 1.014 \wedge \frac{\max(\Delta_{xp1}, \Delta_{xp2}, \Delta_{tot})}{\Delta_{allp}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$$ $\boxed{POSTS = \text{"OK"}}$





$R_{max} := 300$ lb

$M_{max} := 11850 + R_{max} \cdot 2.5 = 12600$ lb·in

$d := 2.5$ in (sleeve dia.)

Chk shear on shoe wall:

$P := \frac{M_{max}}{0.85 \cdot (2.375)}$ $P = 6241$ lb

$f_v := \frac{(P + R_{max})}{2 \cdot (0.315) \cdot (2)}$ $f_v = 5192$ psi

$F_v := \frac{0.57 \cdot (18000)}{1.65}$ $F_v = 6218$ psi

$I := \frac{f_v}{F_v}$ $I = 0.83$ Shear Stress "OK"

Chk Anchor Bolts (assume f'c=4,000 psi conc.):

$V_b := \frac{R_{max}}{4}$ $V_b = 75$ lb

$T_b := \frac{M_{max}}{(L1 - D2) \cdot 0.85 \cdot 2}$ $T_b = 1744$ lb

See Next Sheet for Calculation

Use (4) - 1/2" Dia. S.S. Threaded Rods
W/ Hilti HIT-RE 500 Epoxy Adhesive
Embedment= 3-1/2" min.
Edge Distance= 2-1/4" min.
End Distance = 3"

Chk Aluminum Base Plate:

$L1 := 5$ in $D1 := 0.75$ in

$L2 := 5$ in $D2 := 0.75$ in

$L := L2 - (2 \cdot D2)$ $L = 3.5$ in

$F_y := \frac{1.3 \cdot (18000)}{1.65}$ $F_y = 14182$ psi

$P := \frac{M_{max}}{d \cdot 2}$ $P = 2520$ lb

$M_{pl} := \frac{P \cdot 0.5 \cdot 3^2}{3.5^2}$ $M_{pl} = 926$ in·lb

$t_{req} := \sqrt{\frac{M_{pl} \cdot 6}{F_y \cdot 5}}$ $t_{req} = 0.28$ in

$I := \frac{t_{req}}{0.5}$ $I = 0.56$ Bending Stress "OK"

Use Cast Aluminum Base, as shown
535 casting alloy, Fu= 35 ksi min.

Hilti HIT-RE 500 Epoxy Adjustment for Embed Depth:

Hilti Adhesive	SHT B3

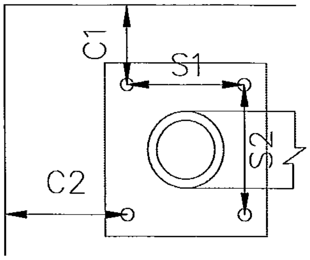
$h_{ef} := 3.5$ in embedment

$s_1 := 3.5$ in spacing 1

$s_2 := 3.5$ in spacing 2

$c_1 := 2.25$ in edge distance 1

$c_2 := 3$ in edge distance 2



Reactions Per Bolt:

$V := 75$ lb shear

$T := 1744$ lb tension

From HILTI Design Guide:

$T_{upper} := 5275$	lb		$h_{efu} := 4.5$	in	
$T_{lower} := 1965$	lb		$h_{efl} := 2.25$	in	
$V_{upper} := 7935$	lb		$h_{efu} = 4.5$	in	
$V_{lower} := 3550$	lb		$h_{efl} = 2.25$	in	

Use (4) - 1/2" Dia. S.S. Threaded Rods
W/ Hilti HIT-RE 500 Epoxy Adhesive
Embedment= 3-1/2" min.
Edge Distance= 2-1/4" min.
End Distance = 3"

Calculations below this line are automatic

$$T_{all} := \frac{(T_{upper} - T_{lower})\cdot(h_{efu} - h_{ef}) - T_{upper}\cdot(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$T_{all} = 3804$ lb Interpolated Tension Value

$$V_{all} := \frac{(V_{upper} - V_{lower})\cdot(h_{efu} - h_{ef}) - V_{upper}\cdot(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$V_{all} = 5986$ lb Interpolated Shear Value

$$f_{AN1} := \begin{cases} 1.00 & \text{if } s_1 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{s_1}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > s_1 > 0.5\cdot h_{ef} \\ \text{"Increase Spacing"} & \text{otherwise} \end{cases}$$

$f_{AN1} = 0.85$ Spacing (Tension and Shear)

$$f_{AN2} := \begin{cases} 1.00 & \text{if } s_2 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{s_2}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > s_2 > 0.5\cdot h_{ef} \\ \text{"Increase Spacing"} & \text{otherwise} \end{cases}$$

$f_{AN2} = 0.85$ Spacing (Tension and Shear)

$$f_{RN} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{c_1}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RN} = 0.74$ Edge Distance (Tension)

$$f_{RV1} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.54\cdot\left(\frac{c_1}{h_{ef}}\right) - 0.09\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RV1} = 0.26$ Edge Distance (Shear Perpendicular to Edge)

$$f_{RV2} := \begin{cases} 1.00 & \text{if } c_2 \ge 1.5\cdot h_{ef} \\ \left[0.36\cdot\left(\frac{c_2}{h_{ef}}\right) + 0.28\right] & \text{if } 1.5h_{ef} > c_2 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RV2} = 0.59$ Edge Distance (Shear Parallel or Away from Edge)

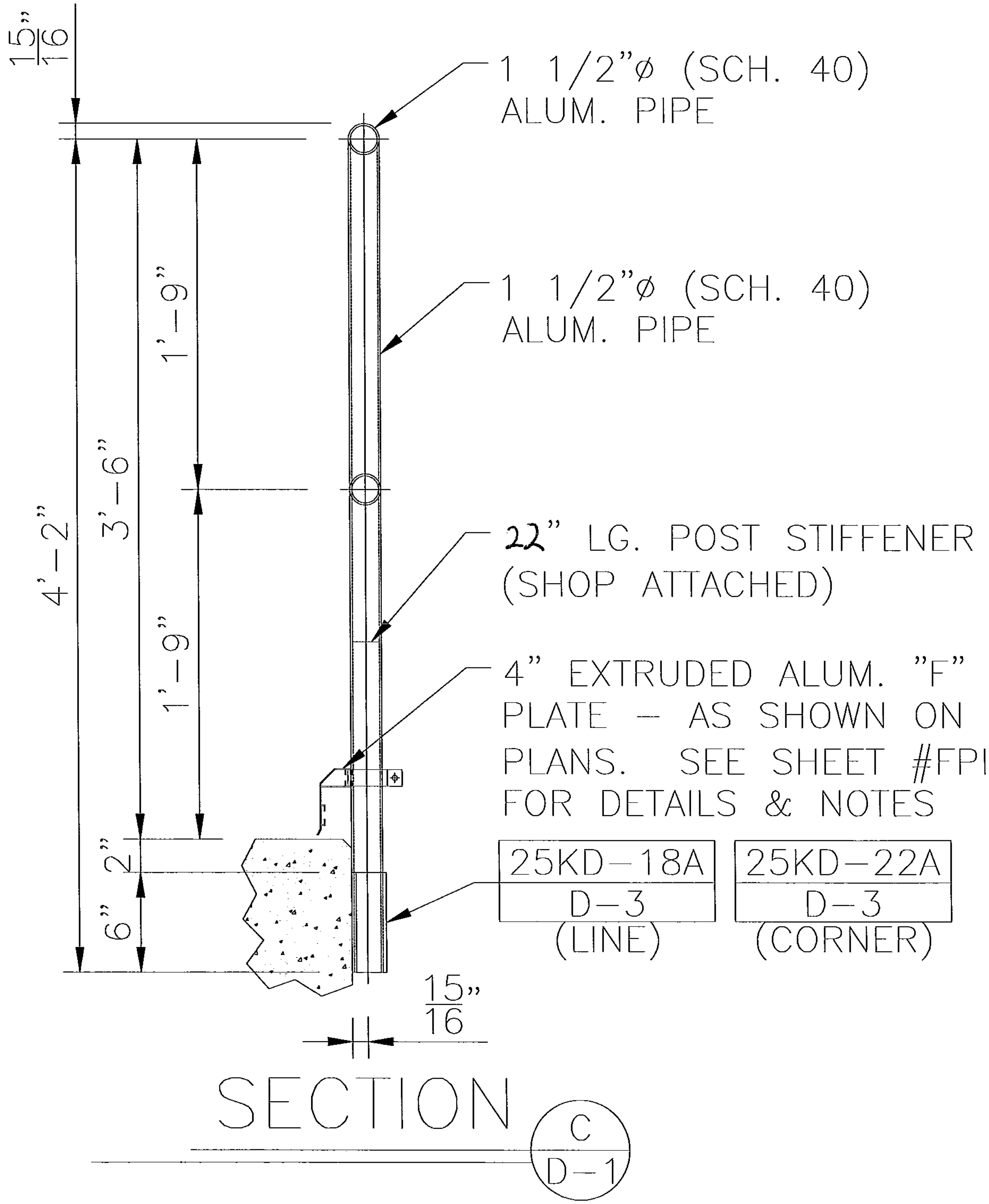
$V_{ball} := V_{all}\cdot f_{AN1}\cdot f_{AN2}\cdot f_{RV1}\cdot f_{RV2}$ $V_{ball} = 655$ lb

$T_{ball} := T_{all}\cdot f_{AN1}\cdot f_{RN}$ $T_{ball} = 2402$ lb

$$I_b := \left(\frac{V}{V_{ball}}\right)^{1.67} + \left(\frac{T}{T_{ball}}\right)^{1.67}$$

$\boxed{I_b = 0.61} < 1.00$

Guardrail "C"	SHT C



Note: *Structural steel, Concrete, CMU and all other anchorage substrates designed by others*

ROCKY MOUNTAIN RAILINGS

RICE ENGINEERING	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
			Engineer: JDB	Sheet No: C
			Date: 2/23/11	Rev:
Template: REI-MC-5707			Chk By:	Date:

Pipe Railing & Post

These calculations are based on emperical test data performed by Julius Blum & Co., Inc.

Guardrail "C" Analysis	SHT C1

Input Variables:

$F_H := 50$ plf Load Case 1 (Uniform Load)

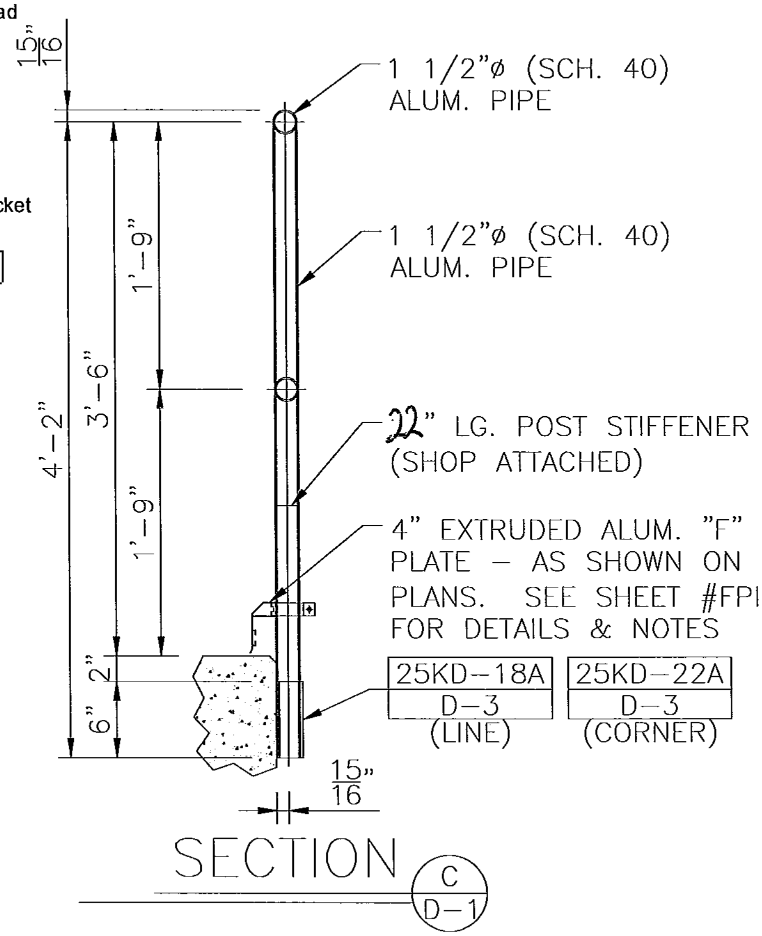
$F_V := 0$ plf Simultaneous Vertical Uniform Load

$P := 200$ lb Load Case 2 (Point Load)

$L_{bp} := 23$ in Unbraced Length of Post

$h := 44$ in Railing Height Above Anchor Bracket

$L := 72$ in **6'-0" MAX POST SPACING**



Number of Railing Spans:

- [x] 1 span
- [x] 2 span
- [x] 3 or more spans

Railing Section:

- [ ] 1 1/4" Schd. 40
- [ ] 1 1/4" Schd. 80
- [x] 1 1/2" Schd. 40
- [ ] 1 1/2" Schd. 80
- [ ] 1 1/2" tube
- [ ] 2" Schd. 40
- [ ] 2" Schd. 80

Post Section:

- [ ] 1 1/4" Schd. 40
- [ ] 1 1/4" Schd. 80
- [x] 1 1/2" Schd. 40
- [ ] 1 1/2" Schd. 80
- [ ] 1 1/2" tube
- [ ] 2" Schd. 40
- [ ] 2" Schd. 80

Railing Temper:

- [ ] 6063-T5
- [ ] 6063-T6
- [x] 6061-T6 or 6105-T5
- [ ] *4/3 increase allowed*

Post Temper:

- [ ] 6063-T6
- [ ] 6005-T5
- [x] 6061-T6 or 6105-T5
- [ ] Post Welded to Base Plate

All calculations below this line are automatic

Railing Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

Post Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

$S_{R1} := \frac{R_r}{t_r}$ $S_{R1} = 6.55$

$S_{R3} := \frac{R_p}{t_p}$ $S_{R3} = 6.55$

Computational Factors

$K_1 := (8 \cdot q1) + (8 \cdot q2) + (9.5 \cdot q3)$ $K_1 = 8$

$K_2 := (4 \cdot q1) + (5 \cdot q2) + (5 \cdot q3)$ $K_2 = 5$

$K_3 := (48 \cdot q1) + (66 \cdot q2) + (87 \cdot q3)$ $K_3 = 66$

$E_r := 10100000$ psi

$I_{xtotr} := I_{xr}$ $I_{xtotr} = 0.31$ in^4 $I_{xtotp} := I_{xp}$ $I_{xtotp} = 0.31$ in^4

$I_{ytotr} := I_{yr}$ $I_{ytotr} = 0.31$ in^4 $I_{ytotp} := I_{yp}$ $I_{ytotp} = 0.31$ in^4

22" Min. Length AL. Ribbed Tube Stub

$I_{st} := 0.174$ in^4 $L_{st} := 16$ in

$S_{st} := 0.224$ in^3 $F_{bst} := 25000$ psi

Railing Analysis:

$W_h := \frac{F_H}{12}$ $W_v := \frac{F_V}{12}$

Guardrail "C" Analysis	SHT C1 A

Case 1 Uniform Load:

$\Delta_{yr1} := \frac{5 \cdot W_h \cdot L^4}{384 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr1} = 0.466$ in Modeled as a simple span

$\Delta_{xr1} := \frac{5 \cdot W_v \cdot L^4}{384 \cdot E_r \cdot I_{xtotr}}$ $\Delta_{xr1} = 0$ in

$\Delta_{allr} := \frac{L}{96}$ $\Delta_{allr} = 0.75$ in Per ASTM Specification E985

$M_{yrmax} := \frac{W_h \cdot L^2}{K_1}$ $M_{yrmax} = 2700$ lb·in

$M_{xrmax} := \frac{W_v \cdot L^2}{K_1}$ $M_{xrmax} = 0$ lb·in

---

$f_{bry1} := \frac{M_{yrmax}}{S_{yr}}$ $f_{bry1} = 8282$ psi

$f_{brx1} := \frac{M_{xrmax}}{S_{xr}}$ $f_{brx1} = 0$ psi

Case 2 - Point Load:

$\Delta_{yr2} := \frac{P \cdot L^3}{K_3 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr2} = 0.361$ in

$M_{yrmax2} := \frac{P \cdot L}{K_2}$ $M_{yrmax2} = 2880$ lb·in

$f_{bry2} := \frac{M_{yrmax2}}{S_{yr}}$ $f_{bry2} = 8834$ psi

$F_{bry} := \begin{cases} (F_{bry1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bry1} & \text{otherwise} \end{cases}$ $\boxed{F_{bry} = 25000}$ psi

Calculation Results:

$Int_{r1} := \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right)$ $Int_{r1} = 0.33$

$Int_{r2} := \frac{f_{bry2}}{F_{bry}}$ $Int_{r2} = 0.35$

$RAILS := \begin{cases} \text{"OK"} & \text{if } \frac{\max(\Delta_{yr1}, \Delta_{xr1}, \Delta_{yr2})}{\Delta_{allr}} \le 1 \wedge \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right) \le 1 \wedge \frac{f_{bry2}}{F_{bry}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ $\boxed{RAILS = \text{"OK"}}$

Post Analysis:

$E_p := E_r$

Guardrail "C" Analysis	SHT C1 B

$$\Delta_{xp1} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp1} = 0.701$ in

$$\Delta_{xp2} := \frac{P \cdot 0.85 \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp2} = 0.397$ in

Max Deflection:

$$\Delta_{tot} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot I_{xp}} + \frac{W_h \cdot L \cdot \left[h^3 - (h - L_{st})^3\right]}{3 \cdot \left[(E_p \cdot I_{xp}) + (E_p \cdot I_{st})\right]}$$ $\boxed{\Delta_{tot} = 1.995}$ in

$$\Delta_{allp} := \frac{h}{12}$$ $\boxed{\Delta_{allp} = 3.67}$ in *Per ASTM E985*

Case 1 - Uniform Load:

$M_{xp} := (W_h \cdot L \cdot h) + W_v \cdot L \cdot \Delta_{tot}$ $M_{xpmax} := 0.5 \cdot M_{xp} \cdot q1 + M_{xp}q2 + M_{xp} \cdot q3$ $M_{xpmax} = 13200$ lb·in

$M_{xp2} := W_h \cdot L \cdot (h - L_{st}) + W_v \cdot L \cdot \Delta_{xp1}$ $M_{xpmax2} := 0.5 \cdot M_{xp2} \cdot q1 + M_{xp2}q2 + M_{xp2} \cdot q3$ $M_{xpmax2} = 8400$ lb·in

Case 2 - Point Load:

$M_{xpmax4} := P \cdot (h - L_{st}) \cdot 0.85$ $M_{xpmax4} = 4760$ lb·in

$M_{xpmax3} := (P \cdot h \cdot 0.85)$ $M_{xpmax3} = 7480$ lb·in

Max Post Stress:

$$f_{bpx} := \frac{\max(M_{xpmax2}, M_{xpmax4})}{S_{xp}}$$ $\boxed{f_{bpx} = 25767}$ psi

$$F_{bpx} := \begin{cases} (F_{bpx1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bpx1} & \text{otherwise} \end{cases}$$ $\boxed{F_{bpx} = 25000}$ psi

Max Post/Stub Combined Stress:

$$f_{bpx2} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{xp}}{(I_{xp} + I_{st}) \cdot S_{xp}}$$ $\boxed{f_{bpx2} = 25934}$ psi

$\boxed{F_{bpx} = 25000}$ psi

Max Stub Stress:

$$f_{bst} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{st}}{(I_{xp} + I_{st}) \cdot S_{st}}$$ $\boxed{f_{bst} = 21185}$ psi

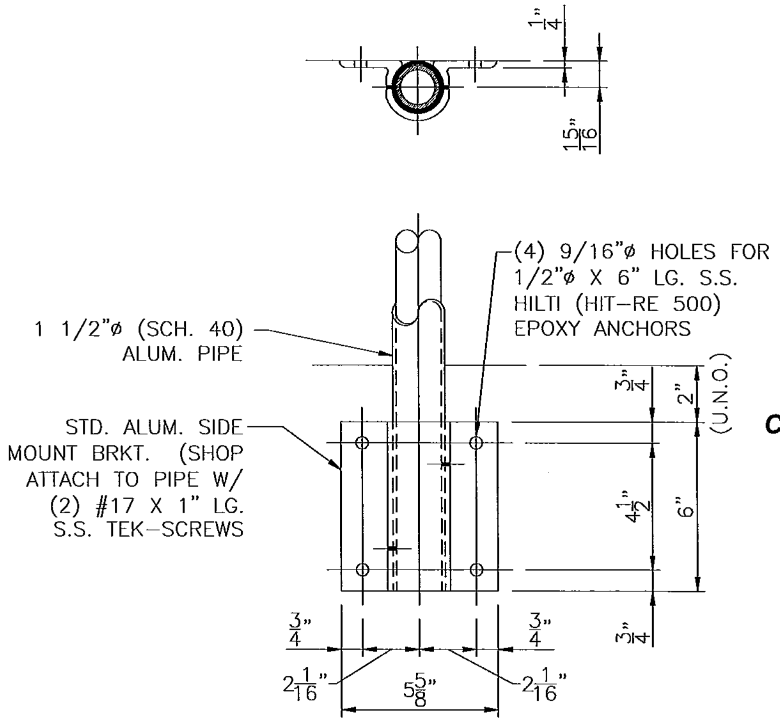
$\boxed{F_{bst} = 25000}$ psi

Calculation Results:

$$Int_{p1} := \max\left(\frac{f_{bpx}}{F_{bpx}}, \frac{f_{bpx2}}{F_{bpx}}, \frac{f_{bst}}{F_{bst}}\right)$$ $Int_{p1} = 1.04$ *4% Over OK*

$$POSTS := \begin{cases} \text{"OK"} & \text{if } Int_{p1} \le 1.04 \wedge \frac{\max(\Delta_{xp1}, \Delta_{xp2}, \Delta_{tot})}{\Delta_{allp}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$$ $\boxed{POSTS = \text{"OK"}}$

Side Mount Anchorage	SHT C2



CONC. SIDE MOUNT 4-HOLE

25KD-18A

$R_{max} := 300$ lb

$M_{max} := 13200 + R_{max} \cdot 3 = 14100$ lb·in

$L1 := 6$ in

$L2 := 5.25$ in

Chk Extruded Aluminum Bracket:

$P := \frac{M_{max}}{L1} + R_{max}$ $P = 2650$ lb

$M_{pl} := \frac{P}{2} \cdot 0.688$ $M_{pl} = 912$ in·lb

$t_{req} := \sqrt{\frac{6 \cdot M_{pl}}{28000 \cdot L1}}$ $t_{req} = 0.18$ in

$I := \frac{t_{req}}{0.25}$ $I = 0.72$

Use Side Mount Bracket, As Shown
6105-T5 alloy

Chk Anchor Bolts: (Assume f'c = 4000 psi Conc.)

$V_b := \frac{R_{max}}{4}$ $V_b = 75$ lb

$T_b := \frac{M_{max}}{L2 \cdot 2 \cdot 0.85} + \frac{R_{max}}{4}$ $T_b = 1655$ lb

See Next Sheet for Calculation

Use (4) - 1/2" Dia. S.S. Threaded Rods
With Hilti HIT-RE 500 Epoxy Adhesive
Embedment = 3-1/2" (min.)
Edge = 2-3/4"
End = 3"

Chk TEK Screws:

$V := \frac{R_{max}}{(2)}$ $V = 150$ lb

$V_{all} := 2148 \cdot 0.333$ $V_{all} = 715$ lb

$I_2 := \left(\frac{V}{V_{all}}\right)$ $I_2 = 0.21$ < 1.0

Use (2) - #17 S.S. TEK Screws
300 Series S.S.
ITW Buildex or Better

Hilti HIT-RE 500 Epoxy Adjustment for Embed Depth:

Hilti Adhesive	SHT C3

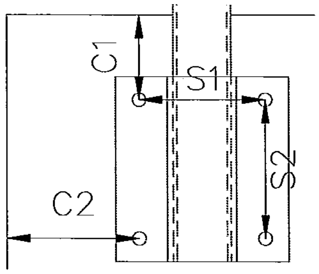
$h_{ef} := 3.5$ in embedment

$s_1 := 4.125$ in spacing 1

$s_2 := 4.5$ in spacing 2

$c_1 := 2.75$ in edge distance 1

$c_2 := 3$ in edge distance 2



Reactions Per Bolt:

$V := 75$ lb shear

$T := 1655$ lb tension

From HILTI Design Guide:

$T_{upper} := 5275$	lb	$h_{efu} := 4.5$	in		
$T_{lower} := 1965$	lb	$h_{efl} := 2.25$	in		
$V_{upper} := 7935$	lb	$h_{efu} = 4.5$	in		
$V_{lower} := 3550$	lb	$h_{efl} = 2.25$	in		

Use (4) - 1/2" Dia. S.S. Threaded Rods
W/ Hilti HIT-RE 500 Epoxy Adhesive
Embedment= 3-1/2" min.
Edge Distance= 2-1/4" min.
End Distance = 3"

Calculations below this line are automatic

$$T_{all} := \frac{(T_{upper} - T_{lower})\cdot(h_{efu} - h_{ef}) - T_{upper}\cdot(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$T_{all} = 3804$ lb Interpolated Tension Value

$$V_{all} := \frac{(V_{upper} - V_{lower})\cdot(h_{efu} - h_{ef}) - V_{upper}\cdot(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$V_{all} = 5986$ lb Interpolated Shear Value

$$f_{AN1} := \begin{cases} 1.00 & \text{if } s_1 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{s_1}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > s_1 > 0.5\cdot h_{ef} \\ \text{"Increase Spacing"} & \text{otherwise} \end{cases}$$

$f_{AN1} = 0.9$ Spacing (Tension and Shear)

$$f_{AN2} := \begin{cases} 1.00 & \text{if } s_2 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{s_2}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > s_2 > 0.5\cdot h_{ef} \\ \text{"Increase Spacing"} & \text{otherwise} \end{cases}$$

$f_{AN2} = 0.94$ Spacing (Tension and Shear)

$$f_{RN} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{c_1}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RN} = 0.79$ Edge Distance (Tension)

$$f_{RV1} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.54\cdot\left(\frac{c_1}{h_{ef}}\right) - 0.09\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RV1} = 0.33$ Edge Distance (Shear Perpendicular to Edge)

$$f_{RV2} := \begin{cases} 1.00 & \text{if } c_2 \ge 1.5\cdot h_{ef} \\ \left[0.36\cdot\left(\frac{c_2}{h_{ef}}\right) + 0.28\right] & \text{if } 1.5h_{ef} > c_2 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RV2} = 0.59$ Edge Distance (Shear Parallel or Away from Edge)

$V_{ball} := V_{all}\cdot f_{AN1}\cdot f_{AN2}\cdot f_{RV1}\cdot f_{RV2}$ $\qquad V_{ball} = 996$ lb

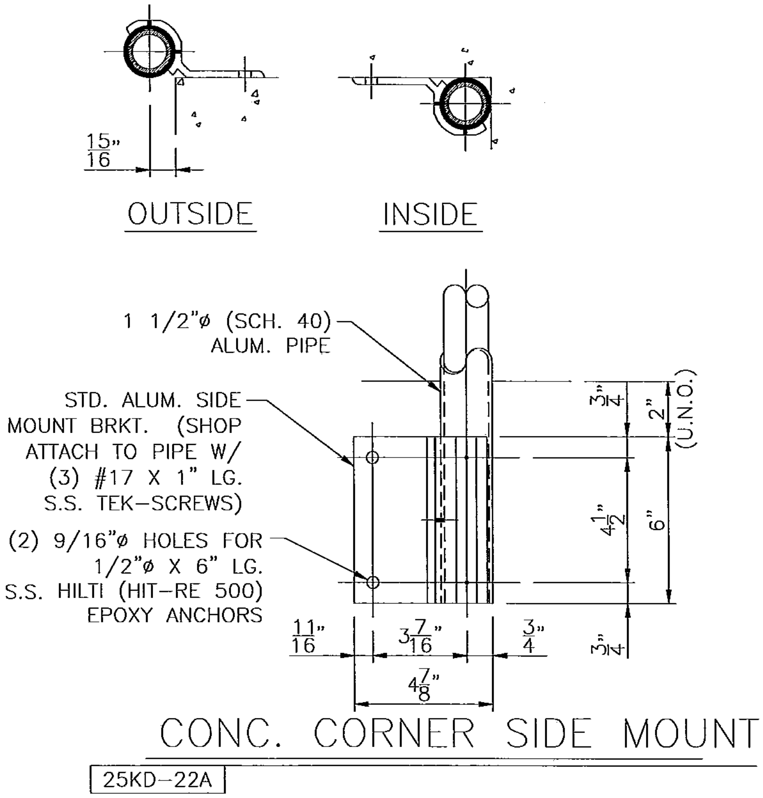
$T_{ball} := T_{all}\cdot f_{AN1}\cdot f_{RN}$ $\qquad T_{ball} = 2701$ lb

$$I_b := \left(\frac{V}{V_{ball}}\right)^{1.67} + \left(\frac{T}{T_{ball}}\right)^{1.67}$$

$\boxed{I_b = 0.45} < 1.00$

RICE ENGINEERING Template:	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
			Engineer: JDB	Sheet No: C3
			Date: 2/23/11	Rev:
			Chk By:	Date:

Corner Side Mount Anchorage	SHT C4



$R_{max} := 97$ lb — *Reactions from RISA Model*

$M_{max} := 0$ lb·in — *(Corner Post Modeled as a Pin Connection)*

$L1 := 6$ in

$L2 := 5.25$ in

Chk Extruded Aluminum Bracket:

$P := \frac{M_{max}}{L1} + R_{max}$ $\quad P = 97$ lb

$M_{pl} := \frac{P}{2} \cdot 0.688$ $\quad M_{pl} = 33$ in·lb

$t_{req} := \sqrt{\frac{6 \cdot M_{pl}}{28000 \cdot L1}}$ $\quad t_{req} = 0.03$ in

$I := \frac{t_{req}}{0.25}$ $\quad I = 0.14$

Use Side Mount Bracket, As Shown
6105-T5 alloy

Chk Anchor Bolts: (Assume f'c = 4000 psi Conc.)

$V_b := \frac{R_{max}}{2}$ $\quad V_b = 49$ lb

$T_b := \frac{M_{max}}{L2 \cdot 1 \cdot 0.85} + \frac{R_{max}}{2}$ $\quad T_b = 49$ lb

See Next Sheet for Calculation

Use (2) - 1/2" Dia. S.S. Threaded Rods
W/ Hilti HIT-RE 500 Epoxy Adhesive
Embedment= 3-1/2" min.
Edge Distance= 2-3/4" min.
End Distance = 2-1/2"

Chk TEK Screws:

$V := \frac{R_{max}}{(3)}$ $\quad V = 32$ lb

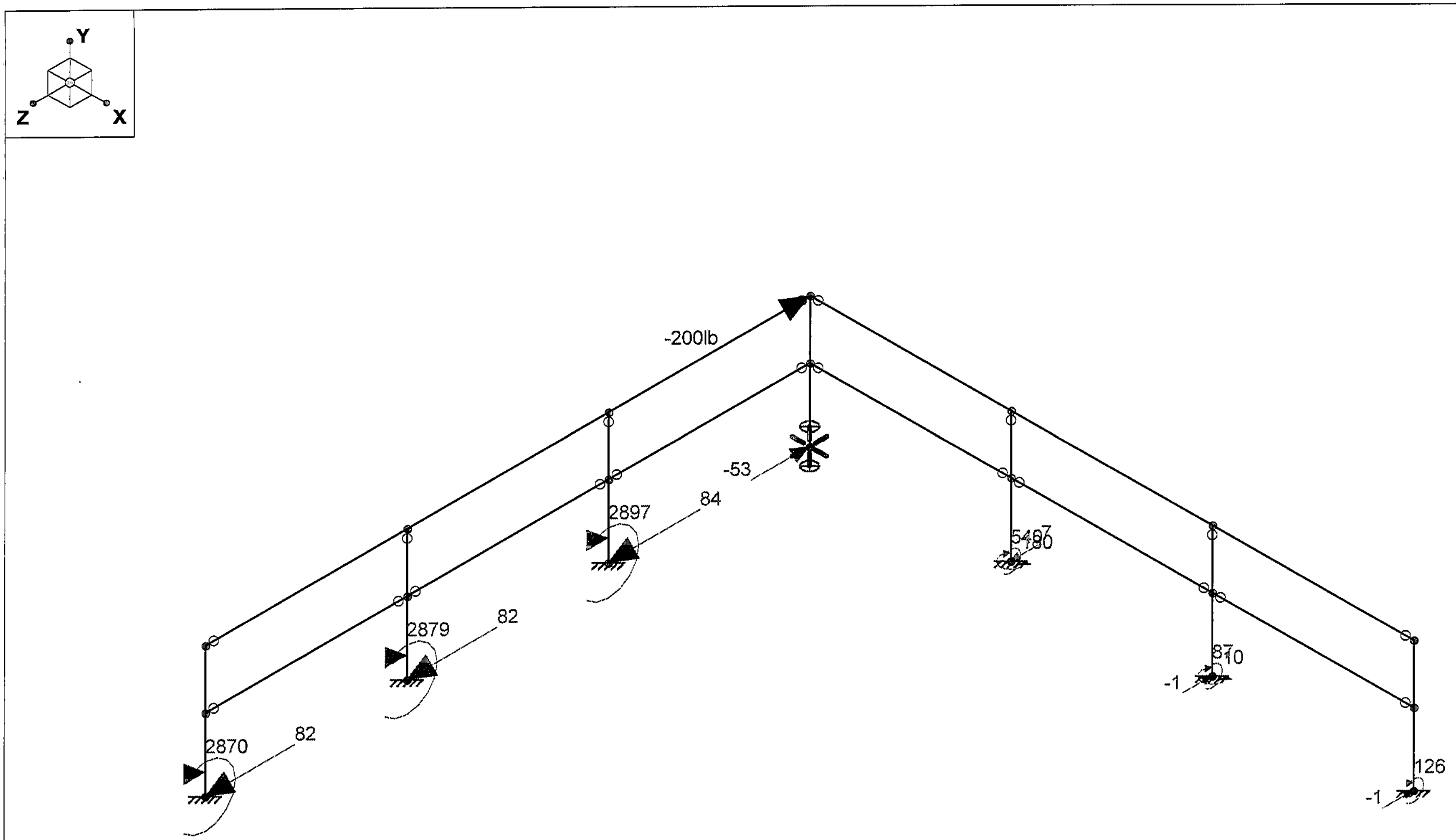
$V_{all} := 2148 \cdot 0.333$ $\quad V_{all} = 715$ lb

$T := \frac{M_{max}}{L2} + \frac{R_{max}}{(2)}$ $\quad T = 49$ lb

$T_{all} := 2065 \cdot 0.33$ $\quad T_{all} = 681$ lb

$I_2 := \left(\frac{V}{V_{all}}\right)^2 + \left(\frac{T}{T_{all}}\right)^2$ $\quad I_2 = 0.01$ < 1.0

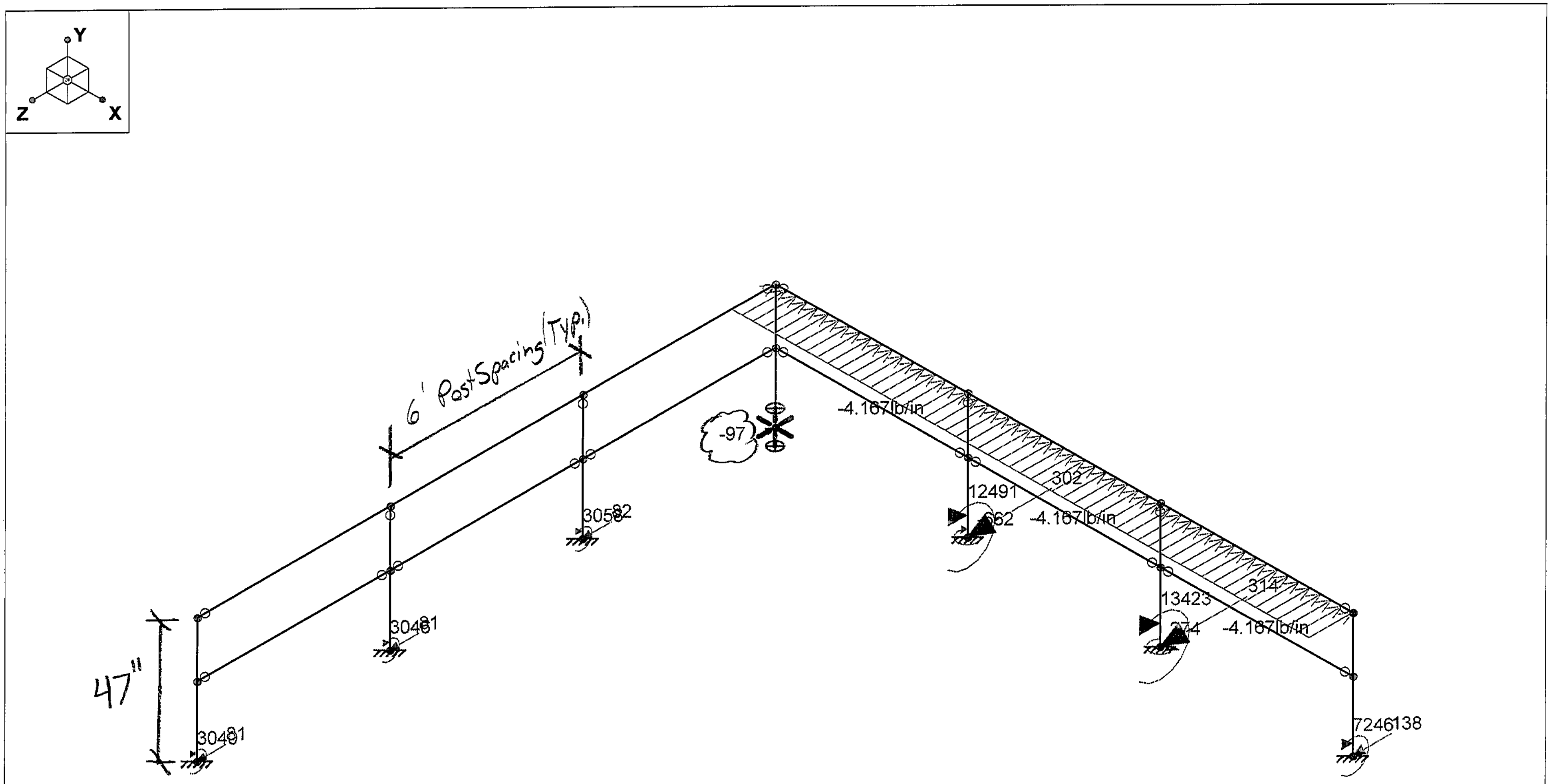
Use (3) - #17 S.S. TEK Screws
300 Series S.S.
ITW Buildex or Better



Loads: BLC 2,
Results for LC 2, Point
Z-moment Reaction units are lb and lb-in

Rice Engineering	R0001 - RMR Standard Calcs	SK - 4
Joe Bauer		Feb 23, 2011 at 4:51 PM
R11-02-15H		Corner Brackets.r3d

C4.1



Loads: BLC 1,
Results for LC 1, Dist 1
Z-moment Reaction units are lb and lb-in

Rice Engineering	R0001 - RMR Standard Calcs	SK - 5
Joe Bauer		Feb 23, 2011 at 4:51 PM
R11-02-15H		Corner Brackets.r3d

C4.2

Hilti HIT-RE 500 Epoxy Adjustment for Embed Depth:

Hilti Adhesive	SHT C5

$h_{ef} := 3.5$ in embedment

$s_2 := 4.5$ in spacing 2

$c_1 := 2.75$ in edge distance 1

$c_2 := 2.5$ in edge distance 2

Reactions Per Bolt:

$V := 49$ lb shear

$T := 49$ lb tension

From HILTI Design Guide:

$T_{upper} := 5275$	lb		$h_{efu} := 4.5$	in	
$T_{lower} := 1965$	lb		$h_{efl} := 2.25$	in	
$V_{upper} := 7935$	lb		$h_{efu} = 4.5$	in	
$V_{lower} := 3550$	lb		$h_{efl} = 2.25$	in	

Use (2) - 1/2" Dia. S.S. Threaded Rods
W/ Hilti HIT-RE 500 Epoxy Adhesive
Embedment= 3-1/2" min.
Edge Distance= 2-3/4" min.
End Distance = 2-1/2"

Calculations below this line are automatic

$$T_{all} := \frac{(T_{upper} - T_{lower})\cdot(h_{efu} - h_{ef}) - T_{upper}\cdot(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$T_{all} = 3804$ lb Interpolated Tension Value

$$V_{all} := \frac{(V_{upper} - V_{lower})\cdot(h_{efu} - h_{ef}) - V_{upper}\cdot(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$V_{all} = 5986$ lb Interpolated Shear Value

$f_{AN1} := 1.0$

$f_{AN1} = 1$ Spacing (Tension and Shear)

$$f_{AN2} := \begin{cases} 1.00 & \text{if } s_2 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{s_2}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > s_2 > 0.5\cdot h_{ef} \\ \text{"Increase Spacing"} & \text{otherwise} \end{cases}$$

$f_{AN2} = 0.94$ Spacing (Tension and Shear)

$$f_{RN} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{c_1}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RN} = 0.79$ Edge Distance (Tension)

$$f_{RV1} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.54\cdot\left(\frac{c_1}{h_{ef}}\right) - 0.09\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RV1} = 0.33$ Edge Distance (Shear Perpendicular to Edge)

$$f_{RV2} := \begin{cases} 1.00 & \text{if } c_2 \ge 1.5\cdot h_{ef} \\ \left[0.36\cdot\left(\frac{c_2}{h_{ef}}\right) + 0.28\right] & \text{if } 1.5h_{ef} > c_2 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

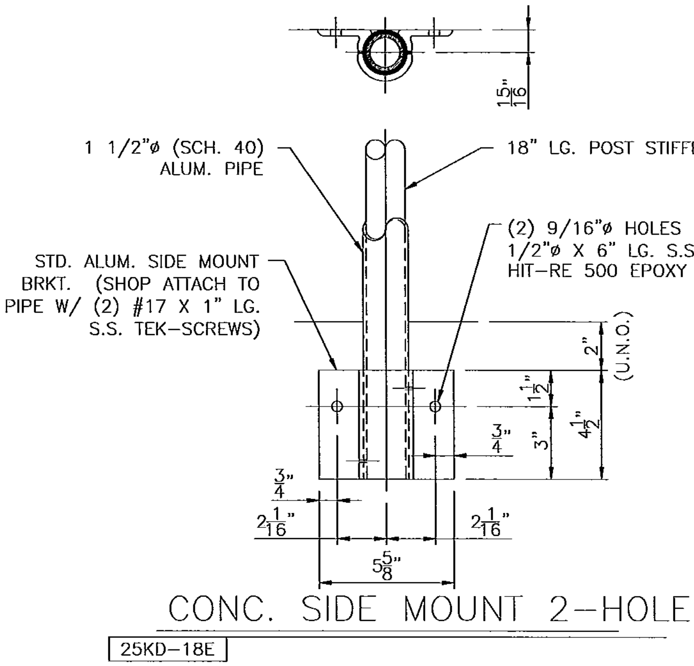
$f_{RV2} = 0.54$ Edge Distance (Shear Parallel or Away from Edge)

$V_{ball} := V_{all}\cdot f_{AN1}\cdot f_{AN2}\cdot f_{RV1}\cdot f_{RV2}$ $V_{ball} = 1006$ lb

$T_{ball} := T_{all}\cdot f_{AN1}\cdot f_{RN}$ $T_{ball} = 2989$ lb

$$I_b := \left(\frac{V}{V_{ball}}\right)^{1.67} + \left(\frac{T}{T_{ball}}\right)^{1.67}$$

$\boxed{I_b = 0.01} < 1.00$



$R_{max} := 300$ lb

$M_{max} := 13200 + R_{max} \cdot 3 = 14100$ lb·in

$L1 := 4.5$ in

$L2 := 3$ in

Chk Extruded Aluminum Bracket:

$P := \frac{M_{max}}{L1} + R_{max}$ $\qquad P = 3433$ lb

$M_{pl} := \frac{P}{2} \cdot 0.688$ $\qquad M_{pl} = 1181$ in·lb

$t_{req} := \sqrt{\frac{6 \cdot M_{pl}}{28000 \cdot L1}}$ $\qquad t_{req} = 0.24$ in

$I := \frac{t_{req}}{0.25}$ $\qquad I = 0.95$

Use Side Mount Bracket, As Shown
6105-T5 alloy

Chk Anchor Bolts: (Assume f'c = 4000 psi Conc.)

Uniform Load

$V_b := \frac{R_{max}}{2}$ $\qquad V_b = 150$ lb

$T_b := \frac{M_{max}}{L2 \cdot 2 \cdot 0.85} + \frac{R_{max}}{2}$ $\qquad T_b = 2915$ lb

Concentrated Load

$V_{b2} := \frac{200 \cdot 0.85}{2}$ $\qquad V_{b2} = 85$ lb

$T_{b2} := \frac{200 \cdot 0.85 \cdot 47}{1.5 \cdot 2 \cdot 0.85} + \frac{200 \cdot 0.85}{2}$ $\qquad T_{b2} = 3218$ lb

See Next Sheet for Calculation

Use (2) - 1/2" Dia. S.S. Threaded Rods
With Hilti HIT-RE 500 Epoxy Adhesive
Embedment = 4-1/2"
Edge = 3-1/2"
End = 3"

Chk TEK Screws:

$V := \frac{R_{max}}{(2)}$ $\qquad V = 150$ lb

$V_{all} := 2148 \cdot 0.333$ $\qquad V_{all} = 715$ lb

$I_2 := \left(\frac{V}{V_{all}}\right)$ $\qquad I_2 = 0.21$ < 1.0

Use (2) - #17 S.S. TEK Screws
300 Series S.S.
ITW Buildex or Better

Hilti HIT-RE 500 Epoxy Adjustment for Embed Depth:

Hilti Adhesive	SHT C7

$h_{ef} := 4.5$ in embedment

$s_1 := 4.125$ in spacing 1

$c_1 := 3.5$ in edge distance 1

$c_2 := 3$ in edge distance 2

Reactions Per Bolt:

$V := 85$ lb shear

$T := 3218$ lb tension

From HILTI Design Guide:

$T_{upper} := 5275$	lb	$h_{efu} := 4.5$	in		
$T_{lower} := 1965$	lb	$h_{efl} := 2.25$	in		
$V_{upper} := 7935$	lb	$h_{efu} = 4.5$	in		
$V_{lower} := 3550$	lb	$h_{efl} = 2.25$	in		

Use (2) - 1/2" Dia. S.S. Threaded Rods
W/ Hilti HIT-RE 500 Epoxy Adhesive
Embedment= 3-1/2" min.
Edge Distance= 2-1/4" min.
End Distance = 3"

Calculations below this line are automatic

$$T_{all} := \frac{(T_{upper} - T_{lower})\cdot(h_{efu} - h_{ef}) - T_{upper}(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$T_{all} = 5275$ lb Interpolated Tension Value

$$V_{all} := \frac{(V_{upper} - V_{lower})\cdot(h_{efu} - h_{ef}) - V_{upper}(h_{efu} - h_{efl})}{-(h_{efu} - h_{efl})}$$

$V_{all} = 7935$ lb Interpolated Shear Value

$$f_{AN1} := \begin{cases} 1.00 & \text{if } s_1 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{s_1}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > s_1 > 0.5\cdot h_{ef} \\ \text{"Increase Spacing"} & \text{otherwise} \end{cases}$$

$f_{AN1} = 0.83$ Spacing (Tension and Shear)

$f_{AN2} := 1.0$

$f_{AN2} = 1$ Spacing (Tension and Shear)

$$f_{RN} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.3\cdot\left(\frac{c_1}{h_{ef}}\right) + 0.55\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RN} = 0.78$ Edge Distance (Tension)

$$f_{RV1} := \begin{cases} 1.00 & \text{if } c_1 \ge 1.5\cdot h_{ef} \\ \left[0.54\cdot\left(\frac{c_1}{h_{ef}}\right) - 0.09\right] & \text{if } 1.5h_{ef} > c_1 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

$f_{RV1} = 0.33$ Edge Distance (Shear Perpendicular to Edge)

$$f_{RV2} := \begin{cases} 1.00 & \text{if } c_2 \ge 1.5\cdot h_{ef} \\ \left[0.36\cdot\left(\frac{c_2}{h_{ef}}\right) + 0.28\right] & \text{if } 1.5h_{ef} > c_2 > 0.5\cdot h_{ef} \\ \text{"Increase Edge Distance"} & \text{otherwise} \end{cases}$$

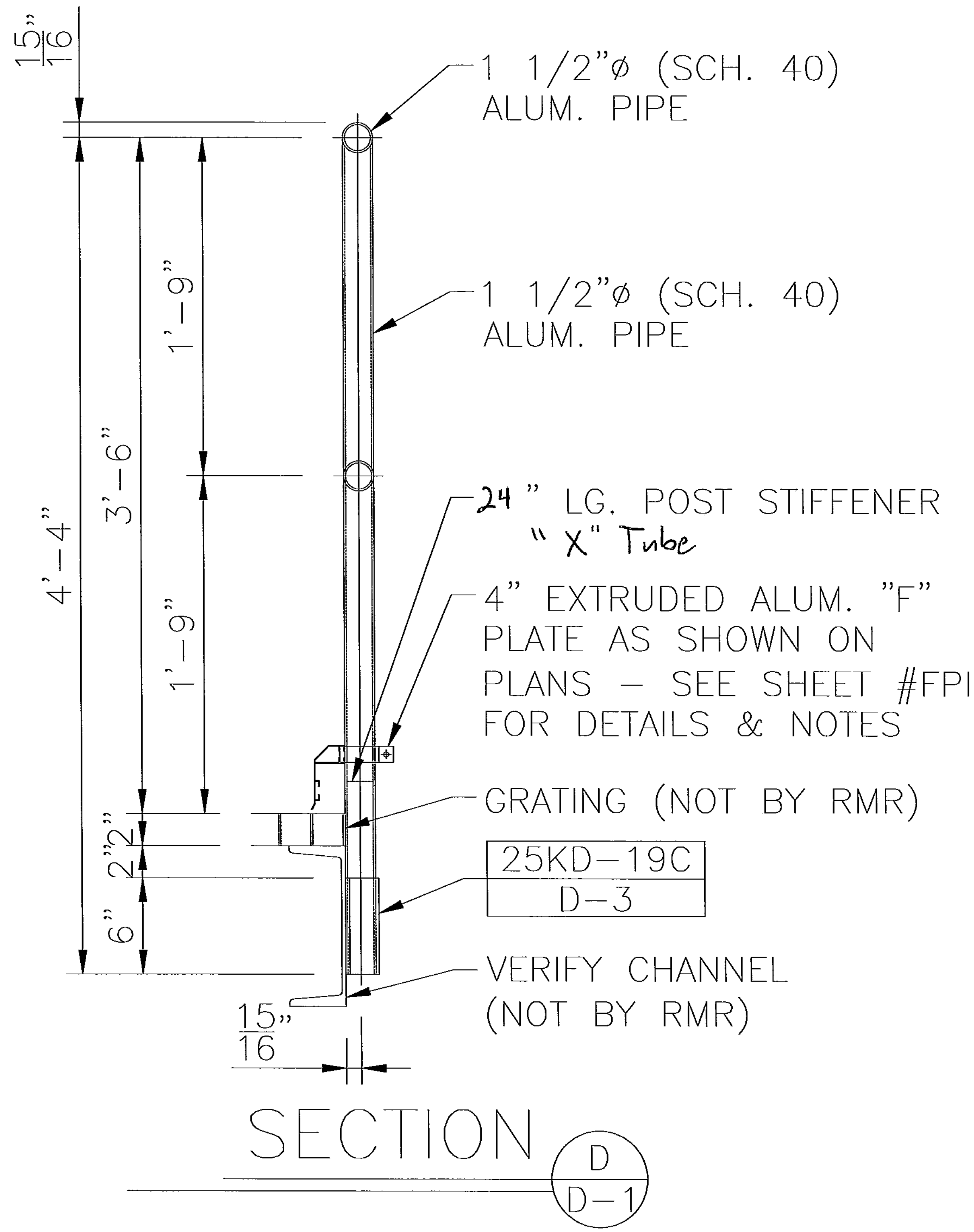
$f_{RV2} = 0.52$ Edge Distance (Shear Parallel or Away from Edge)

$V_{ball} := V_{all}\cdot f_{AN1}\cdot f_{AN2}\cdot f_{RV1}\cdot f_{RV2}$ $V_{ball} = 1123$ lb

$T_{ball} := T_{all}\cdot f_{AN1}\cdot f_{RN}$ $T_{ball} = 3409$ lb

$$I_b := \left(\frac{V}{V_{ball}}\right)^{1.67} + \left(\frac{T}{T_{ball}}\right)^{1.67}$$

$I_b = 0.92$ < 1.00



Note: *Structural steel, Concrete, CMU and all other anchorage substrates designed by others*

ROCKY MOUNTAIN RAILINGS

RICE ENGINEERING Template: REI-MC-5707	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
			Engineer: JDB	Sheet No: D
			Date: 2/23/11	Rev:
			Chk By:	Date:

Pipe Railing & Post

These calculations are based on emperical test data performed by Julius Blum & Co., Inc.

Guardrail "D" Analysis	SHT D1

Input Variables:

$F_H := 50$ plf — Load Case 1 (Uniform Load)

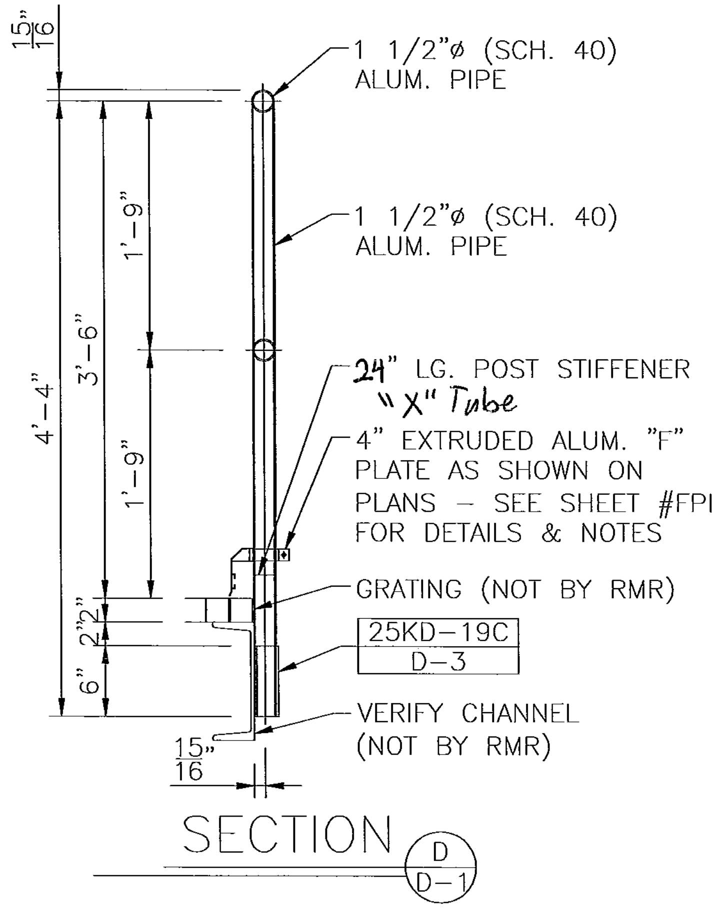
$F_V := 0$ plf — Simultaneous Vertical Uniform Load

$P := 200$ lb — Load Case 2 (Point Load)

$L_{bp} := 25$ in — Unbraced Length of Post

$h := 46$ in — Railing Height Above Anchor Bracket

$L := 72$ in — **6'-0" MAX POST SPACING**



Number of Railing Spans:

- [x] 1 span
- [x] 2 span
- [x] 3 or more spans

Railing Section:

- [ ] 1 1/4" Schd. 40
- [ ] 1 1/4" Schd. 80
- [x] 1 1/2" Schd. 40
- [ ] 1 1/2" Schd. 80
- [ ] 1 1/2" tube
- [ ] 2" Schd. 40
- [ ] 2" Schd. 80

Post Section:

- [ ] 1 1/4" Schd. 40
- [ ] 1 1/4" Schd. 80
- [x] 1 1/2" Schd. 40
- [ ] 1 1/2" Schd. 80
- [ ] 1 1/2" tube
- [ ] 2" Schd. 40
- [ ] 2" Schd. 80

Railing Temper:

- [ ] 6063-T5
- [ ] 6063-T6
- [x] 6061-T6 or 6105-T5
- [ ] *4/3 increase allowed*

Post Temper:

- [ ] 6063-T6
- [ ] 6005-T5
- [x] 6061-T6 or 6105-T5
- [ ] Post Welded to Base Plate

All calculations below this line are automatic

Railing Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

Post Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

$S_{R1} := \frac{R_r}{t_r}$ $S_{R1} = 6.55$

$S_{R3} := \frac{R_p}{t_p}$ $S_{R3} = 6.55$

Computational Factors

$K_1 := (8 \cdot q1) + (8 \cdot q2) + (9.5 \cdot q3)$ $K_1 = 8$

$K_2 := (4 \cdot q1) + (5 \cdot q2) + (5 \cdot q3)$ $K_2 = 5$

$K_3 := (48 \cdot q1) + (66 \cdot q2) + (87 \cdot q3)$ $K_3 = 66$

$E_r := 10100000$ psi

$I_{xtotr} := I_{xr}$ $I_{xtotr} = 0.31$ in^4 $I_{xtotp} := I_{xp}$ $I_{xtotp} = 0.31$ in^4

$I_{ytotr} := I_{yr}$ $I_{ytotr} = 0.31$ in^4 $I_{ytotp} := I_{yp}$ $I_{ytotp} = 0.31$ in^4

24" Min. Length AL. "X" Tube Stub

$I_{st} := 0.249$ in^4 $L_{st} := 18$ in

$S_{st} := 0.311$ in^3 $F_{bst} := 25000$ psi

RICE ENGINEERING	105 School Creek Trail, Luxemburg, WI 54217, Phone: (920)845-1042, Fax: (920)845-1048, www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H
Template: REI-MC-5707			Engineer: JDB — Sheet No: D1
			Date: 2/23/11 — Rev:
			Chk By: — Date:

Railing Analysis:

$W_h := \frac{F_H}{12}$ $W_v := \frac{F_V}{12}$

Guardrail "D" Analysis	SHT D1 A

Case 1 Uniform Load:

$\Delta_{yr1} := \frac{5 \cdot W_h \cdot L^4}{384 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr1} = 0.466$ in Modeled as a simple span

$\Delta_{xr1} := \frac{5 \cdot W_v \cdot L^4}{384 \cdot E_r \cdot I_{xtotr}}$ $\Delta_{xr1} = 0$ in

$\Delta_{allr} := \frac{L}{96}$ $\Delta_{allr} = 0.75$ in Per ASTM Specification E985

$M_{yrmax} := \frac{W_h \cdot L^2}{K_1}$ $M_{yrmax} = 2700$ lb·in

$M_{xrmax} := \frac{W_v \cdot L^2}{K_1}$ $M_{xrmax} = 0$ lb·in

---

$f_{bry1} := \frac{M_{yrmax}}{S_{yr}}$ $f_{bry1} = 8282$ psi

$f_{brx1} := \frac{M_{xrmax}}{S_{xr}}$ $f_{brx1} = 0$ psi

Case 2 - Point Load:

$\Delta_{yr2} := \frac{P \cdot L^3}{K_3 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr2} = 0.361$ in

$M_{yrmax2} := \frac{P \cdot L}{K_2}$ $M_{yrmax2} = 2880$ lb·in

$f_{bry2} := \frac{M_{yrmax2}}{S_{yr}}$ $f_{bry2} = 8834$ psi

$F_{bry} := \begin{cases} (F_{bry1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bry1} & \text{otherwise} \end{cases}$ $\boxed{F_{bry} = 25000}$ psi

Calculation Results:

$Int_{r1} := \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right)$ $Int_{r1} = 0.33$

$Int_{r2} := \frac{f_{bry2}}{F_{bry}}$ $Int_{r2} = 0.35$

$RAILS := \begin{cases} \text{"OK"} & \text{if } \frac{\max(\Delta_{yr1}, \Delta_{xr1}, \Delta_{yr2})}{\Delta_{allr}} \le 1 \land \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right) \le 1 \land \frac{f_{bry2}}{F_{bry}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ $\boxed{RAILS = \text{"OK"}}$

Post Analysis:

$E_p := E_r$

Guardrail "D" Analysis	SHT D1 B

$$\Delta_{xp1} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp1} = 0.701$ in

$$\Delta_{xp2} := \frac{P \cdot 0.85 \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp2} = 0.397$ in

Max Deflection:

$$\Delta_{tot} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot I_{xp}} + \frac{W_h \cdot L \cdot \left[h^3 - (h - L_{st})^3\right]}{3 \cdot \left[(E_p \cdot I_{xp}) + (E_p \cdot I_{st})\right]}$$ $\boxed{\Delta_{tot} = 2.036}$ in

$$\Delta_{allp} := \frac{h}{12}$$ $\boxed{\Delta_{allp} = 3.83}$ in *Per ASTM E985*

Case 1 - Uniform Load:

$M_{xp} := (W_h \cdot L \cdot h) + W_v \cdot L \cdot \Delta_{tot}$ $M_{xpmax} := 0.5 \cdot M_{xp} \cdot q1 + M_{xp} q2 + M_{xp} \cdot q3$ $M_{xpmax} = 13800$ lb·in

$M_{xp2} := W_h \cdot L \cdot (h - L_{st}) + W_v \cdot L \cdot \Delta_{xp1}$ $M_{xpmax2} := 0.5 \cdot M_{xp2} \cdot q1 + M_{xp2} q2 + M_{xp2} \cdot q3$ $M_{xpmax2} = 8400$ lb·in

Case 2 - Point Load:

$M_{xpmax4} := P \cdot (h - L_{st}) \cdot 0.85$ $M_{xpmax4} = 4760$ lb·in

$M_{xpmax3} := (P \cdot h \cdot 0.85)$ $M_{xpmax3} = 7820$ lb·in

Max Post Stress:

$$f_{bpx} := \frac{\max(M_{xpmax2}, M_{xpmax4})}{S_{xp}}$$ $\boxed{f_{bpx} = 25767}$ psi

$$F_{bpx} := \begin{cases} (F_{bpx1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bpx1} & \text{otherwise} \end{cases}$$ $\boxed{F_{bpx} = 25000}$ psi

Max Post/Stub Combined Stress:

$$f_{bpx2} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{xp}}{(I_{xp} + I_{st}) \cdot S_{xp}}$$ $\boxed{f_{bpx2} = 23475}$ psi

$\boxed{F_{bpx} = 25000}$ psi

Max Stub Stress:

$$f_{bst} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{st}}{(I_{xp} + I_{st}) \cdot S_{st}}$$ $\boxed{f_{bst} = 19765}$ psi

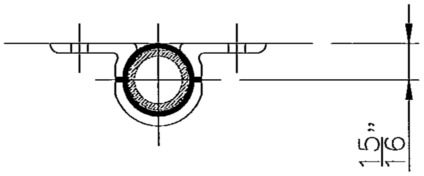
$\boxed{F_{bst} = 25000}$ psi

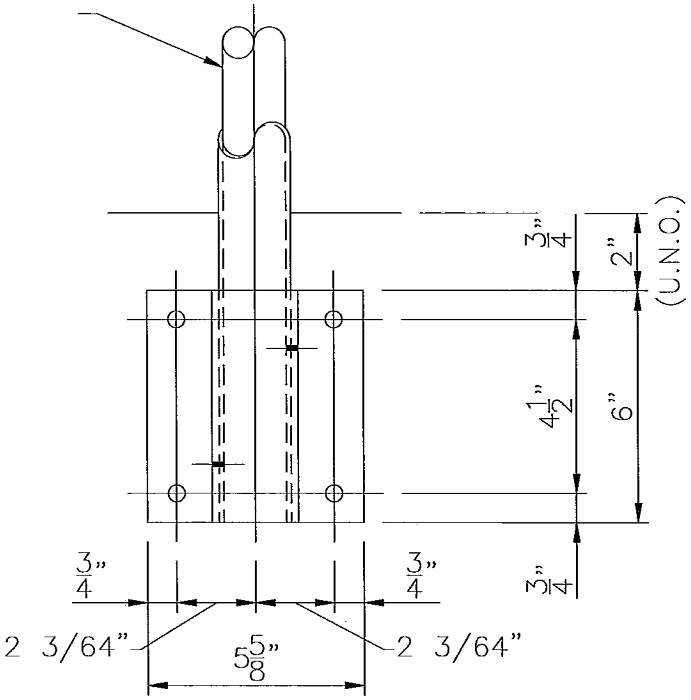
Calculation Results:

$$Int_{p1} := \max\left(\frac{f_{bpx}}{F_{bpx}}, \frac{f_{bpx2}}{F_{bpx}}, \frac{f_{bst}}{F_{bst}}\right)$$ $Int_{p1} = 1.03$ *3% Over OK*

$$POSTS := \begin{cases} \text{"OK"} & \text{if } Int_{p1} \le 1.034 \wedge \frac{\max(\Delta_{xp1}, \Delta_{xp2}, \Delta_{tot})}{\Delta_{allp}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$$ $\boxed{POSTS = \text{"OK"}}$

Side Mount Anchorage	SHT D2





$R_{max} := 300$ lb

$M_{max} := 13800 + R_{max} \cdot 3 = 14700$ lb·in

$L1 := 6$ in

$L2 := 5.25$ in

Chk Extruded Aluminum Bracket:

$P := \frac{M_{max}}{L1} + R_{max}$ $P = 2750$ lb

$M_{pl} := \frac{P}{2} \cdot 0.688$ $M_{pl} = 946$ in·lb

$t_{req} := \sqrt{\frac{6 \cdot M_{pl}}{28000 \cdot L1}}$ $t_{req} = 0.18$ in

$I := \frac{t_{req}}{0.25}$ $I = 0.74$

Use Side Mount Bracket, As Shown
6105-T5 alloy

Chk Anchor Bolts:

$V_b := \frac{R_{max}}{4}$ $V_b = 75$ lb

$T_b := \frac{M_{max}}{L2 \cdot 2 \cdot 0.85} + \frac{R_{max}}{4}$ $T_b = 1722$ lb

$V_{ball} := 0.196 \cdot 23000$ $V_{ball} = 4508$ lb

$T_{ball} := 0.142 \cdot 40000 \cdot \frac{0.1875}{0.341}$ $T_{ball} = 3123$ lb

$I := \left(\frac{V_b}{V_{ball}}\right)^2 + \left(\frac{T_b}{T_{ball}}\right)^2$ $I = 0.3$ < 1.0

Use (4) - 1/2" Dia. S.S. Thru Bolts or 3/16" Min. Thread Engagement
Cond "CW", Fy= 65 ksi minimum
Structural Steel Channel
Designed By Others

Chk TEK Screws:

$V := \frac{R_{max}}{(2)}$ $V = 150$ lb

$V_{all} := 2148 \cdot 0.333$ $V_{all} = 715$ lb

$I_2 := \left(\frac{V}{V_{all}}\right)$ $I_2 = 0.21$ < 1.0

Use (2) - #17 S.S. TEK Screws
300 Series S.S.
ITW Buildex or Better

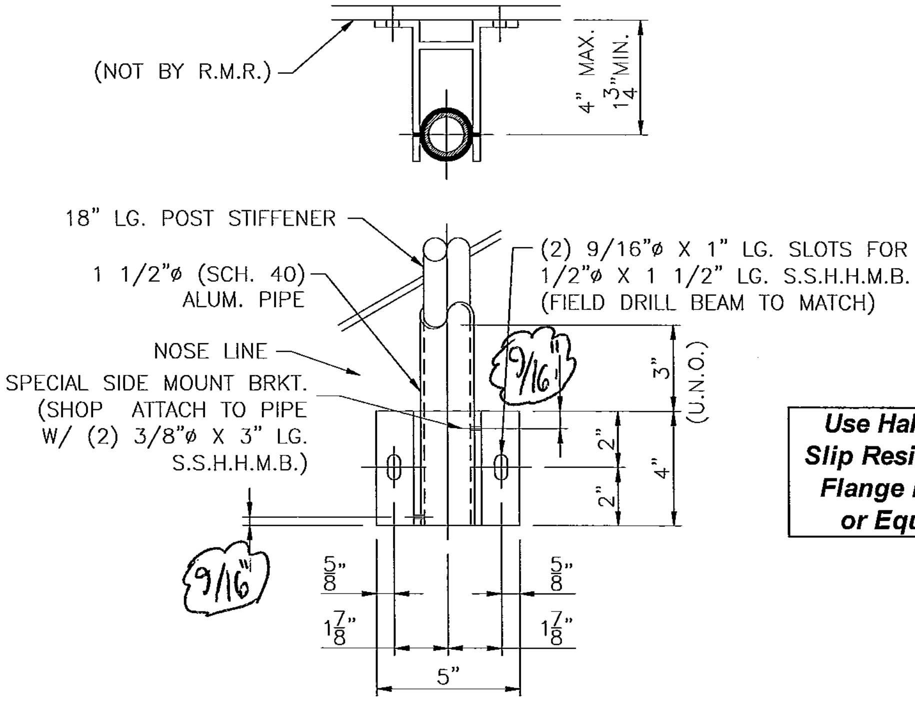
Side Mount Anchorage	SHT D3

$R_{max} := 300$ lb

$M_{max} := R_{max} \cdot 39 = 11700$ lb·in

$L1 := 4$ in

$L2 := 2$ in



SPECIAL SIDE MOUNT 2-HOLE

25KD-19E

Use Halfen Slip Resistant Flange Nuts or Equal

Chk Post Attachment to Bracket:

$V := \frac{M_{max}}{2.875 \cdot (1)} + \frac{R_{max}}{(2)}$ $V = 4220$ lb

$V_{all} := 0.110 \cdot 23000 \cdot (2)$ $V_{all} = 5060$ lb

Use (2) - 3/8" Dia. S.S. Thru-Bolts @ 2-7/8" O.C.
300 Series S.S.

Chk Extruded Aluminum Bracket:

$P := \frac{M_{max}}{L1} + R_{max}$ $P = 3225$ lb

$M_{pl} := \frac{P}{2} \cdot 0.7$ $M_{pl} = 1129$ in·lb

$t_{req} := \sqrt{\frac{6 \cdot M_{pl}}{28000 \cdot L1}}$ $t_{req} = 0.25$ in

$I := \frac{t_{req}}{0.25}$ $I = 0.98$

Use Side Mount Bracket, 4" Long
6105-T5 alloy

Chk Anchor Bolts:

$V_b := \frac{R_{max}}{2}$ $V_b = 150$ lb

$T_b := \frac{M_{max}}{L2 \cdot 2} + \frac{R_{max}}{2}$ $T_b = 3075$ lb

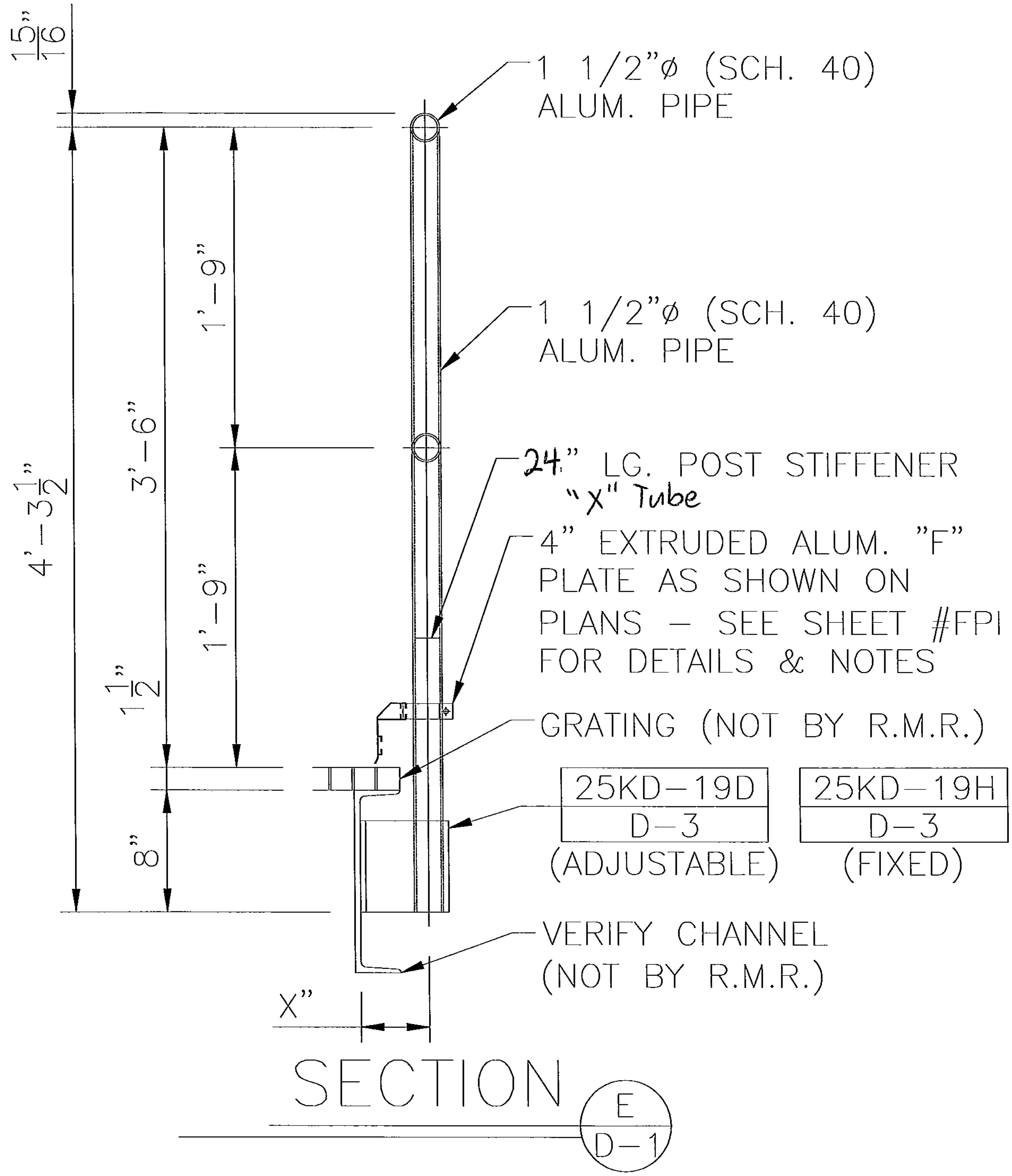
$V_{all} := 0.196 \cdot 23000$ $V_{all} = 4508$ lb

$T_{all} := 0.142 \cdot 40000 \cdot \frac{0.25}{0.456}$ $T_{all} = 3114$ lb

$I := \left(\frac{V_b}{V_{all}}\right)^2 + \left(\frac{T_b}{T_{all}}\right)^2$ $I = 0.98 < 1.0$

Use (4) - 1/2" Dia. S.S. Thru Bolts
(or Drill & Tap - 1/4" Min. Thread Engagement)
Cond "CW", Fy= 65 ksi minimum
Steel Stringers Designed By Others

Guardrail "E"	SHT E



Note: *Structural steel, Concrete, CMU and all other anchorage substrates designed by others*

ROCKY MOUNTAIN RAILINGS

RICE ENGINEERING Template: REI-MC-5707	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
			Engineer: JDB	Sheet No: E
			Date: 2/23/11	Rev:
			Chk By:	Date:

Pipe Railing & Post

These calculations are based on emperical test data performed by Julius Blum & Co., Inc.

Guardrail "E" Analysis	SHT E1

Input Variables:

$F_H := 50$ plf — Load Case 1 (Uniform Load)

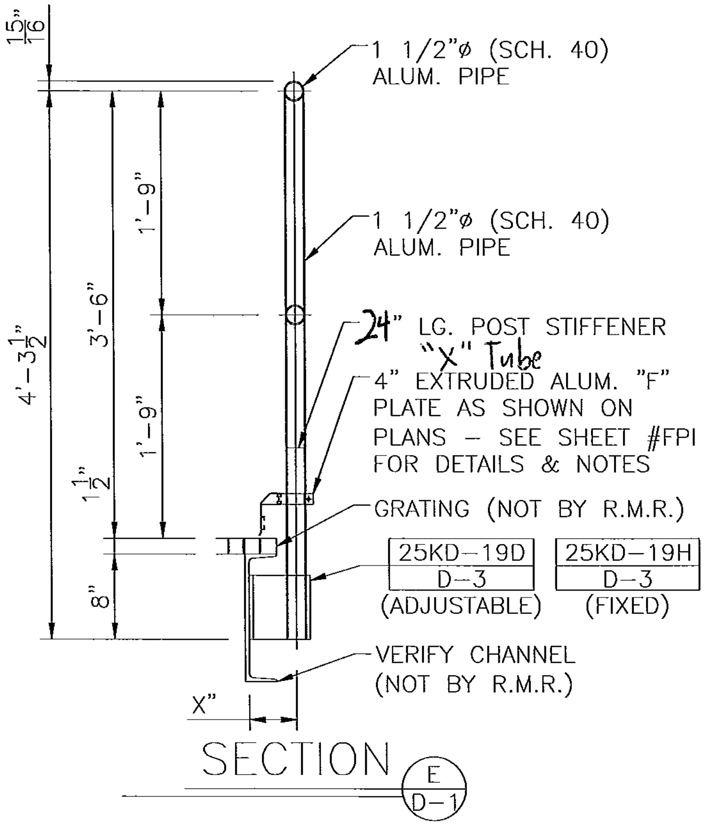
$F_V := 0$ plf — Simultaneous Vertical Uniform Load

$P := 200$ lb — Load Case 2 (Point Load)

$L_{bp} := 24.5$ in — Unbraced Length of Post

$h := 46.5$ in — Railing Height Above Top Anchor Bolt

$L := 72$ in — **6'-0" MAX POST SPACING**



Number of Railing Spans:

- ☑ 1 span
- ☑ 2 span
- ☑ 3 or more spans

Railing Section:

- ☐ 1 1/4" Schd. 40
- ☐ 1 1/4" Schd. 80
- ☑ 1 1/2" Schd. 40
- ☐ 1 1/2" Schd. 80
- ☐ 1 1/2" tube
- ☐ 2" Schd. 40
- ☐ 2" Schd. 80

Post Section:

- ☐ 1 1/4" Schd. 40
- ☐ 1 1/4" Schd. 80
- ☑ 1 1/2" Schd. 40
- ☐ 1 1/2" Schd. 80
- ☐ 1 1/2" tube
- ☐ 2" Schd. 40
- ☐ 2" Schd. 80

Railing Temper:

- ☐ 6063-T5
- ☐ 6063-T6
- ☑ 6061-T6 or 6105-T5
- ☐ *4/3 increase allowed*

Post Temper:

- ☐ 6063-T6
- ☐ 6005-T5
- ☑ 6061-T6 or 6105-T5
- ☐ Post Welded to Base Plate

All calculations below this line are automatic

Railing Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

Post Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

$S_{R1} := \frac{R_r}{t_r}$ $\quad S_{R1} = 6.55$

$S_{R3} := \frac{R_p}{t_p}$ $\quad S_{R3} = 6.55$

Computational Factors

$K_1 := (8 \cdot q1) + (8 \cdot q2) + (9.5 \cdot q3)$ $\quad K_1 = 8$

$K_2 := (4 \cdot q1) + (5 \cdot q2) + (5 \cdot q3)$ $\quad K_2 = 5$

$K_3 := (48 \cdot q1) + (66 \cdot q2) + (87 \cdot q3)$ $\quad K_3 = 66$

$E_r := 10100000$ psi

$I_{xtotr} := I_{xr}$ $\quad I_{xtotr} = 0.31$ in^4 $\qquad I_{xtotp} := I_{xp}$ $\quad I_{xtotp} = 0.31$ in^4

$I_{ytotr} := I_{yr}$ $\quad I_{ytotr} = 0.31$ in^4 $\qquad I_{ytotp} := I_{yp}$ $\quad I_{ytotp} = 0.31$ in^4

24" Min. Length AL. "X" Tube Stub

$I_{st} := 0.249$ in^4 $\qquad L_{st} := 19$ in

$S_{st} := 0.311$ in^3 $\qquad F_{bst} := 25000$ psi

Railing Analysis:

$W_h := \frac{F_H}{12}$ $W_v := \frac{F_V}{12}$

Guardrail "E" Analysis	SHT E1 A

Case 1 Uniform Load:

$\Delta_{yr1} := \frac{5 \cdot W_h \cdot L^4}{384 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr1} = 0.466$ in Modeled as a simple span

$\Delta_{xr1} := \frac{5 \cdot W_v \cdot L^4}{384 \cdot E_r \cdot I_{xtotr}}$ $\Delta_{xr1} = 0$ in

$\Delta_{allr} := \frac{L}{96}$ $\Delta_{allr} = 0.75$ in Per ASTM Specification E985

$M_{yrmax} := \frac{W_h \cdot L^2}{K_1}$ $M_{yrmax} = 2700$ lb·in

$M_{xrmax} := \frac{W_v \cdot L^2}{K_1}$ $M_{xrmax} = 0$ lb·in

---

$f_{bry1} := \frac{M_{yrmax}}{S_{yr}}$ $f_{bry1} = 8282$ psi

$f_{brx1} := \frac{M_{xrmax}}{S_{xr}}$ $f_{brx1} = 0$ psi

Case 2 - Point Load:

$\Delta_{yr2} := \frac{P \cdot L^3}{K_3 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr2} = 0.361$ in

$M_{yrmax2} := \frac{P \cdot L}{K_2}$ $M_{yrmax2} = 2880$ lb·in

$f_{bry2} := \frac{M_{yrmax2}}{S_{yr}}$ $f_{bry2} = 8834$ psi

$F_{bry} := \begin{cases} (F_{bry1} \cdot 1.33) & \text{if IBC} = 1 \\ F_{bry1} & \text{otherwise} \end{cases}$ $F_{bry} = 25000$ psi

Calculation Results:

$Int_{r1} := \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right)$ $Int_{r1} = 0.33$

$Int_{r2} := \frac{f_{bry2}}{F_{bry}}$ $Int_{r2} = 0.35$

$RAILS := \begin{cases} \text{"OK"} & \text{if } \frac{\max(\Delta_{yr1}, \Delta_{xr1}, \Delta_{yr2})}{\Delta_{allr}} \le 1 \wedge \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right) \le 1 \wedge \frac{f_{bry2}}{F_{bry}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ RAILS = "OK"

Post Analysis:

$E_p := E_r$

Guardrail "E" Analysis	SHT E1 B

$$\Delta_{xp1} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp1} = 0.664$ in

$$\Delta_{xp2} := \frac{P \cdot 0.85 \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp2} = 0.376$ in

Max Deflection:

$$\Delta_{tot} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot I_{xp}} + \frac{W_h \cdot L \cdot \left[h^3 - (h - L_{st})^3\right]}{3 \cdot \left[(E_p \cdot I_{xp}) + (E_p \cdot I_{st})\right]}$$ $\boxed{\Delta_{tot} = 2.077}$ in

$$\Delta_{allp} := \frac{h}{12}$$ $\boxed{\Delta_{allp} = 3.88}$ in *Per ASTM E985*

Case 1 - Uniform Load:

$M_{xp} := (W_h \cdot L \cdot h) + W_v \cdot L \cdot \Delta_{tot}$ $M_{xpmax} := 0.5 \cdot M_{xp} \cdot q1 + M_{xp}q2 + M_{xp} \cdot q3$ $M_{xpmax} = 13950$ lb·in

$M_{xp2} := W_h \cdot L \cdot (h - L_{st}) + W_v \cdot L \cdot \Delta_{xp1}$ $M_{xpmax2} := 0.5 \cdot M_{xp2} \cdot q1 + M_{xp2}q2 + M_{xp2} \cdot q3$ $M_{xpmax2} = 8250$ lb·in

Case 2 - Point Load:

$M_{xpmax4} := P \cdot (h - L_{st}) \cdot 0.85$ $M_{xpmax4} = 4675$ lb·in

$M_{xpmax3} := (P \cdot h \cdot 0.85)$ $M_{xpmax3} = 7905$ lb·in

Max Post Stress:

$$f_{bpx} := \frac{\max(M_{xpmax2}, M_{xpmax4})}{S_{xp}}$$ $\boxed{f_{bpx} = 25307}$ psi

$$F_{bpx} := \begin{cases} (F_{bpx1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bpx1} & \text{otherwise} \end{cases}$$ $\boxed{F_{bpx} = 25000}$ psi

Max Post/Stub Combined Stress:

$$f_{bpx2} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{xp}}{(I_{xp} + I_{st}) \cdot S_{xp}}$$ $\boxed{f_{bpx2} = 23730}$ psi

$\boxed{F_{bpx} = 25000}$ psi

Max Stub Stress:

$$f_{bst} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{st}}{(I_{xp} + I_{st}) \cdot S_{st}}$$ $\boxed{f_{bst} = 19980}$ psi

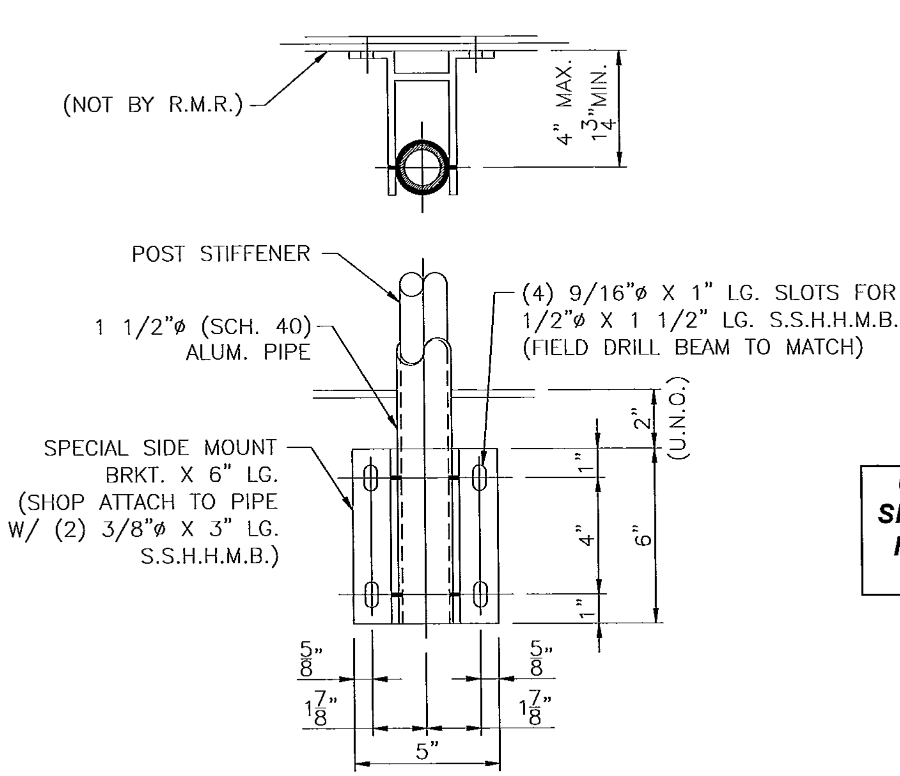
$\boxed{F_{bst} = 25000}$ psi

Calculation Results:

$$Int_{p1} := \max\left(\frac{f_{bpx}}{F_{bpx}}, \frac{f_{bpx2}}{F_{bpx}}, \frac{f_{bst}}{F_{bst}}\right)$$ $Int_{p1} = 1.01$ *1% Over OK*

$$POSTS := \begin{cases} \text{"OK"} & \text{if } Int_{p1} \le 1.014 \wedge \frac{\max(\Delta_{xp1}, \Delta_{xp2}, \Delta_{tot})}{\Delta_{allp}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$$ $\boxed{POSTS = \text{"OK"}}$

Side Mount Anchorage	SHT E2



SPECIAL SIDE MOUNT 4-HOLE

25KD-19D

$R_{max} := 300$ lb

$M_{max} := 13950 + R_{max} \cdot 3 = 14850$ lb·in

$L1 := 6$ in

$L2 := 5$ in

Use Halfen Slip Resistant Flange Nuts or Equal

Chk Post Attachment to Bracket:

$V := \frac{M_{max}}{4 \cdot (1)} + \frac{R_{max}}{(2)}$ $V = 3863$ lb

$V_{all} := 0.110 \cdot 23000 \cdot (2)$ $V_{all} = 5060$ lb

<u>Use (2) - 3/8" Dia. S.S. Thru-Bolts @ 4" O.C.</u>
300 Series S.S.

Chk Extruded Aluminum Bracket:

$P := \frac{M_{max}}{L1} + R_{max}$ $P = 2775$ lb

$M_{pl} := \frac{P}{2} \cdot 0.8125$ $M_{pl} = 1127$ in·lb

$t_{req} := \sqrt{\frac{6 \cdot M_{pl}}{28000 \cdot L1}}$ $t_{req} = 0.2$ in

$I := \frac{t_{req}}{0.25}$ $I = 0.8$

<u>Use Side Mount Bracket, As Shown</u>
6105-T5 alloy

Chk Anchor Bolts:

$V_b := \frac{R_{max}}{4}$ $V_b = 75$ lb

$T_b := \frac{M_{max}}{L2 \cdot 2} + \frac{R_{max}}{4}$ $T_b = 1560$ lb

$V_{all} := 0.196 \cdot 23000$ $V_{all} = 4508$ lb

$T_{all} := 0.142 \cdot 40000 \cdot \frac{0.1875}{0.456}$ $T_{all} = 2336$ lb

$I := \left(\frac{V_b}{V_{all}}\right)^2 + \left(\frac{T_b}{T_{all}}\right)^2$ $I = 0.45 < 1.0$

<u>Use (4) - 1/2" Dia. S.S. Thru Bolts</u>
<u>(or Drill & Tap - 3/16" Min. Thread Engagement)</u>
Cond "CW", Fy= 65 ksi minimum
Steel Stringers Designed By Others

Side Mount Anchor	SHT E3

Reactions:

$R_{max} := 300$ lb $L1 := 5$ in

$M_{max} := 13950 + R_{max} \cdot 3 = 14850$ lb·in $L2 := 4$ in

Chk Extruded Aluminum Bracket:

$P := \frac{M_{max}}{L1} + R_{max}$ $P = 3270$ lb

$M_{pl} := \frac{P \cdot 3}{4}$ $M_{pl} = 2453$ in·lb

$t_{req} := \sqrt{\frac{6 \cdot M_{pl}}{28000 \cdot 0.85 \cdot L1}}$ $t_{req} = 0.35$ in

$I := \frac{t_{req}}{0.375}$ $I = 0.94$

Use Extruded Bracket as shown (6105-T5)

Chk Fasteners:

$V := \frac{R_{max}}{2}$ lb (upward) $V = 150$ lb

Use (2) - 3/8" Dia. S.S. Set Screws OK By Inspection

Chk Anchor Bolts (Structural Steel By Others):

$V_b := \frac{R_{max}}{4}$ $V_b = 75$ lb

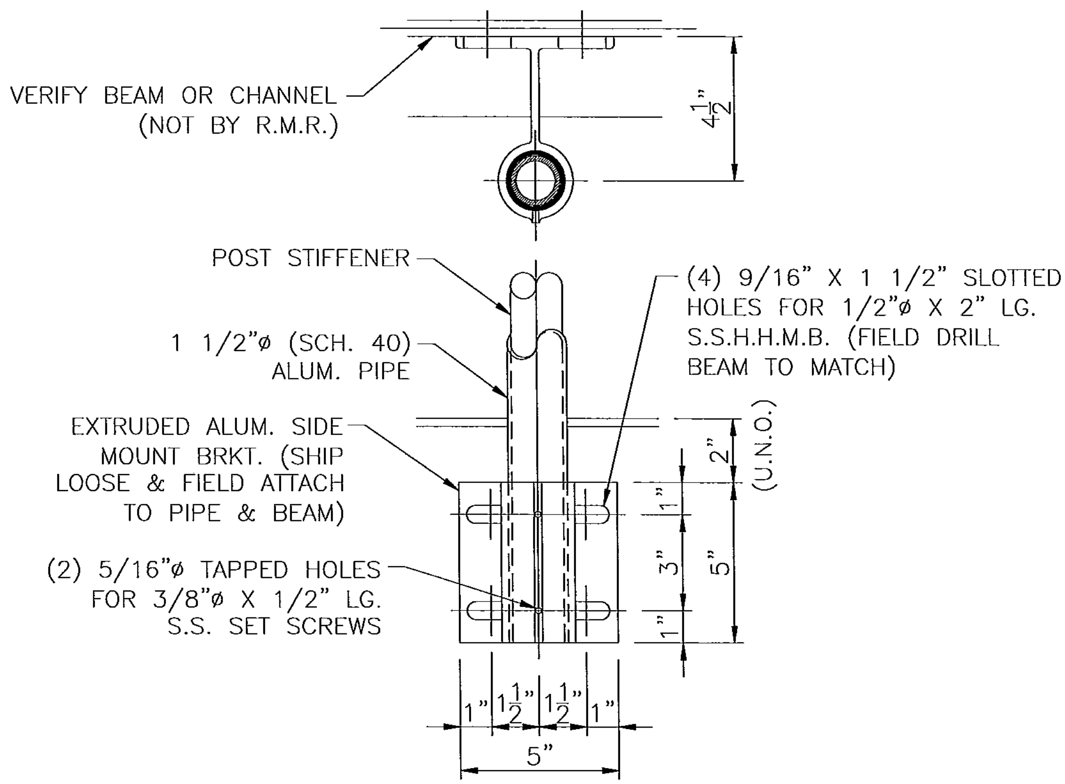
$T_b := \frac{M_{max}}{L2 \cdot 2} + \frac{R_{max}}{4}$ $T_b = 1931$ lb

$V_{all} := 0.196 \cdot 23000$ $V_{all} = 4508$ lb

$T_{all} := 0.142 \cdot 40000 \cdot \frac{0.1875}{0.456}$ $T_{all} = 2336$ lb

$I := \left(\frac{V_b}{V_{all}}\right)^2 + \left(\frac{T_b}{T_{all}}\right)^2$ $I = 0.68$ < 1.0

Use (4) - 1/2-13 S.S. Bolts ***Drill & Tap or Thru-Bolt*** *Min. Thread Engagement = 3/16"* *(300 Series S.S., Cond. CW, Fy = 65 ksi)*

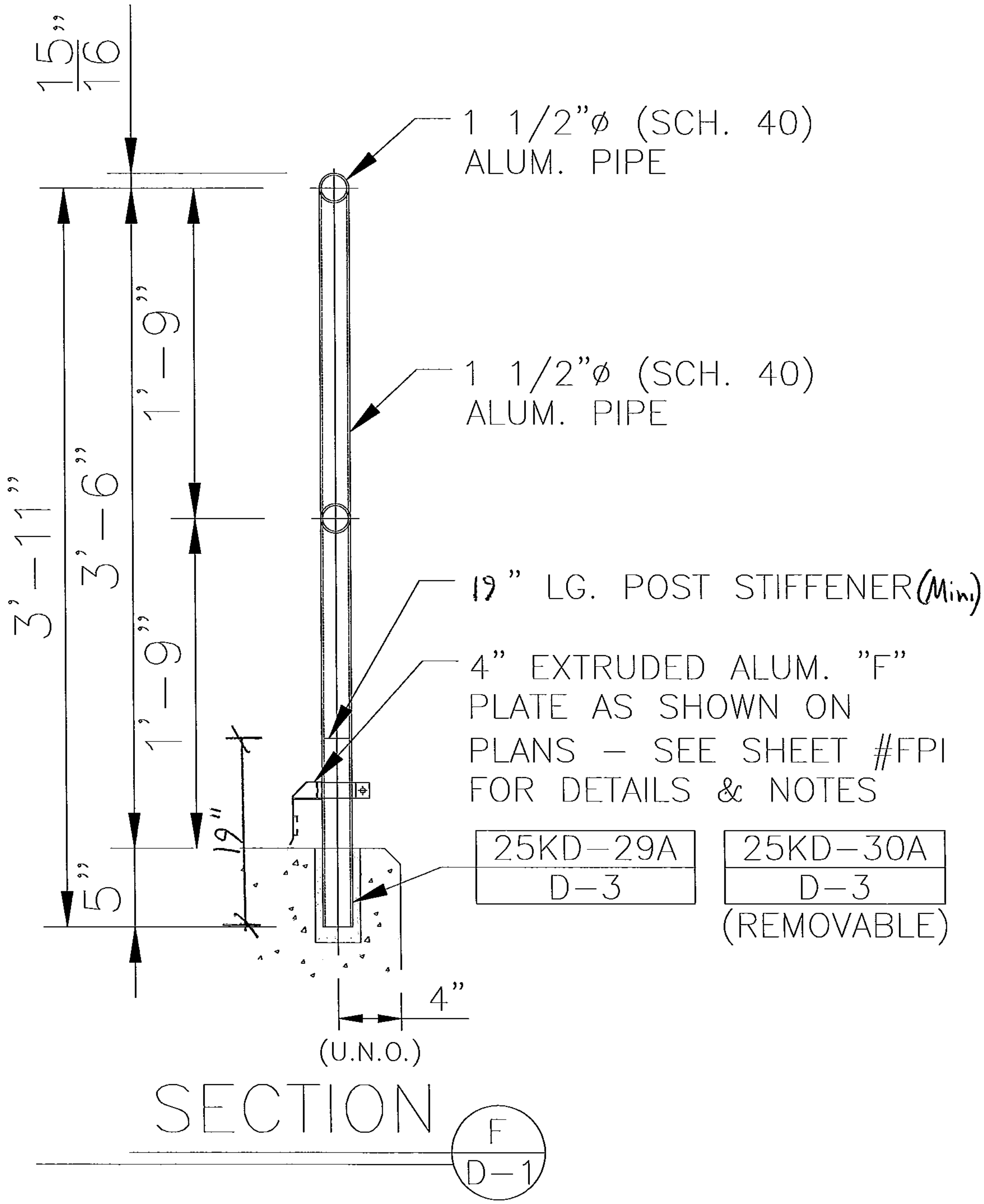


STL. SIDE MOUNT 4-SLOT

25KD-19H

RICE ENGINEERING Template:	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H Engineer: JDB Date: 2/23/11 Chk By:	Sheet No: E3 Rev: Date:

Guardrail "F"	SHT F



Note: *Structural steel, Concrete, CMU and all other anchorage substrates designed by others*

ROCKY MOUNTAIN RAILINGS

RICE ENGINEERING Template: REI-MC-5707	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H Engineer: JDB Date: 2/23/11 Chk By:	Sheet No: F Rev: Date:

Pipe Railing & Post

These calculations are based on emperical test data performed by Julius Blum & Co., Inc.

Guardrail "F" Analysis	SHT F1

Input Variables:

$F_H := 50$ plf — Load Case 1 (Uniform Load)

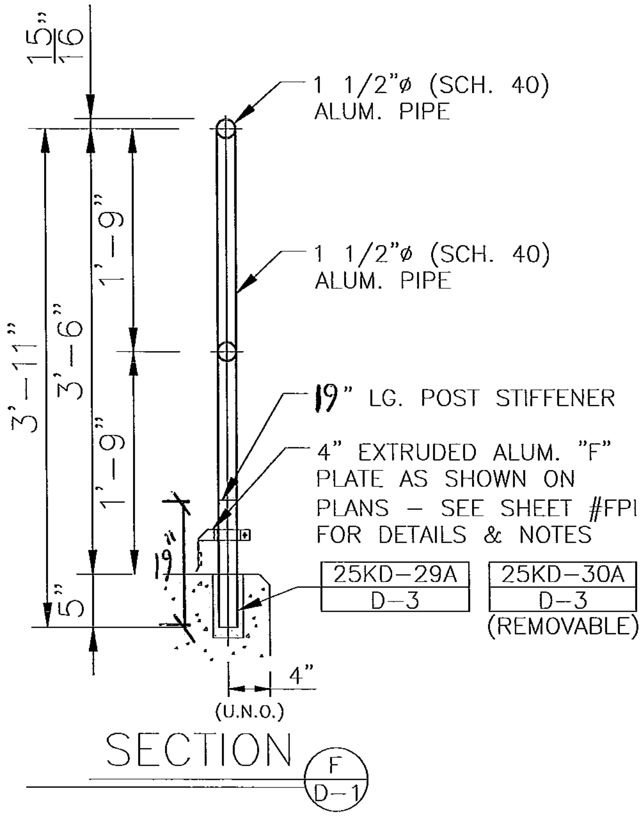
$F_V := 0$ plf — Simultaneous Vertical Uniform Load

$P := 200$ lb — Load Case 2 (Point Load)

$L_{bp} := 21$ in — Unbraced Length of Post

$h := 42$ in — Railing Height

$L := 72$ in — **6'-0" MAX POST SPACING**



Number of Railing Spans:

- [x] 1 span
- [x] 2 span
- [x] 3 or more spans

Railing Section:	Post Section:
[ ] 1 1/4" Schd. 40	[ ] 1 1/4" Schd. 40
[ ] 1 1/4" Schd. 80	[ ] 1 1/4" Schd. 80
[x] 1 1/2" Schd. 40	[x] 1 1/2" Schd. 40
[ ] 1 1/2" Schd. 80	[ ] 1 1/2" Schd. 80
[ ] 1 1/2" tube	[ ] 1 1/2" tube
[ ] 2" Schd. 40	[ ] 2" Schd. 40
[ ] 2" Schd. 80	[ ] 2" Schd. 80

Railing Temper:	Post Temper:
[ ] 6063-T5	[ ] 6063-T6
[ ] 6063-T6	[ ] 6005-T5
[x] 6061-T6 or 6105-T5	[x] 6061-T6 or 6105-T5
[ ] *4/3 increase allowed*	[ ] Post Welded to Base Plate

All calculations below this line are automatic

Railing Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

Post Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

$S_{R1} := \frac{R_r}{t_r}$ $\quad S_{R1} = 6.55$

$S_{R3} := \frac{R_p}{t_p}$ $\quad S_{R3} = 6.55$

Computational Factors

$K_1 := (8 \cdot q1) + (8 \cdot q2) + (9.5 \cdot q3)$ $\quad K_1 = 8$

$K_2 := (4 \cdot q1) + (5 \cdot q2) + (5 \cdot q3)$ $\quad K_2 = 5$

$K_3 := (48 \cdot q1) + (66 \cdot q2) + (87 \cdot q3)$ $\quad K_3 = 66$

$E_r := 10100000$ psi

$I_{xtotr} := I_{xr}$ $\quad I_{xtotr} = 0.31$ in^4 $\quad I_{xtotp} := I_{xp}$ $\quad I_{xtotp} = 0.31$ in^4

$I_{ytotr} := I_{yr}$ $\quad I_{ytotr} = 0.31$ in^4 $\quad I_{ytotp} := I_{yp}$ $\quad I_{ytotp} = 0.31$ in^4

19" Min. Length AL. Ribbed Tube Stub

$I_{st} := 0.174$ in^4 $\quad L_{st} := 14$ in

$S_{st} := 0.224$ in^3 $\quad F_{bst} := 25000$ psi

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Railing Analysis:

$W_h := \frac{F_H}{12}$ $W_v := \frac{F_V}{12}$

Guardrail "F" Analysis	SHT F1 A

Case 1 Uniform Load:

$\Delta_{yr1} := \frac{5 \cdot W_h \cdot L^4}{384 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr1} = 0.466$ in Modeled as a simple span

$\Delta_{xr1} := \frac{5 \cdot W_v \cdot L^4}{384 \cdot E_r \cdot I_{xtotr}}$ $\Delta_{xr1} = 0$ in

$\Delta_{allr} := \frac{L}{96}$ $\Delta_{allr} = 0.75$ in Per ASTM Specification E985

$M_{yrmax} := \frac{W_h \cdot L^2}{K_1}$ $M_{yrmax} = 2700$ lb·in

$M_{xrmax} := \frac{W_v \cdot L^2}{K_1}$ $M_{xrmax} = 0$ lb·in

---

$f_{bry1} := \frac{M_{yrmax}}{S_{yr}}$ $f_{bry1} = 8282$ psi

$f_{brx1} := \frac{M_{xrmax}}{S_{xr}}$ $f_{brx1} = 0$ psi

Case 2 - Point Load:

$\Delta_{yr2} := \frac{P \cdot L^3}{K_3 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr2} = 0.361$ in

$M_{yrmax2} := \frac{P \cdot L}{K_2}$ $M_{yrmax2} = 2880$ lb·in

$f_{bry2} := \frac{M_{yrmax2}}{S_{yr}}$ $f_{bry2} = 8834$ psi

$F_{bry} := \begin{cases} (F_{bry1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bry1} & \text{otherwise} \end{cases}$ $F_{bry} = 25000$ psi

Calculation Results:

$Int_{r1} := \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right)$ $Int_{r1} = 0.33$

$Int_{r2} := \frac{f_{bry2}}{F_{bry}}$ $Int_{r2} = 0.35$

$RAILS := \begin{cases} \text{"OK"} & \text{if } \frac{\max(\Delta_{yr1}, \Delta_{xr1}, \Delta_{yr2})}{\Delta_{allr}} \le 1 \wedge \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right) \le 1 \wedge \frac{f_{bry2}}{F_{bry}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ RAILS = "OK"

Post Analysis:

$E_p := E_r$

Guardrail "F" Analysis	SHT F1 B

$$\Delta_{xp1} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp1} = 0.701$ in

$$\Delta_{xp2} := \frac{P \cdot 0.85 \cdot (h - L_{st})^3}{3 \cdot E_p \cdot (I_{xp})}$$ $\Delta_{xp2} = 0.397$ in

Max Deflection:

$$\Delta_{tot} := \frac{W_h \cdot L \cdot (h - L_{st})^3}{3 \cdot E_p \cdot I_{xp}} + \frac{W_h \cdot L \cdot \left[h^3 - (h - L_{st})^3\right]}{3 \cdot \left[(E_p \cdot I_{xp}) + (E_p \cdot I_{st})\right]}$$ $\boxed{\Delta_{tot} = 1.768}$ in

$$\Delta_{allp} := \frac{h}{12}$$ $\boxed{\Delta_{allp} = 3.5}$ in *Per ASTM E985*

Case 1 - Uniform Load:

$M_{xp} := (W_h \cdot L \cdot h) + W_v \cdot L \cdot \Delta_{tot}$ $M_{xpmax} := 0.5 \cdot M_{xp} \cdot q1 + M_{xp}q2 + M_{xp} \cdot q3$ $M_{xpmax} = 12600$ lb·in

$M_{xp2} := W_h \cdot L \cdot (h - L_{st}) + W_v \cdot L \cdot \Delta_{xp1}$ $M_{xpmax2} := 0.5 \cdot M_{xp2} \cdot q1 + M_{xp2}q2 + M_{xp2} \cdot q3$ $M_{xpmax2} = 8400$ lb·in

Case 2 - Point Load:

$M_{xpmax4} := P \cdot (h - L_{st}) \cdot 0.85$ $M_{xpmax4} = 4760$ lb·in

$M_{xpmax3} := (P \cdot h \cdot 0.85)$ $M_{xpmax3} = 7140$ lb·in

Max Post Stress:

$$f_{bpx} := \frac{\max(M_{xpmax2}, M_{xpmax4})}{S_{xp}}$$ $\boxed{f_{bpx} = 25767}$ psi

$$F_{bpx} := \begin{cases} (F_{bpx1} \cdot 1.33) & \text{if } IBC = 1 \\ F_{bpx1} & \text{otherwise} \end{cases}$$ $\boxed{F_{bpx} = 25000}$ psi

Max Post/Stub Combined Stress:

$$f_{bpx2} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{xp}}{(I_{xp} + I_{st}) \cdot S_{xp}}$$ $\boxed{f_{bpx2} = 24755}$ psi

$\boxed{F_{bpx} = 25000}$ psi

Max Stub Stress:

$$f_{bst} := \max(M_{xpmax}, M_{xpmax3}) \cdot \frac{I_{st}}{(I_{xp} + I_{st}) \cdot S_{st}}$$ $\boxed{f_{bst} = 20222}$ psi

$\boxed{F_{bst} = 25000}$ psi

Calculation Results:

$$Int_{p1} := \max\left(\frac{f_{bpx}}{F_{bpx}}, \frac{f_{bpx2}}{F_{bpx}}, \frac{f_{bst}}{F_{bst}}\right)$$ $Int_{p1} = 1.03$ *3% Over OK*

$$POSTS := \begin{cases} \text{"OK"} & \text{if } Int_{p1} \le 1.034 \wedge \frac{\max(\Delta_{xp1}, \Delta_{xp2}, \Delta_{tot})}{\Delta_{allp}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$$ $\boxed{POSTS = \text{"OK"}}$

Post Embedment in Grout	SHT F2

Chk conc. grout:

$\phi := 0.65$

$R_{max} := 300$ lb

$f'_{c1} := 6000$ psi *Grout Strength*

$M := 12600$ lb·in

$f'_{c2} := 4000$ psi *Conc. Strength*

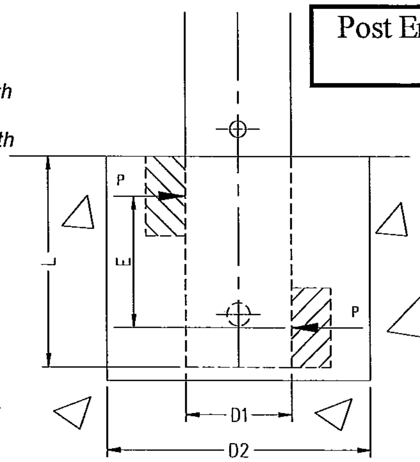
$LF := 1.6$ *(Load Factor)*

$L := 5$ in

$D_1 := 1.9$ in *(Post Width)*

$c := \frac{L}{2}$

$D_2 := 3$ in *(Grout Pocket Width)*



Assume Whitney stress block for bearing distribution:

$$\beta_1 := \max\left(\begin{pmatrix} 0.85 - .05\cdot\frac{f'_{c1} - 4000}{1000} \\ 0.65 \end{pmatrix}\right) \qquad \beta_1 = 0.75 \quad a_1 := \beta_1 \cdot c \quad a_1 = 1.88$$

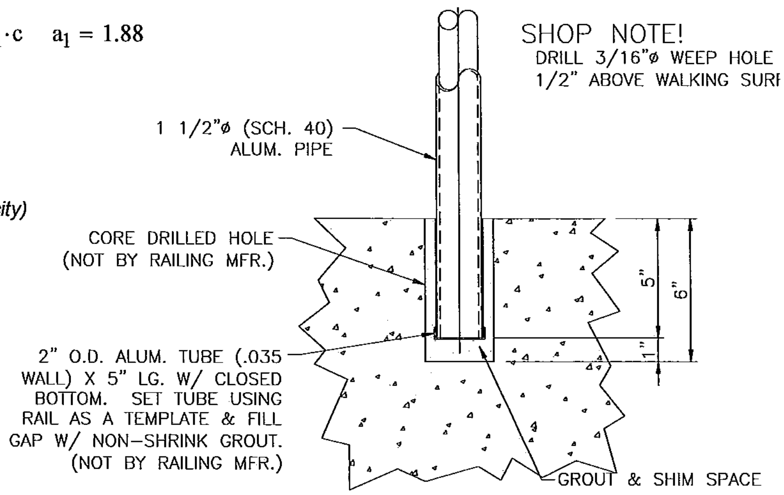
$A_1 := a_1 \cdot D_1$ $\quad A_1 = 3.56$ in *(Bearing Area)*

$E_1 := L - a_1$ $\quad E_1 = 3.13$ in *(Load Eccentricity)*

$P_1 := \frac{M}{E_1} + \frac{R_{max}}{2}$ $\quad P_1 = 4182$ lb *(Bearing Load)*

$\phi F_{p1} := \phi \cdot 0.85 \cdot A_1 \cdot f'_{c1}$ $\quad \phi F_{p1} = 11810$ lb *(Allowable Bearing Load)*

$I_1 := \frac{LF \cdot P_1}{\phi F_{p1}}$ $\quad \boxed{I_1 = 0.57}$



REMOVABLE SLEEVE

25KD-30A

Chk concrete (for reference only):

$$\beta_2 := \max\left(\begin{pmatrix} 0.85 - .05\cdot\frac{f'_{c2} - 4000}{1000} \\ 0.65 \end{pmatrix}\right) \qquad \beta_2 = 0.85 \quad a_2 := \beta_2 \cdot c \quad a_2 = 2.13$$

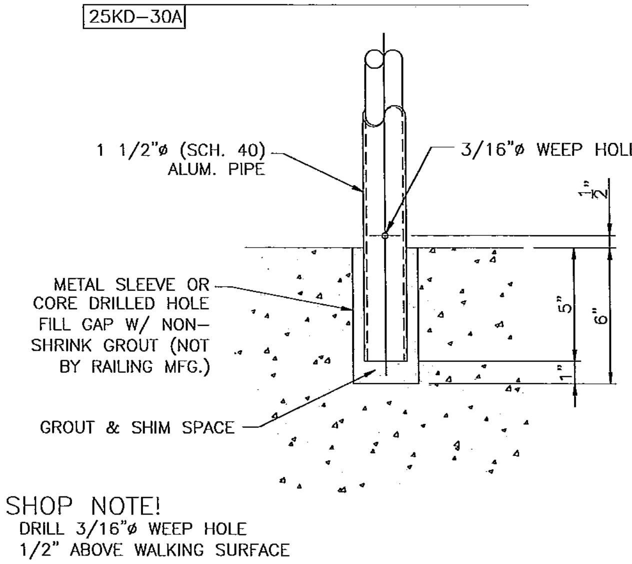
$A_2 := a_2 \cdot D_2$ $\quad A_2 = 6.38$ in *(Bearing Area)*

$E_2 := L - a_2$ $\quad E_2 = 2.88$ in *(Load Eccentricity)*

$P_2 := \frac{M}{E_2} + \frac{R_{max}}{2}$ $\quad P_2 = 4533$ lb *(Bearing Load)*

$\phi F_{p2} := \phi \cdot 0.85 \cdot A_2 \cdot f'_{c2}$ $\quad \phi F_{p2} = 14089$ lb *(Allowable Bearing Load)*

$I_2 := \frac{LF \cdot P_2}{\phi F_{p2}}$ $\quad \boxed{I_2 = 0.51}$



Use 6,000 psi, non-shrink Grout
-Design of Bearing on Concrete by others
-Design of Concrete Breakout and point loads By others

FIXED SLEEVE

25KD-29A

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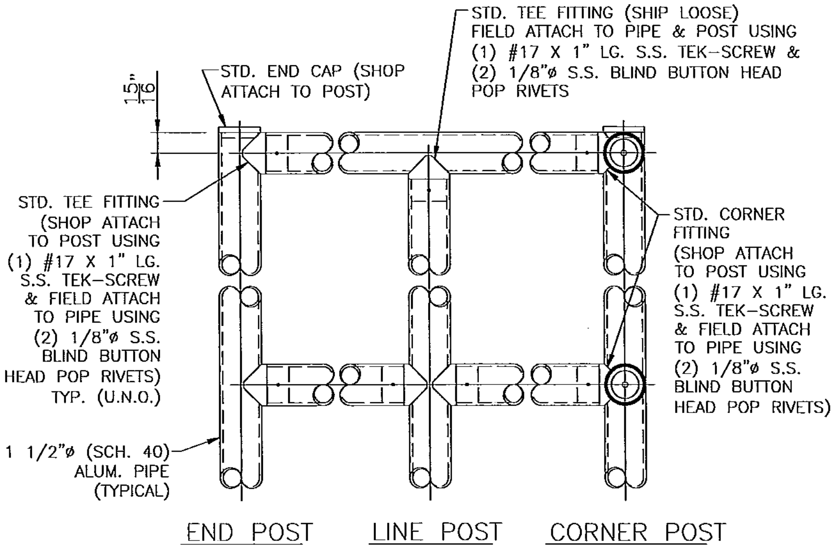
Miscellaneous Connections	SHT M1

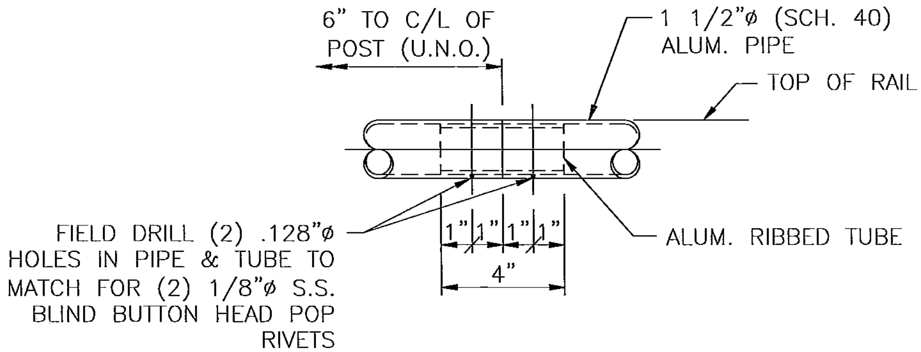


TYPICAL LEVEL RAIL CONNECTIONS

25KD-2

$R_{max} := 300$ lb

$M_{max} := 1680$ lb·in



Chk 1/4-20 Screws @ Tee/Rail:

$V := \frac{R_{max}}{2}$ $\boxed{V = 150}$ lb

$V_{all} := 520 \cdot 0.33$ $\boxed{V_{all} = 172}$ lb

Use (2) - 1/8 S.S. Blind Button Head Rivets (Pop Rivets)
(Safety Factor = 3)

Chk Splice Piece: $S_x := 0.104$ in^3

$f_b := \frac{M_{max}}{S_x}$ $\boxed{f_b = 16154}$ psi

$\boxed{F_b := 21000}$ psi

Use Ribbed Tube Aluminum Splice Piece
6105-T5 Alloy

Chk #17 S.S. TEK Screw @ Tee/Post :

$V_2 := R_{max}$ $\boxed{V_2 = 300}$ lb

$V_{all2} := 2184 \cdot 0.33$ $\boxed{V_{all2} = 721}$ lb

Use (1) #17 S.S. TEK Screw per "Tee"
300 Series S.S.

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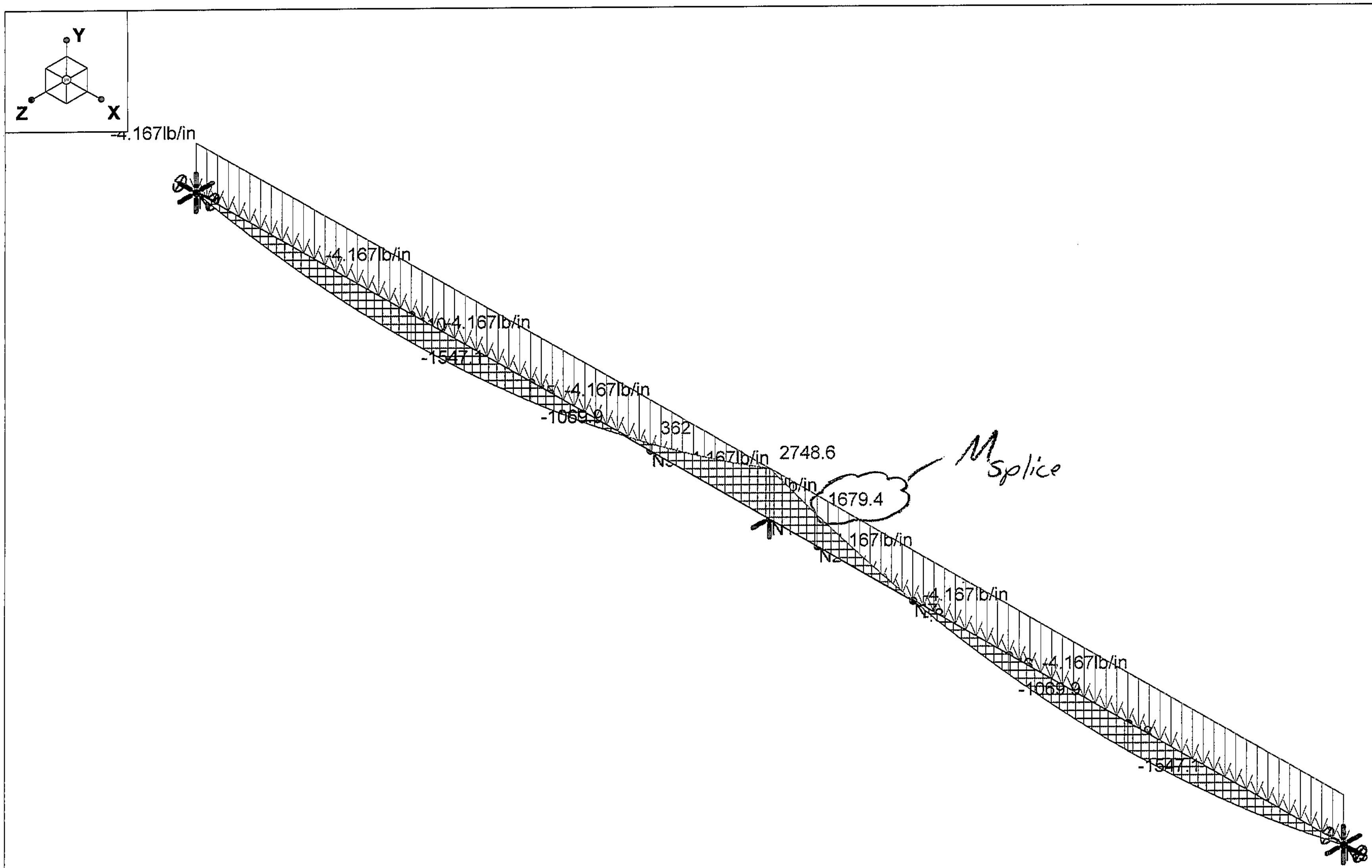


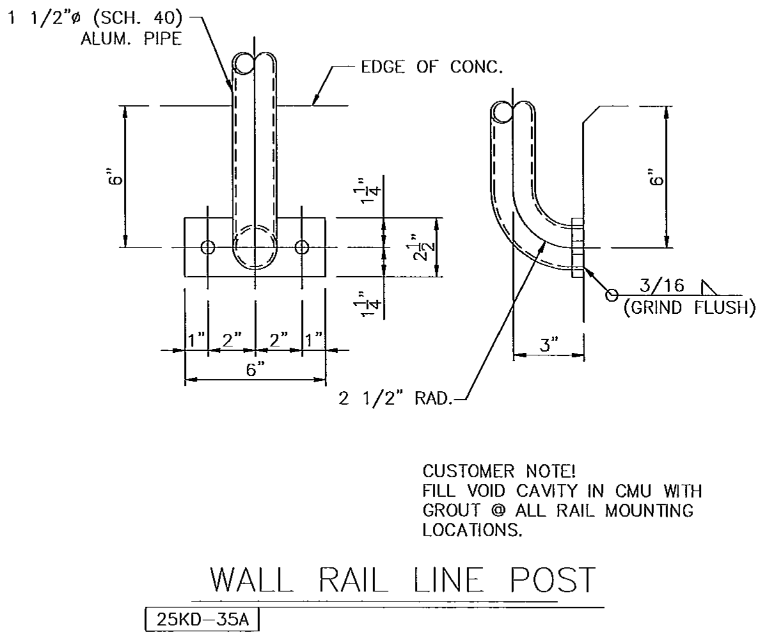
Loads: BLC 1, 50 PLF
Results for LC 1, 50 PLF
Member z Bending Moments (lb-in)

Rice Engineering	R0001 - RMR Standard Calcs	SK - 1
Joe Bauer		Feb 23, 2011 at 3:13 PM
R11-02-15H		6 ft Splice Loads.r3d

MIA

ASSUME GROUT FILLED CMU
DESIGNED BY OTHERS

Wall Rail Post Bracket Analysis	SHT M2



(Reaction From RISA Model)

$R_{max} := 113$ lb

$M_{max} := 2287$ lb·in

Chk weld to base plate:

$t_w := 0.1875$ in (thickness of weld)

$d := 1.9$ in (stub depth)

$A_w := t_w \cdot (\pi \cdot 0.5 \cdot d)$ $\quad A_w = 0.56$ in^2

$T := \frac{M_{max}}{d}$ $\quad T = 1204$ lb

$f_w := \frac{T}{A_w}$ $\quad f_w = 2151$ psi

$F_w := 6500$ psi

Use 3/16" weld all around as noted
5356 filler alloy

Chk Aluminum Base Plate:

$L1 := 6$ in $\quad D1 := 1$ in

$L2 := 2.5$ in $\quad D2 := 2.5$ in

$t := 0.5$ in

$L := L1 - (2 \cdot D1)$ $\quad L = 4$ in

$P := \frac{M_{max}}{d}$ $\quad P = 1204$ lb

$M_{p1} := 0.5 \cdot P \cdot 1$ $\quad M_{p1} = 602$ in·lb

$M_{pl2} := 0.5 \cdot P \cdot (1.05)$ $\quad M_{pl2} = 632$ in·lb

$t_{req1} := \sqrt{\frac{M_{p1} \cdot 6}{(12000) \cdot L2}}$ $\quad t_{req1} = 0.347$ in

$t_{req2} := \sqrt{\frac{M_{pl2} \cdot 6}{(28000) \cdot L2}}$ $\quad t_{req2} = 0.233$ in

$I_2 := \frac{\max(t_{req1}, t_{req2})}{t}$ $\quad I_2 = 0.69$

Use 1/2" x 6" x 2-1/2" AL Plate
6061-T6 alloy

Note! Anchor Type Size + Embedment

Chk Bolts to Grout Filled CMU:

$V_b := \frac{R_{max}}{2}$ $\quad V_b = 57$ lb

$T_b := \frac{M_{max}}{2 \cdot (0.5 \cdot D2)}$ $\quad T_b = 915$ lb

$T_{all} := \min(1100, 1975 \cdot 0.5)$ $\quad T_{all} = 988$ lb

$V_{all} := \min(1419, 2756 \cdot 0.5)$ $\quad V_{all} = 1378$ lb

$I_b := \left(\frac{T_b}{T_{all}}\right)^{1.67} + \left(\frac{V_b}{V_{all}}\right)^{1.67}$ $\quad I_b = 0.88$

Use (2) - 3/8" Dia. S.S. Threaded Rods
W/ Hilti HIT-HY 150 MAX Adhesive
Edge Distance: 4"
End Distance: 4"
Embedment: 3-3/8"

RICE ENGINEERING
105 School Creek Trail
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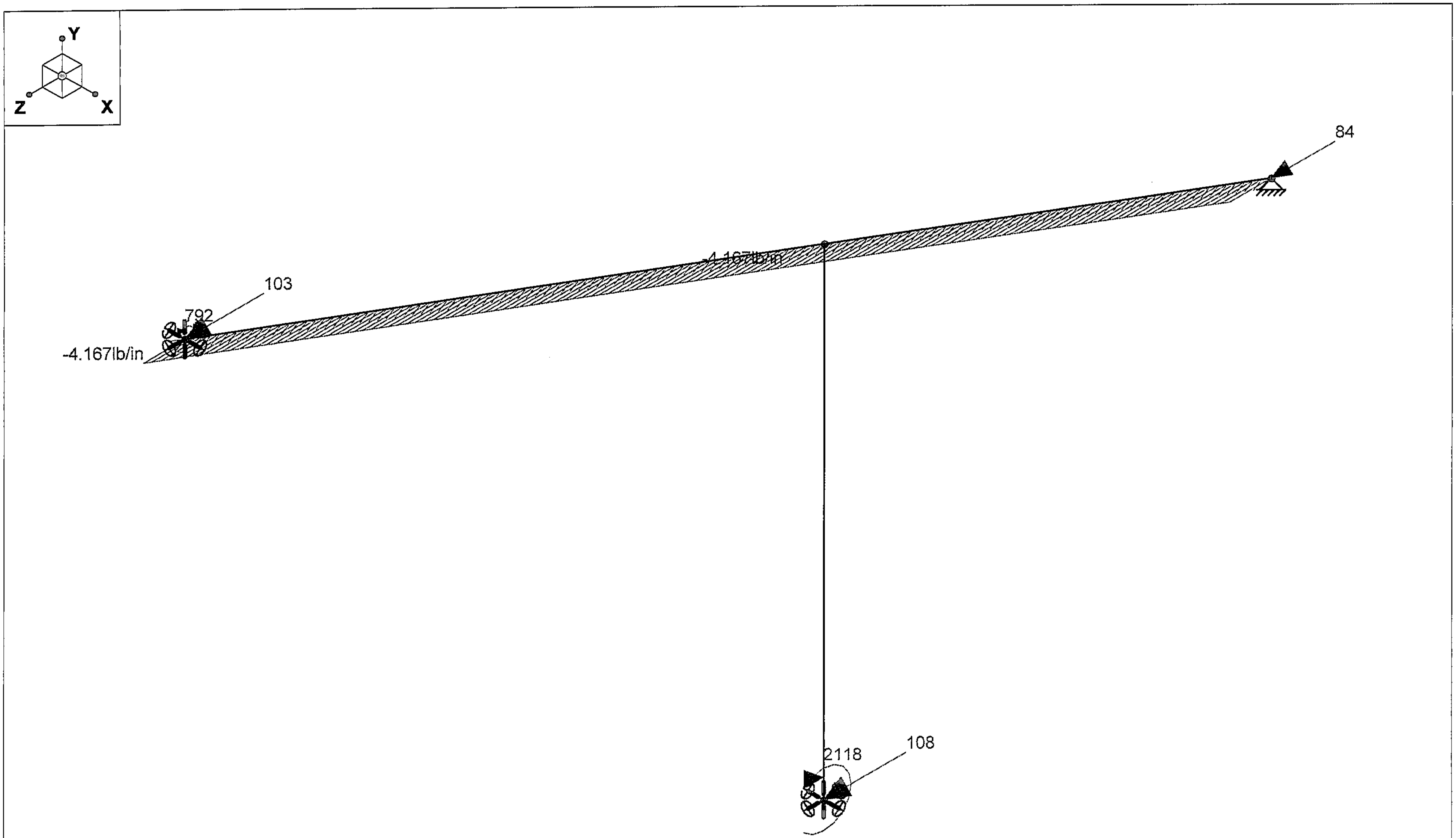
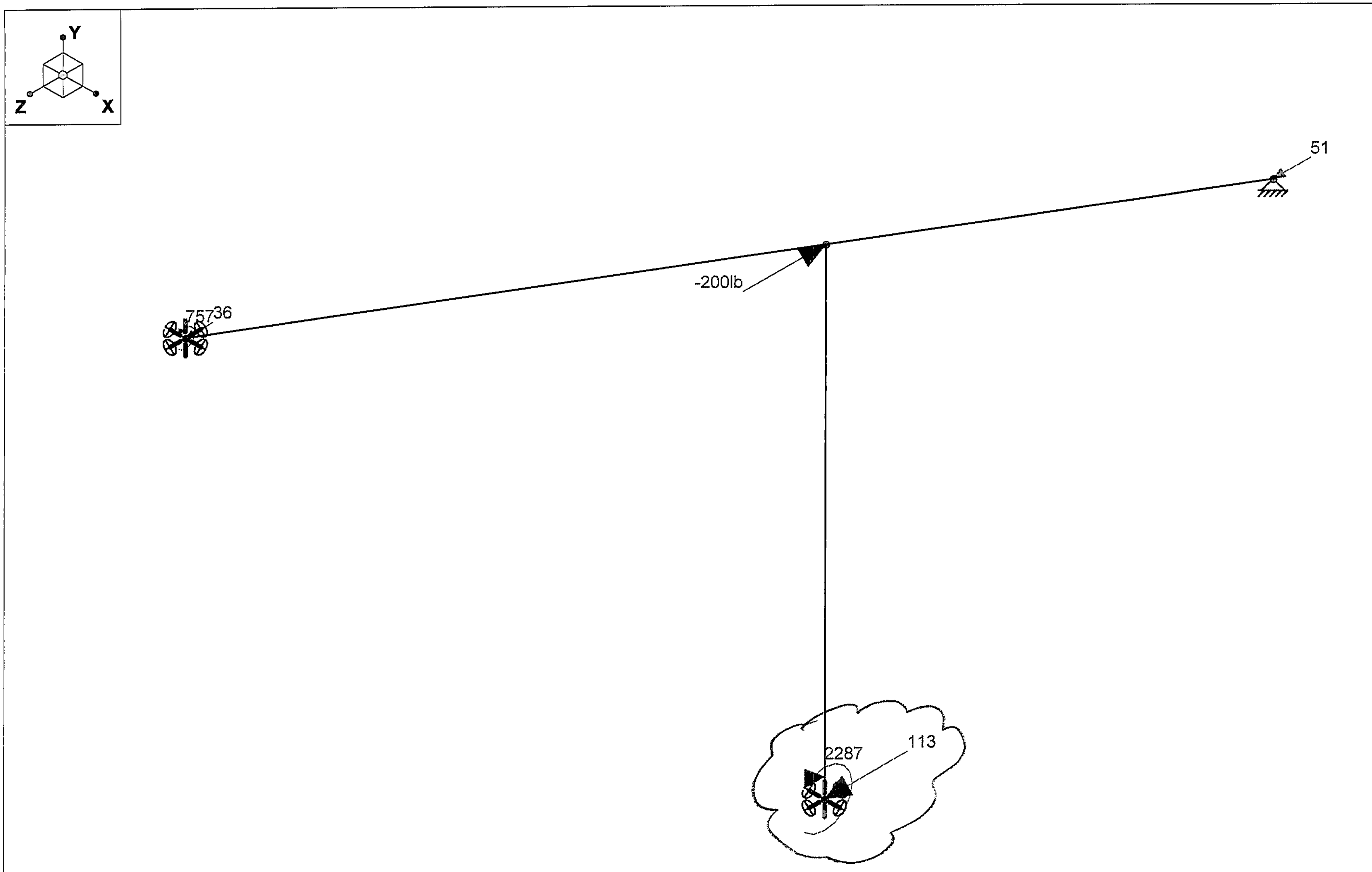
Template:	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H	
		Engineer: JDB	Sheet No: M2
		Date: 2/23/11	Rev:
		Chk By:	Date:



Loads: BLC 1,
Results for LC 1, Dist 1
Z-moment Reaction units are lb and lb-in

Rice Engineering	R0001 - RMR Standard Calcs	SK - 2
Joe Bauer		Feb 23, 2011 at 3:23 PM
R11-02-15H		Handrail Post Bracket.r3d

M2A



Loads: BLC 2,
Results for LC 2, Point
Z-moment Reaction units are lb and lb-in

Rice Engineering	R0001 - RMR Standard Calcs	SK - 3
Joe Bauer		Feb 23, 2011 at 3:24 PM
R11-02-15H		Handrail Post Bracket.r3d

M2B

Pipe Handrail

These calculations are based on emperical test data performed by Julius Blum & Co., Inc.

Wall or Grab Rail Analysis	SHT M3

Input Variables:

$F_H := 50$ $\frac{lb}{ft}$ Load Case 1 (Uniform Load)

$F_V := 0$ $\frac{lb}{ft}$ Simultaneous Vertical Uniform Load

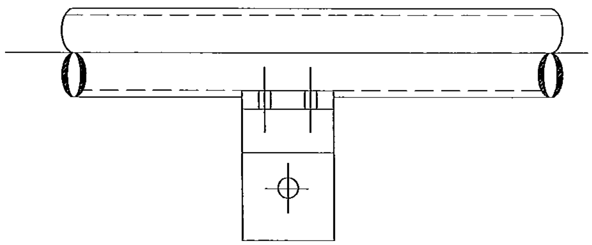
$P := 200$ lb Load Case 2 (Point Load)

$L := 60$ in **MAX BRACKET SPACING (cl to cl)**

Number of Railing Spans:

- 1 span ☑
- 2 span ☑
- 3 or more spans ☑

Railing Section:



- ☐ 1 1/4" Schd. 40
- ☐ 1 1/4" Schd. 80
- ☑ 1 1/2" Schd. 40
- ☐ 1 1/2" Schd. 80
- ☐ 1 1/2" tube
- ☐ 2" Schd. 40
- ☐ 2" Schd. 80

Railing Temper:

- ☑ 6105-T5 or 6061-T6
- ☐ 6063-T5

☐ *4/3 increase allowed*

All calculations below this line are automatic

Railing Properties

Ixr=	0.31
Iyr=	0.31
Sxr=	0.326
Syr=	0.326
R=	0.95
t=	0.145

Computational Factors

$K_1 := (8 \cdot q1) + (8 \cdot q2) + (9.5 \cdot q3)$ $K_1 = 8$

$K_2 := (4 \cdot q1) + (5 \cdot q2) + (5 \cdot q3)$ $K_2 = 5$

$K_3 := (48 \cdot q1) + (66 \cdot q2) + (87 \cdot q3)$ $K_3 = 66$

$E_r := 10100000$ psi

$I_{xtotr} := I_{xr}$ $I_{xtotr} = 0.31$ in^4

$I_{ytotr} := I_{yr}$ $I_{ytotr} = 0.31$ in^4

$S_{R1} := \frac{R_r}{t_r}$ $S_{R1} = 6.55$

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Template: REI-MC-5702			Engineer: JDB	Sheet No: M3
			Date: 2/23/11	Rev:
			Chk By:	Date:

Railing Analysis:

$W_h := \frac{F_H}{12}$ $W_v := \frac{F_V}{12}$

Wall or Grab Rail Analysis	SHT M3 A

Case 1 Uniform Load:

$\Delta_{yr1} := \frac{5 \cdot W_h \cdot L^4}{384 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr1} = 0.225$ in Modeled as a simple span

$\Delta_{xr1} := \frac{5 \cdot W_v \cdot L^4}{384 \cdot E_r \cdot I_{xtotr}}$ $\Delta_{xr1} = 0$ in

$\Delta_{allr} := \frac{L}{96}$ $\Delta_{allr} = 0.63$ in Per ASTM E985

$M_{yrmax} := \frac{W_h \cdot L^2}{K_1}$ $M_{yrmax} = 1875$ lb·in

$M_{xrmax} := \frac{W_v \cdot L^2}{K_1}$ $M_{xrmax} = 0$ lb·in

---

$f_{bry1} := \frac{M_{yrmax}}{S_{yr}}$ $f_{bry1} = 5752$ psi

$f_{brx1} := \frac{M_{xrmax}}{S_{xr}}$ $f_{brx1} = 0$ psi

Case 1 Point Load:

$\Delta_{yr2} := \frac{P \cdot L^3}{K_3 \cdot E_r \cdot I_{ytotr}}$ $\Delta_{yr2} = 0.209$ in

$M_{yrmax2} := \frac{P \cdot L}{K_2}$ $M_{yrmax2} = 2400$ lb·in

$f_{bry2} := \frac{M_{yrmax2}}{S_{yr}}$ $f_{bry2} = 7362$ psi

$F_{bry} := \begin{cases} (F_{bry1} \cdot 1.34) & \text{if IBC} = 1 \\ F_{bry1} & \text{otherwise} \end{cases}$ $F_{bry} = 25000$ psi

Calculation Results:

$Int_{r1} := \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right)$ $Int_{r1} = 0.23$

$Int_{r2} := \frac{f_{bry2}}{F_{bry}}$ $Int_{r2} = 0.29$

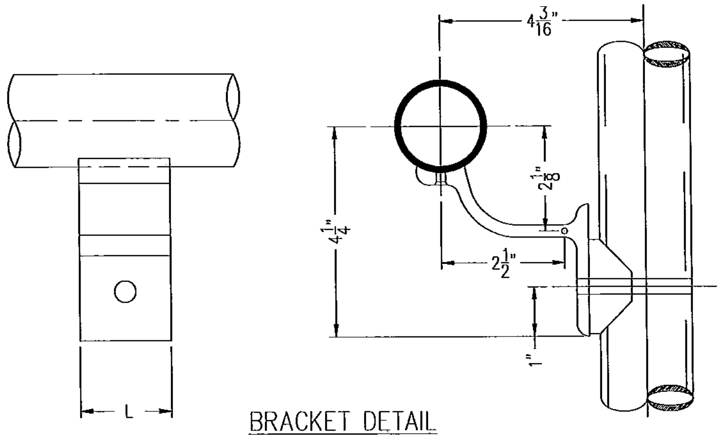
$RAILS := \begin{cases} \text{"OK"} & \text{if } \frac{\max(\Delta_{yr1}, \Delta_{xr1}, \Delta_{yr2})}{\Delta_{allr}} \le 1 \wedge \left(\frac{f_{brx1}}{F_{bry}}\right) + \left(\frac{f_{bry1}}{F_{bry}}\right) \le 1 \wedge \frac{f_{bry2}}{F_{bry}} \le 1 \\ \text{"FAIL"} & \text{otherwise} \end{cases}$ RAILS = "OK"

Grab Rail Bracket Analysis	SHT M4

Inputs:

$L_s := 60$	in	(bracket span)	$A := 3.0$	in
$w_h := 0$	plf	(horiz uniform load)	$B := 2.125$	in
$w_v := 50$	plf	(vert uniform load)	$C := 2.5$	in
$P := 200$	lb	(conc. load)	$D := 1.0$	in
$F_b := 28000$	psi	(Allowable Stress)	$H := 4.25$	in
			$L := 2$	in
			$t := 0.25$	in

☐ 4/3 Stress Increase Allowed



5' 0" Max Bracket Spacing

Horizontal Uniform Loading:

$R_1 := \frac{w_h \cdot L_s}{12}$ $R_1 = 0$ lbs

$M_1 := B \cdot R_1$ $M_1 = 0$ in-lb

Vertical Uniform Loading:

$R_2 := \frac{w_v \cdot L_s}{12}$ $R_2 = 250$ lbs

$M_2 := C \cdot R_2$ $M_2 = 625$ in-lb

$M_{b1} := M_1 + M_2$ $M_{b1} = 625$ in-lb

Concentrated Loading:

$M_{b2} := P \cdot B$ $M_{b2} = 425$ in-lb

$M_b := \max(M_{b1}, M_{b2})$ $M_b = 625$ in-lb

$$F_{b1} := \begin{cases} (F_b \cdot 1.34) & \text{if } IBC = 1 \\ F_b & \text{otherwise} \end{cases}$$

$t_{req} := \sqrt{\frac{6M_b}{F_{b1} \cdot L}}$ $t_{req} = 0.26$ in

Interaction:

$I := \frac{t_{req}}{t}$ $I = 1.04$ < 5% Over OK

Use Aluminum Rail Bracket, 6105-T5 or 6061-T6 Alloy, 2" Long

Anchorage to Post *(Horizontal Load Case)*:

$M_3 := H \cdot P$ $M_3 = 850$ in-lb

$T_p := \frac{M_3}{0.85D} + P$ $T_p = 1200$ lbs

$V := \max(R_2, 200)$ $V = 250$ lbs

$T_{all} := 3100 \cdot \frac{0.145}{0.341}$ $T_{all} = 1318$ lbs

$V_{all} := 1614$ lbs

$I_b := \left(\frac{T_p}{T_{all}}\right)^2 + \left(\frac{V}{V_{all}}\right)^2$ $I_b = 0.85$

Use (1) - 3/8" Dia. S.S. Thru Bolts
Cond "CW", Fy= 65 ksi

Bracket to Grab Rail Screws:

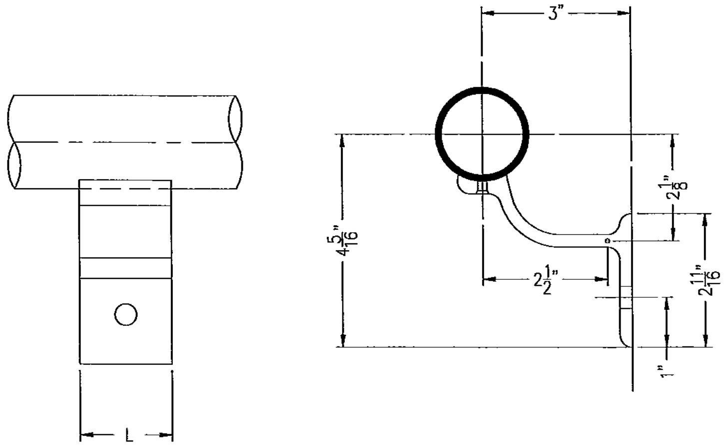
Use (2) #1/4-20 S.S. Fasteners "OK" per inspection

Wall Rail Bracket Analysis	SHT M5

Inputs:

$L_s := 60$	in	(bracket span)	$A := 2.5$	in
$w_h := 0$	plf	(horiz uniform load)	$B := 2.125$	in
$w_v := 50$	plf	(vert uniform load)	$C := 2.5$	in
$P := 200$	lb	(conc. load)	$D := 1.0$	in
$F_b := 28000$	psi	(Allowable Stress)	$H := 4.313$	in
			$L := 2$	in
☐ 4/3 Stress Increase Allowed			$t := 0.25$	in

ASSUME GROUT FILLED CMU DESIGNED BY OTHERS



BRACKET DETAIL

5' 0" Max Bracket Spacing

Horizontal Uniform Loading:

$R_1 := \frac{w_h \cdot L_s}{12}$ $R_1 = 0$ lbs

$M_1 := B \cdot R_1$ $M_1 = 0$ in-lb

Vertical Uniform Loading:

$R_2 := \frac{w_v \cdot L_s}{12}$ $R_2 = 250$ lbs

$M_2 := C \cdot R_2$ $M_2 = 625$ in-lb

Concentrated Loading:

$M_3 := P \cdot \max(B, C)$ $M_3 = 500$ in-lb

$M_b := \max(M_1, M_2, M_3)$ $M_b = 625$ in-lb

$F_{b1} := \begin{cases} (F_b \cdot 1.34) & \text{if } IBC = 1 \\ F_b & \text{otherwise} \end{cases}$

Note: Anchor Size, Type & Embedment

$t_{req} := \sqrt{\frac{6 \cdot M_b}{F_{b1} \cdot L}}$ $t_{req} = 0.26$ in

Interaction:

$I := \frac{t_{req}}{t}$ $I = 1.04$ < 5% OK

Use Aluminum Wall Bracket, 6105-T5 or 6061-T6 Alloy, 2" Long

Wall Anchorage *(Horizontal Load Case)*:

$M_4 := \max(P \cdot H, R_1 \cdot H, R_2 \cdot A)$ $M_4 = 863$ in-lb

$T_p := \frac{M_4}{D \cdot 0.85} + P$ $T_p = 1215$ lbs

$V := \max(R_2, 200)$ $V = 250$ lbs

$T_{all} := 1319$ lbs

$V_{all} := 2181$ lbs

$I_b := \left(\frac{T_p}{T_{all}}\right)^{1.67} + \left(\frac{V}{V_{all}}\right)^{1.67}$ $I_b = 0.9$

Use (1) - 1/2" Dia. S.S. Threaded Rod
W/ Hilti HIT-HY 150 MAX Adhesive
Edge Distance: 4"
End Distance: 4"
Embedment: 4-1/2"

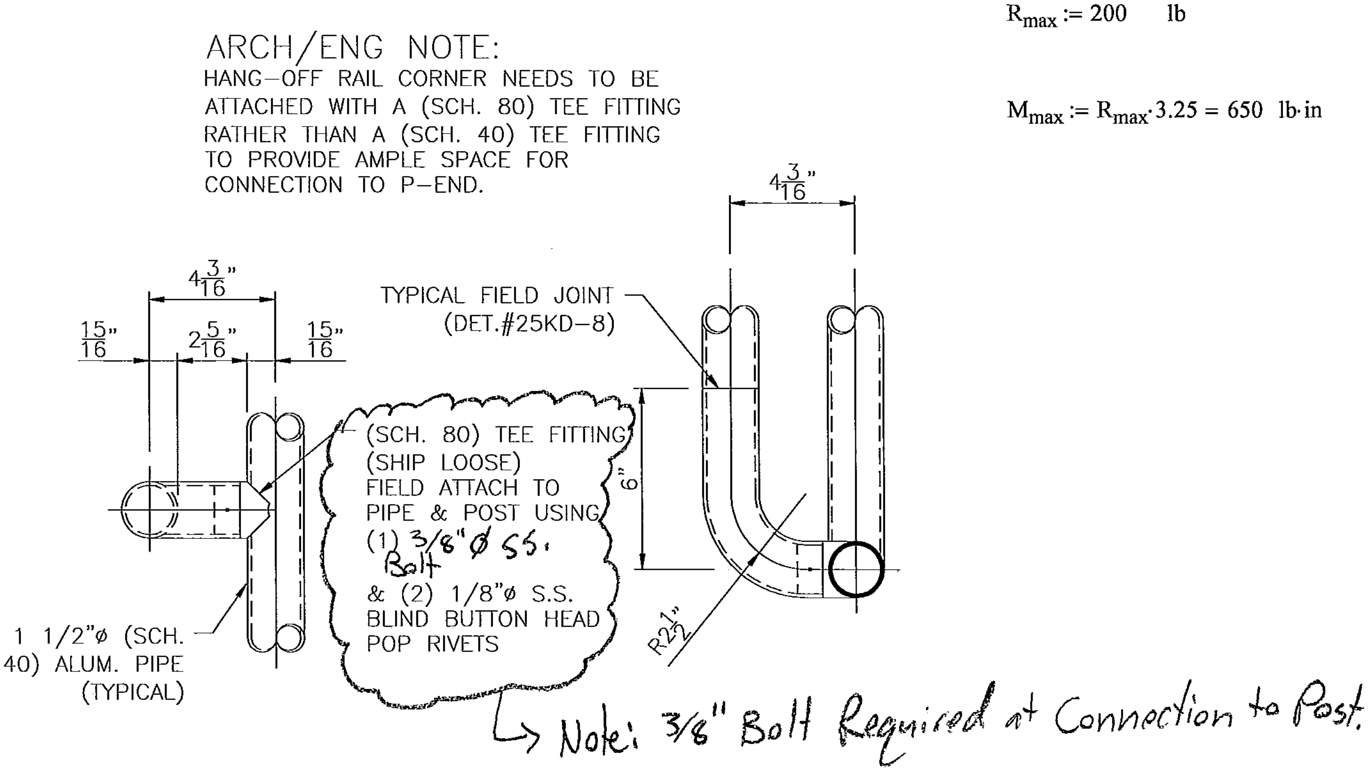
Bracket to Grab Rail Screws:

Use (2) #1/4-20 S.S. Fasteners "OK" per inspection

RICE ENGINEERING Template:	105 School Creek Trail Luxemburg, WI 54217 Phone: (920)845-1042 Fax: (920)845-1048 www.rice-inc.com	Project Description: R0001 - RMR Standard Calcs	Job No: R11-02-15H Engineer: JDB Date: 2/23/11 Chk By:	Sheet No: M5 Rev: Date:

$R_{max} := 200$ lb

$M_{max} := R_{max} \cdot 3.25 = 650$ lb·in



SPECIAL OFFSET RAIL CONNECTION

25KD-35E

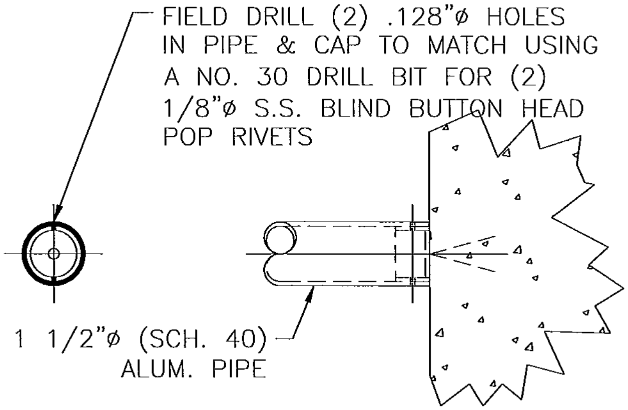
Chk Thru-Bolts @ Tee:

$$T := \frac{M_{max}}{1.9 \cdot 0.5} \qquad T = 684 \text{ lb}$$

$$T_{all} := 3100 \cdot \frac{0.145}{0.553} \qquad T_{all} = 813 \text{ lb}$$

Use (1) - 3/8" Dia. S.S. Bolt
Drill & Tap or Thru-Bolt
Cond "CW", Fy= 65 ksi
0.145" min. Thread Engagement

Wall Mount End Cap	SHT M7



CUSTOMER NOTE!
FILL VOID CAVITY IN CMU WITH GROUT @ ALL RAIL MOUNTING LOCATIONS.

WALL MOUNT END CAP

25KD-33

Chk Fasteners:

Use (2) 1/8" Dia. S.S. Blind Buton Head Pop Rivets
(OK By Inspection)

Chk End Cap:

Use End Cap as shown
(OK By Inspection)

Chk Anchors: (Assume Grout Filled CMU)

$R_{max} := 200$ lb

$V := \frac{R_{max}}{1}$ $V = 200$ lb

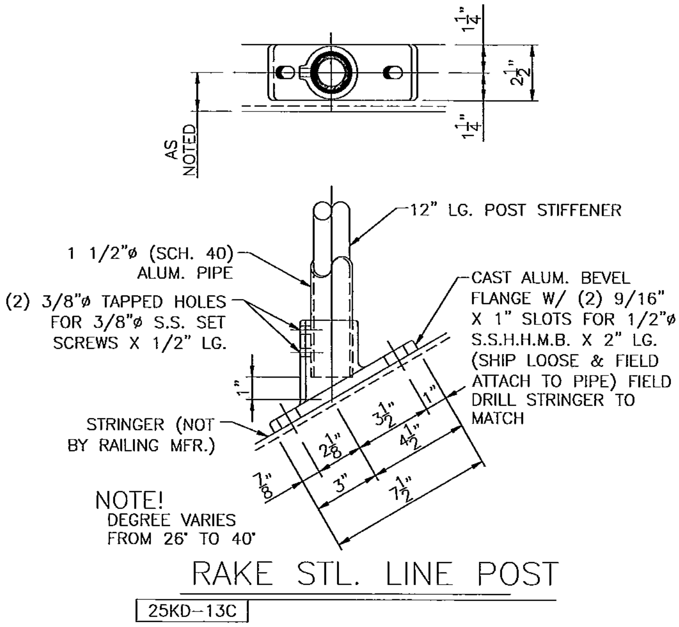
$V_{all} := 1419 \cdot 0.5$ $V_{all} = 710$ lb $V_{all2} := 380$ lb

Use (1) - 3/8" Dia. S.S. Threaded Rod w/ Hilti HIT-RE 500 MAX Adhesive
3-3/8" Min. Embedment
4" Min. Edge Distance

OR

Use (1) 1/4" Dia. S.S. Hilti Kwik Bolt 3
(300 Series S.S.)
1-1/8" Min. Embedment
4" Min. Edge Distance

Note: Values for HIT-RE 500 Epoxy Adhesive Based on HIT-HY 150 MAX Adhesive with a Safety Factor of 8



2-Bolt Raked Base Plate	SHT M8

$R_{max} := 250$ lb

$M := R_{max} \cdot 42 = 10500$ lb·in

$M_{max} := \cos(32deg) \cdot M = 8905$ lb·in

$d := 2.5$ in (sleeve dia.)

Note: Model based on 5'-0" max post spacing (measured along rail) and a post height of 3'-6" above bottom of base

Note: 6'-0" max post spacing (measured along rail) along rail and a post height of 2'-10" above bottom of base

$\frac{M}{34} = 309$ lb > $4.167 \cdot 72 = 300$ lb

Chk Bolts to Steel Stringer:

$V_b := \frac{R_{max}}{2}$ — $V_b = 125$ lb

$T_b := \frac{M_{max}}{2 \cdot 1.25}$ — $T_b = 3562$ lb

$V_{all} := 0.196 \cdot 23094$ — $V_{all} = 4526$ lb

$T_{all} := 0.142 \cdot 40000 \cdot \frac{0.375}{0.456}$ — $T_{all} = 4671$ lb

$I_3 := \left(\frac{V_b}{V_{all}}\right)^2 + \left(\frac{T_b}{T_{all}}\right)^2$ — $I_3 = 0.58$

<u>Use (2) - 1/2" Dia. S.S. Thru-Bolts</u>
<u>or Drill & Tap w/ 3/8" Min. Thread Engagement</u>
Condition "CW"

Chk shear on shoe wall:

$P := \frac{M_{max}}{0.67 \cdot (2.375)}$ — $P = 5596$ lb

$f_v := \frac{(P + R_{max})}{2 \cdot (0.315) \cdot (2)}$ — $f_v = 4640$ psi

$F_v := \frac{0.57 \cdot (18000)}{1.65}$ — $F_v = 6218$ psi

$I := \frac{f_v}{F_v}$ — $I = 0.75$ <u>Shear Stress "OK"</u>

Chk Aluminum Base Plate:

$L1 := 7.5$ in — $D1 := 1$ in

$L2 := 2.5$ in — $D2 := 1.25$ in

$t := 0.5$ in

$L := L1 - (2 \cdot D1)$ — $L = 5.5$ in

$P := \frac{M_{max}}{d}$ — $P = 3562$ lb

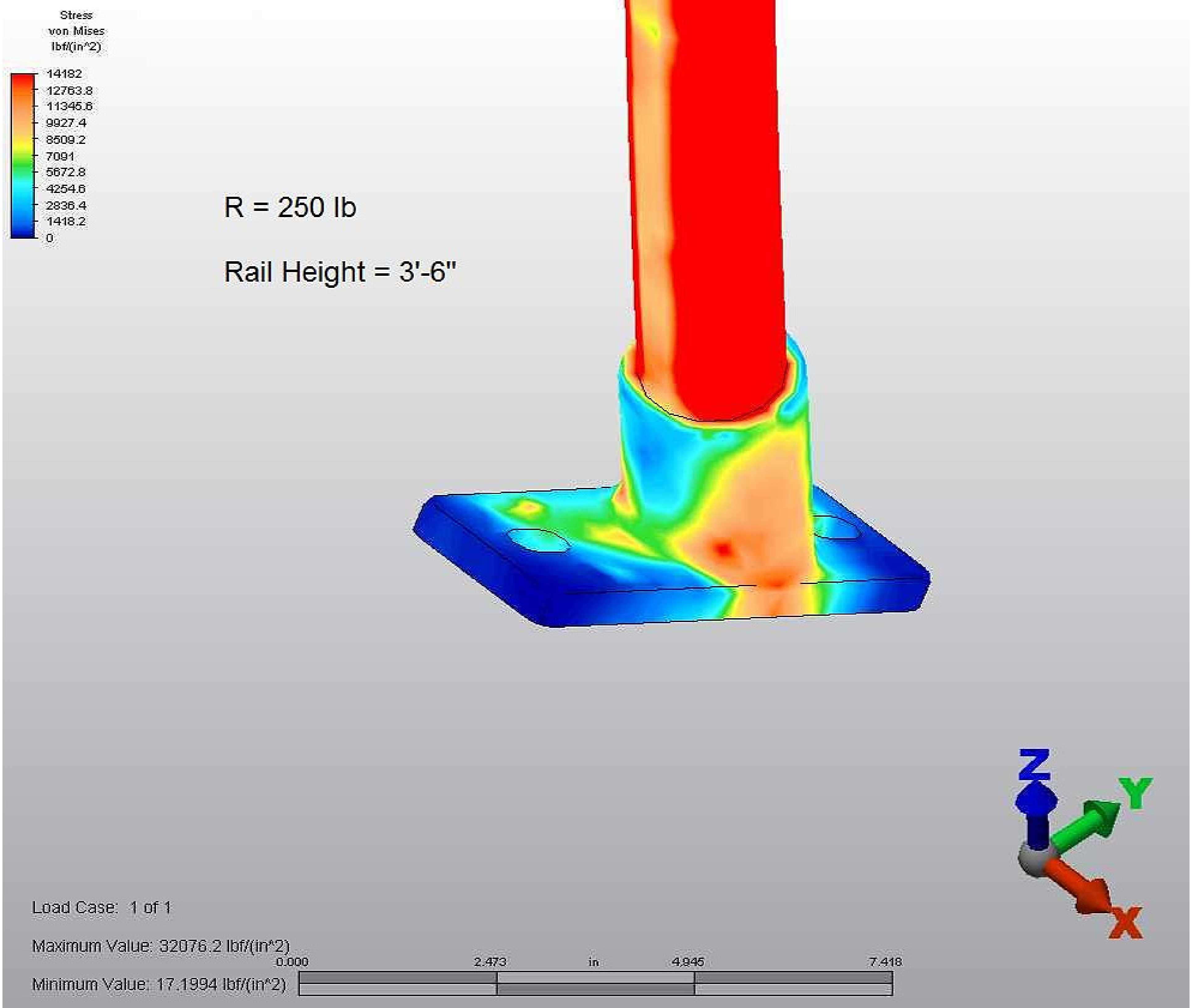
$\sigma_{max} := 14182$ psi *See Next Sheet For Model*

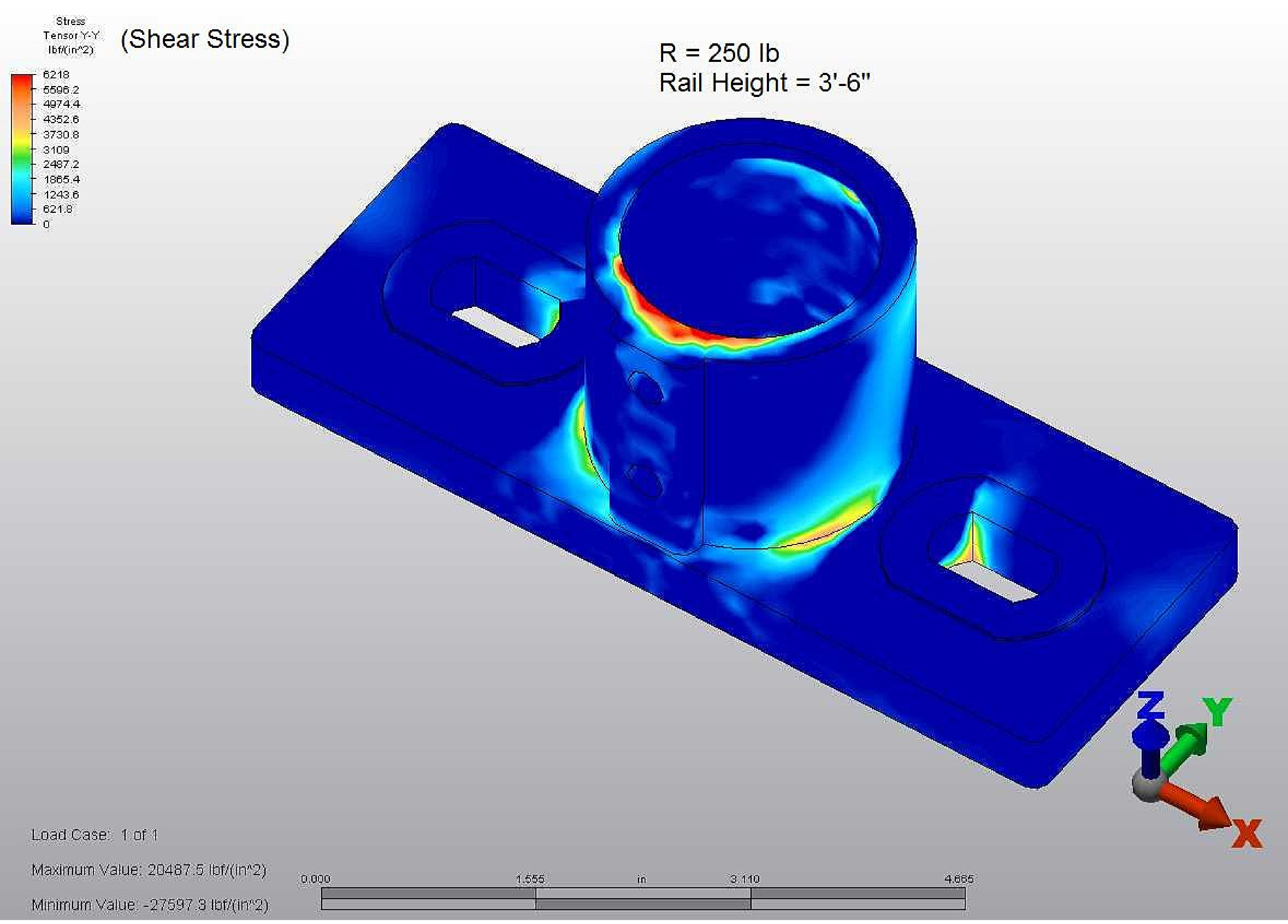
$\sigma_{all} := \frac{1.3 \cdot (18000)}{1.65}$ — $\sigma_{all} = 14182$ psi

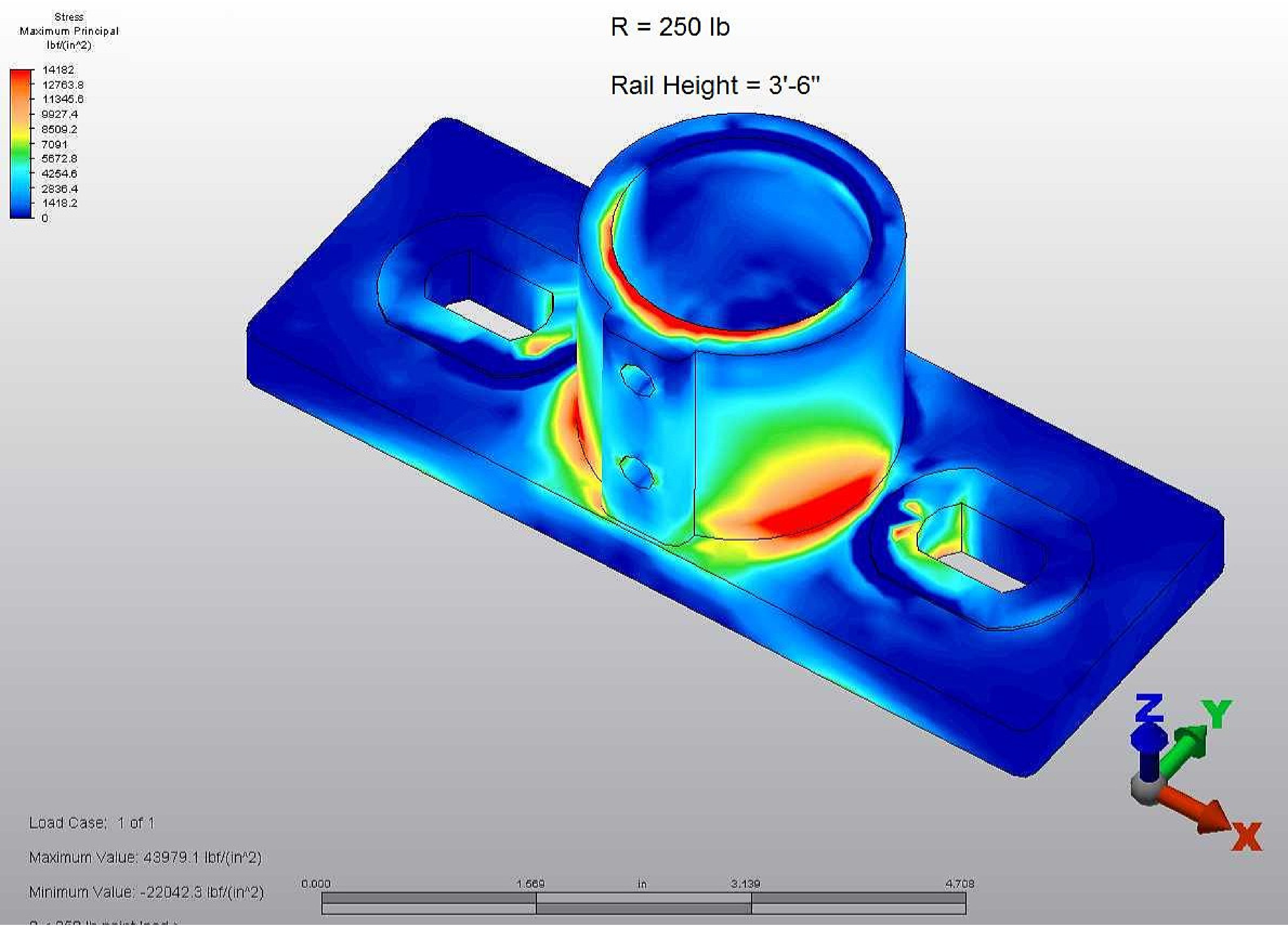
$I_2 := \frac{\sigma_{max}}{\sigma_{all}}$ — $I_2 = 1$

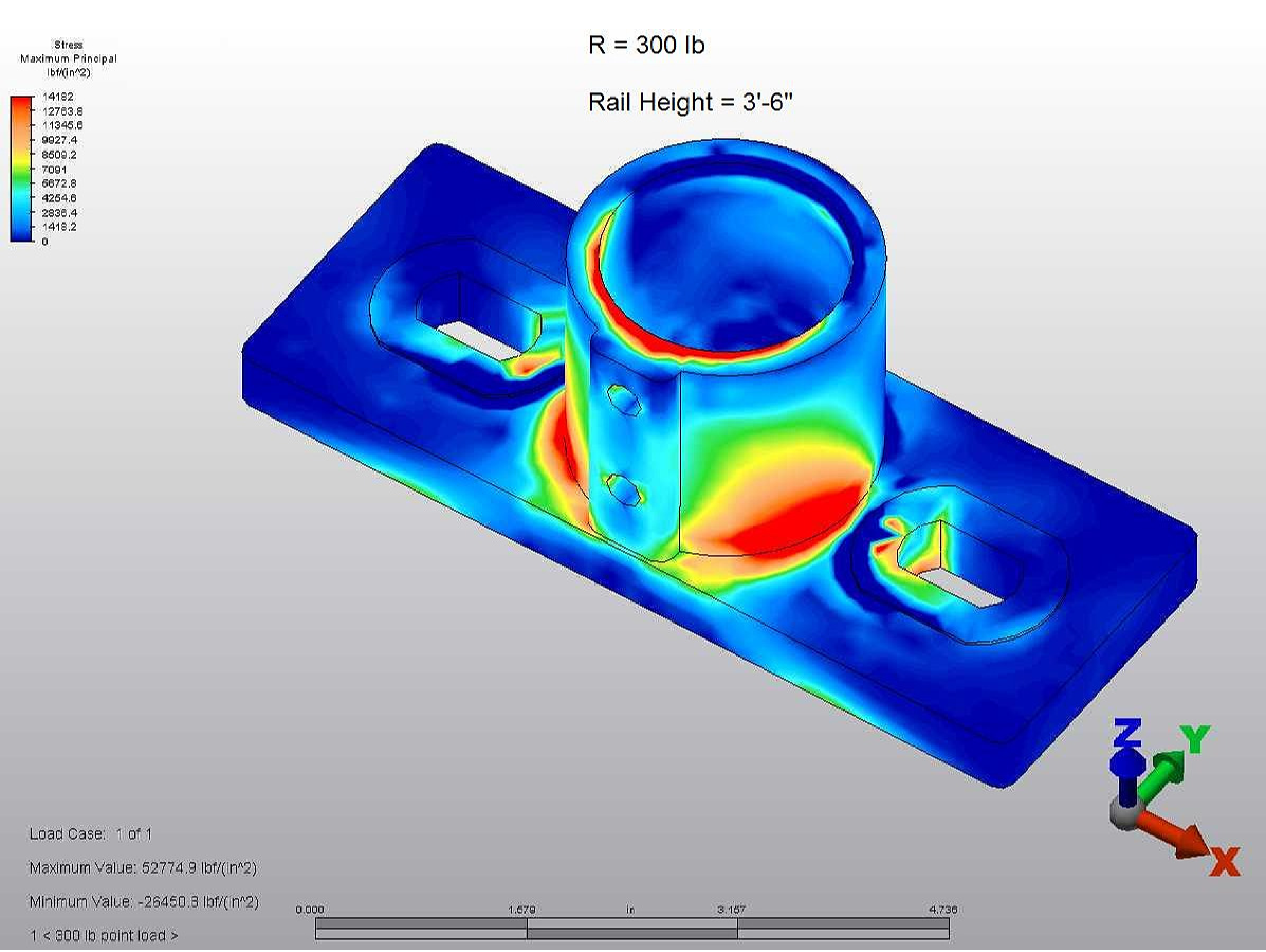
Note: Model based on 5'-0" max post spacing measured along rail and a post height of 3'-6"

<u>Use Cast Aluminum Base, as shown</u>
535 casting alloy, Fu= 35 ksi min.


Stress
von Mises
lbf/(in^2)
14182
12763.8
11345.6
9927.4
8509.2
7091
5672.8
4254.6
2836.4
1418.2
0
R = 250 lb
Rail Height = 3'-6"
Z
Y
X
Load Case: 1 of 1
Maximum Value: 32076.2 lbf/(in^2)
Minimum Value: 17.1994 lbf/(in^2)
0.000
2.473
in
4.946
7.418


Stress
Tensor Y-Y
lbf/(in^2)
(Shear Stress)
R = 250 lb
Rail Height = 3'-6"
6218
5596.2
4974.4
4352.6
3730.8
3109
2487.2
1865.4
1243.6
621.8
0
Z
Y
X
Load Case: 1 of 1
Maximum Value: 20487.5 lbf/(in^2)
Minimum Value: -27597.3 lbf/(in^2)
0.000
1.555
in
3.110
4.665


R = 250 lb
Rail Height = 3'-6"
Stress
Maximum Principal
lbf/(in^2)
14182
12763.8
11345.6
9927.4
8509.2
7091
5672.8
4254.6
2836.4
1418.2
0
Load Case: 1 of 1
Maximum Value: 43979.1 lbf/(in^2)
Minimum Value: -22042.3 lbf/(in^2)
0.000
1.569
in
3.139
4.708
Z
Y
X



R = 300 lb
Rail Height = 3'-6"
Stress
Maximum Principal
lbf/(in^2)
14182
12763.8
11345.6
9927.4
8509.2
7091
5672.8
4254.6
2836.4
1418.2
0
Load Case: 1 of 1
Maximum Value: 52774.9 lbf/(in^2)
Minimum Value: -26450.8 lbf/(in^2)
1 < 300 lb point load >
0.000
1.579
in
3.157
4.736
Z
Y
X

Spec Sheet	SHT S1

TABLE 11

STAINLESS STEEL - Alloy Groups 1, 2 and 3, Condition CW												
Nominal Thread Diameter & Thread/Inch	D Nominal Thread Diameter (Inch)	A(S) Tensile Stress Area (Sq. In.)	A(R) Thread Root Area (Sq. In.)	Allowable Tension (Pounds)	Allowable Shear		Bearing (Pounds)			Minimum Material Thickness to Equal Tensile Capacity of Fastener (In.)		
					Single (Pounds)	Double (Pounds)	1/8" St. A36	1/8" Al. 6063-T5	1/8" Al. 6063-T6	A36	6063-T5	6063-T6
#6-32	0.1380	0.0091	0.0078	364	180	360	1201	276	414	0.126	0.274	0.198
#8-32	0.1640	0.0140	0.0124	560	286	573	1427	328	492	0.162	0.368	0.251
#10-24	0.1900	0.0175	0.0152	700	351	702	1653	380	570	0.170	0.372	0.287
#12-24	0.2160	0.0242	0.0214	968	494	958	1879	432	648	0.200	0.450	0.321
1/4-20	0.2500	0.0318	0.0280	1272	647	1293	2175	500	750	0.226	0.541	0.360
5/16-18	0.3125	0.0524	0.0469	2096	1083	2166	2719	625	938	0.284	***	0.459
3/8-16	0.3750	0.0775	0.0699	3100	1614	3229	3262	750	1125	0.341	***	0.553
7/16-14	0.4375	0.1063	0.0961	4252	2219	4439	3806	875	1313	0.395	***	0.642
1/2-13	0.5000	0.1419	0.1292	5676	2984	5967	4350	1000	1500	0.456	***	0.745
9/16-12	0.5625	0.1819	0.1664	7276	3843	7686	4894	1125	1688	0.510	***	0.836
5/8-11	0.6250	0.2260	0.2071	9040	4783	9566	5437	1250	1875	0.553	***	0.923
3/4-10	0.7500	0.3345	0.3091	11289	6023	12046	6525	1500	2250	0.590	***	0.963
7/8-9	0.8750	0.4617	0.4286	15582	8352	16703	7612	1750	2625	0.666	***	1.123
1-8	1.0000	0.6057	0.5630	20442	10970	21941	8700	2000	3000	0.778	***	1.276

	DIAMETER Up Thru 5/8"	DIAMETER 3/4" and Over
F_u (Min. Ultimate Tensile Strength)	110,000 psi	85,000 psi
F_y (Min. Tensile Yield Strength)	65,000 psi	45,000 psi
F_t (Allowable Tensile Stress)	40,000 psi	33,750 psi
F_v (Allowable Shear Stress)	23,094 psi	19,486 psi

$$A(R) = 0.7854\left(D - \frac{1.2269}{N}\right)^2$$

$$A(S) = 0.7854\left(D - \frac{0.9743}{N}\right)^2$$

For Diameters Up Thru 5/8":

$$F_t = 0.40F_u$$

$$\text{Allowable tension} = 0.40F_u[A(S)]$$

$$F_v = \frac{0.40}{\sqrt{3}}F_u$$

$$\text{Allowable shear (Single)} = \frac{0.40}{\sqrt{3}}F_u[A(R)]$$

For Diameters 3/4" and Over:

$$F_t = 0.75F_y$$

$$\text{Allowable tension} = 0.75F_y[A(S)]$$

$$F_v = \frac{0.75}{\sqrt{3}}F_y$$

$$\text{Allowable shear (Single)} = \frac{0.75}{\sqrt{3}}F_y[A(R)]$$

In Tables 9 thru 15, for Group Type and Condition Definitions see pages 22 and 23.

TABLE 27 TEKS –

STAINLESS STEEL - Alloy Groups 1, 2 and 3, Condition CW												
Nominal Thread Diameter & Thread/Inch	D Nominal Thread Diameter (Inch)	K Basic Minor Diameter (Inch)	A(R) Thread Root Area (Sq. In.)	Allowable Tension (Pounds)	Allowable Shear		Bearing (Pounds)			Minimum Material Thickness to Equal Tensile Capacity of Fastener (In.)		
					Single (Pounds)	Double (Pounds)	1/8" St. A36	1/8" Al. 6063-T5	1/8" Al. 6063-T6	A36	6063-T5	6063-T6
#6-20	0.1380	0.0997	0.0078	312	180	360	1201	276	414	0.112	0.240	0.174
#8-18	0.1640	0.1257	0.0124	496	286	573	1427	328	492	0.147	0.329	0.235
#10-16	0.1900	0.1309	0.0152	608	351	702	1653	380	570	0.153	0.328	0.238
#12-14	0.2160	0.1649	0.0214	856	494	958	1879	432	648	0.182	0.403	0.289
1/4-14	0.2500	0.1887	0.0280	1120	647	1293	2175	500	750	0.205	0.449	0.323
5/16-12	0.3125	0.2443	0.0469	1876	1083	2166	2719	625	938	0.260	0.627	0.416
3/8-12	0.3750	0.2983	0.0699	2796	1614	3229	3262	750	1125	0.313	0.763	0.505

F_u (Minimum Ultimate Tensile Strength)	100,000 psi
F_y (Minimum Tensile Yield Strength)	65,000 psi

$$A(R) = .7854K^2$$

Where: A(R) = Thread Root Area, sq. in.
K = Basic Minor Diameter, in.

$$F_t = 0.40F_u$$

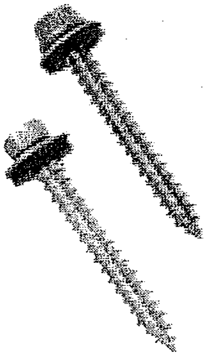
$$\text{Allowable tension} = 0.40F_u[A(R)]$$

$$F_v = \frac{0.40}{\sqrt{3}}F_u$$

$$\text{Allowable shear (Single)} = \frac{0.40}{\sqrt{3}}F_u[A(R)]$$

304 SS & CARBON TAPPERS

Selector Guide



Carbon Steel Electro Zinc Part #	304 Series Electro Zinc Part #	Description	Carbon Steel Box Qty.	304 SS Box Qty.
1874200	1863000	14 x 3/4" HWH W/ BD Type A Tappers	2,500	2,500
1875200	1864000	14 x 1" HWH W/ BD Type A Tappers	2,500	2,500
1877200	1866000	14 x 1-1/2" HWH W/ BD Type A Tappers	2,000	2,000
1879200	--	14 x 2" HWH W/ BD Type A Tappers	1,500	1,500
1880200	--	14 x 2-1/2" HWH W/ BD Type A Tappers	1,000	1,000
1881200	--	14 x 3" HWH W/ BD Type A Tappers	1,000	750
1886200	--	17 x 3/4" HWH W/ BD Type A Tappers	2,500	2,000
1887200	--	17 x 1" HWH W/ BD Type A Tappers	--	2,000

Performance Data

with Bonded Washer		PULLOUT VALUES (avg. lbs ultimate)						
		Gauge	26	24	22	20	18	16	14
Fastener		Thickness	0.018	0.024	0.030	0.036	0.048	0.060	0.075
14	Type A	Drill Size	1/8"	5/32"	5/32"	3/16"	3/16"	#7	#7
			191	252	336	371	545	694	884
Fastener		Gauge	26	24	22	20	18	16	14
		Thickness	0.018	0.024	0.030	0.036	0.048	0.060	0.075
17	Type A	Drill Size	1/8"	5/32"	5/32"	3/16"	#2	#2	1/4"
			263	307	425	475	559	791	

with Bonded Washer		PULLOVER VALUES (avg. lbs ultimate)							
		Gauge	26	24	22	20	18	16	14
Fastener		Thickness	0.018	0.024	0.030	0.036	0.048	0.060	0.075
14	Type A	Drill Size	1/8"	5/32"	5/32"	3/16"	3/16"	#7	#7
			595	827	1093	1341	1931	2229	2696
Fastener		Gauge	26	24	22	20	18	16	14
		Thickness	0.018	0.024	0.030	0.036	0.048	0.060	0.075
17	Type A	Drill Size	1/8"	5/32"	5/32"	3/16"	#2	#2	1/4"
			565	792	970	1100	1556	1813	2065

with Bonded Washer		SHEAR VALUES (avg. lbs ultimate)					
Fastener		Gauge	26-14	24-14	22-14	20-14	18-14
14	Type A	Drill Size	#7	#5	#2	#2	0.234"
			534	704	863	1245	2120
Fastener		Gauge	26-18	24-18	22-14	20-14	18-14
17	Type A	Drill Size	#2	1/4"	1/4"	1/4"	1/4"
			454	1013	1264	1544	1294

304 SS FASTENER VALUES (avg. lbs ultimate)

Fastener (dia-tpi)	Tensile (lbs min.)	Shear (avg. lbs ult.)	Torque (min. in lbs)
14-10	2684	2148	127
17-9	N/A	N/A	229

CARBON STEEL FASTENER VALUES (avg. lbs ultimate)

Fastener (dia-tpi)	Tensile (lbs min.)	Shear (avg. lbs ult.)	Torque (min. in lbs)
14-10	4060	2600	150
17-9	5000	2750	173

Tools and Techniques

- A standard screwgun with a depth sensitive nosepiece should be used to install Tappers. For optimal fastener performance, the screwgun should be a minimum of 6 amps and have an RPM range of 0-2500.
- Adjust the screwgun nosepiece to properly seat the fastener.
- New magnetic sockets must be correctly set before use. Remove chip build-up as needed.
- The fastener is fully seated when the head is flush with the work surface.
- Overdriving may result in torsional failure of the fastener or stripout of the substrate.
- The fastener must penetrate beyond the metal structure a minimum of 3 pitches of thread.

ITW Buildex

1349 West Bryn Mawr Avenue
Itasca, Illinois 60143
630-595-3500 Fax: 630-595-3549
www.itwbuildex.com

LOADS TESTINGS AND

STRUCTURAL CALCULATIONS

FOR

GUARD RAILINGS

W.P.C.P. PHASE II DIGESTERS 12 13 14 15 & 16
SAN JOSE, CALIFORNIA

ROCKY MOUNTAIN RAILINGS
11939 EAST 51ST AVENUE
DENVER, COLORADO 80239

PROJECT NUMBER
R1376

COLORADO REGISTERED
ROY E. WOOTEN
7232
PROFESSIONAL ENGINEER
8/12/09

ROY E. WOOTEN and ASSOCIATES
• CONSULTING ENGINEERS •

7585 West Arkansas Avenue, Suite 206 - Lakewood, Colorado 80232 - Phone (303)980-8603 Fax (303)980-8647

ROY E. WOOTEN and ASSOCIATES

• Consulting Engineers • **wootenrp@aol.com**

7585 West Arkansas Avenue, Suite 206, Lakewood, CO 80232, Ph. (303)980-8603 Fax (303)980-8647

August 12, 2009

Mr. Scot Hooper
Rocky Mountain Railings
11939 East 51st Avenue
Denver, Colorado 80239

REFERENCE: RMR NO. R1376
SAN JOSE, CALIFORNIA

Dear Mr. Hooper,

At your request, full size tests were conducted on August 7, 2009 as required by the City of San Jose, California. The purpose of the tests is to verify the adequacy of rails, posts, fittings and bases associated with the subject project. The tests were conducted at the facilities of Reliance Industries, LLC, 10790 W. 50th Avenue, Wheat Ridge, Colorado 80033, specifically, lead engineer Daniel Adam in conjunction with you and me as coordinates and observers. The following tests were conducted with results tabulated:

1. **Post and Base Connections** – 1-1/2" Ø schedule 40, 6005-T5 with 12" standard stiffeners in 16E 5"x 5", four (4) hole base mounts with ½" Ø T 316 stainless steel machine bolts anchored to a W10 x 33 steel beam. Posts were spaced 12'-0 apart and loads applied with a calibrated hydraulic ram system. Ram was supported on a pipe to minimize the dead load influence to the system. Deflections were measured to the nearest 1/16" and compared with calculated deflections assuming a fixed base condition. Measure deflections at all loads, i.e., 200 lb., 250 lb., and 300 lb. were 2 + times greater than calculated loads as would be expected due to minor looseness in pipe-to-base mount fitting. Also some rotation of the fitting occurs as load is applied and the base collar and ½" plate deflects due to bolt spacing, 3-1/2" x 3-1/2". See 16E drawing sketches.

2. **Post and Base Connections** – West post is 1-1/2" Ø schedule 80 in 16 H 5" x 8" four (4) bolt base; East post is unstiffened 1-1/2"Ø schedule 40 in 2-5/8" x 7" 2-bolt 11C base. Posts are spaced 12'-6 o.c. and bases anchored to the W10 x 33 beam with 1/2" Ø T 316 stainless steel machine bolts. Anchor bolt spacing of 16H base is 6-1/4" x 3-1/2"; Bolt spacing of 11C base is 4-3/8". Hydraulic ram is supported on pipe to negate dead load influence. Loads of 200 lbs, 250 lbs, and 300 lbs. were applied and overall lengths of deflected posts measured and individual post deflection calculated by inverse I ratio. These proportioned measured deflections were compared to fixed base calculated deflections. Measured proportioned deflections were 2-3/4 + times calculated deflection for Schedule 80 posts, all loads and 2-

3/4 +/- for 200 lb. and 250 lb. load on Schedule 40 post. At 300 lbs., Schedule 40 post measured deflection jumped to 3-3/8 times calculated. The 11C base fitting went from elastic stress range into plastic and ¼" measured permanent base plate deformation was measured. The increased measured deflection of both posts and bases is probably due to the winder bolt spacing allowing more rotation of the ½" thick base plate/collar sections as compared to Test 1.

3. **Continuous Top Rail Splice/Expansion Joint Connection** – Top rail is 1-1/2" Ø Sch 40, 6005 TS connected to four 1-1/2" Ø posts, 3 spaces at 6'-0 o.c. and 8" overhang each end. West rail length is 12"-2 and east rail length is 7'-2. Splice/expansion joint is standard 6" from east mid post. Test loads of 300 plus pounds are applied to middle 6'-0 span at 6", 1'-6, 2'-6, 3'-6, 4'-6 and 5'-6 from west mid post. Center deflection was measured to nearest 1/16" as each load was recorded and visual inspection of the splice/expansion joint to check for displacement. Only visual displacement was observed at 340 lb. load applied just west of joint, i.e., 5'- 5-7/8". Splice joint flat head #20 screws removed from west side to form expansion joint condition then reloaded to 340 lb. Maximum vertical displacement was less than 1/64" visually, approximately the fit differential between the ID of the rail and the OD of the fitting, i.e., 1.610" vs 1.596".

In summary, the results of the tests substantiate the calculated performance of the products, rails, posts, fittings, anchorages, connectors, etc., of the Rocky Mountain Railing System for the San Jose, California W.P.C.P., Phase II Project, Job No. R1376. We did not test post installed concrete anchors since these are special proprietary products requiring ICC testing and approval for each Supplier's systems. Base mount 11C is not part of the San Jose package but was tested to check the calculated performance.

Since both, 16E and 16H, four (4) bolts base mount fittings are being considered for the project and both previously submitted for review and comment, the final acceptance will be by the City of San Jose personnel individual preference. Both are adequate. Actual field deflections will be less than those measured since global geometry, i.e., used on circular tanks, will allow deflections to be resisted by axial tension or compression of the top rail system.

Let me know if any clarification or additional backup data is requested.

Very truly yours,

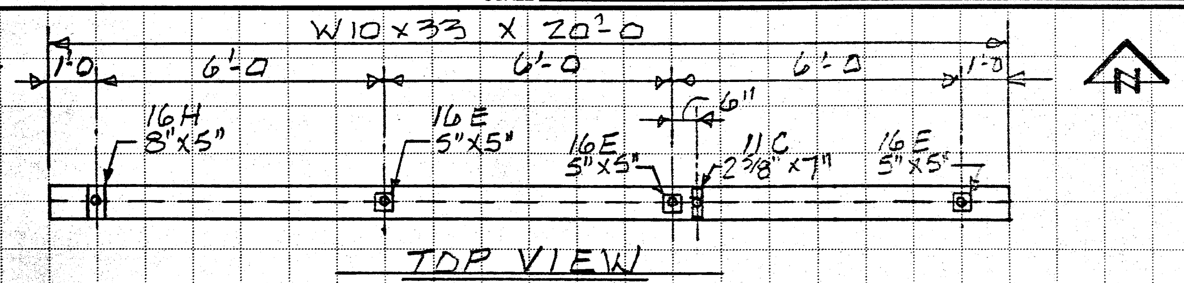
Roy E. Wooten, P.E.

COLORADO REGISTERED PROFESSIONAL ENGINEER
ROY E. WOOTEN
7232
8/12/09

Attachments

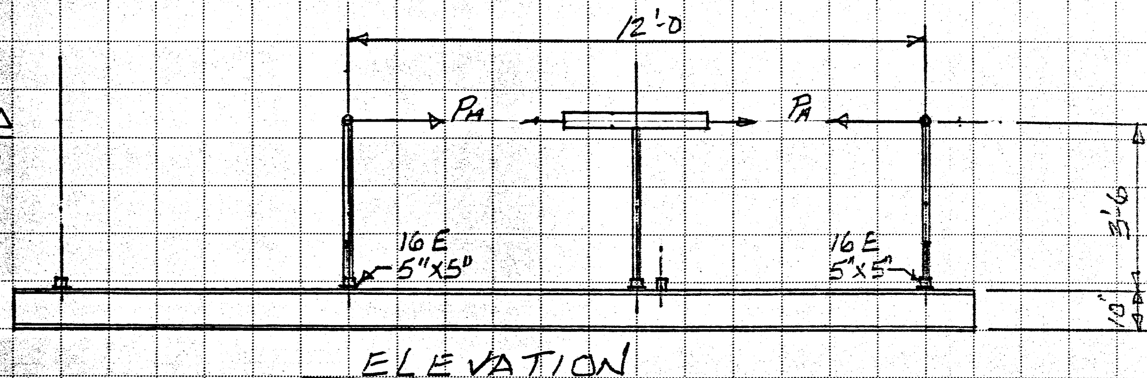
ROY E. WOOTEN AND ASSOCIATES
Consulting Engineers
7585 W. Arkansas Ave., #206
Lakewood, Colorado 80232
(303) 980-8603

JOB RMR No. R1376, San Jose, CA 20941
SHEET NO. 1 OF 1
CALCULATED BY REW DATE 08/11/09
CHECKED BY DATE
SCALE 1/4" = 1'-0



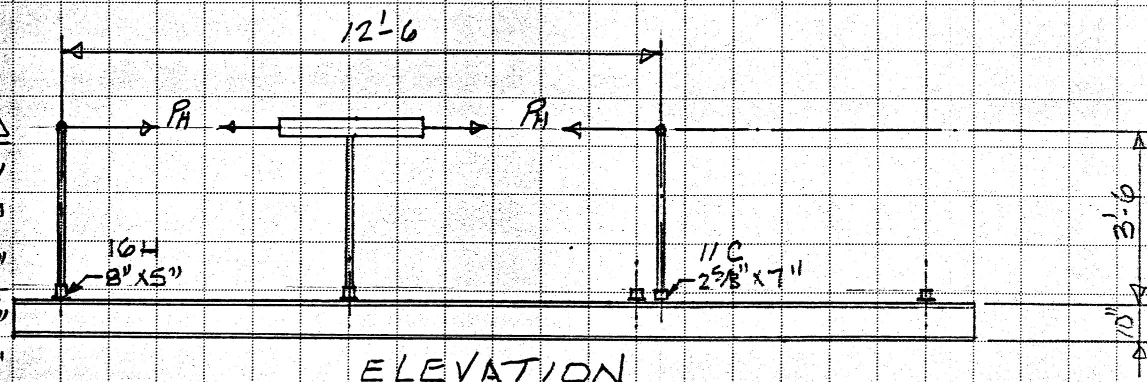
TEST No. 1

P_H	DEFL Δ	CALC Δ
200 lb	2 1/2"	1.22"
250 lb	3 1/8"	1.53"
300 lb	3 3/4"	1.83"



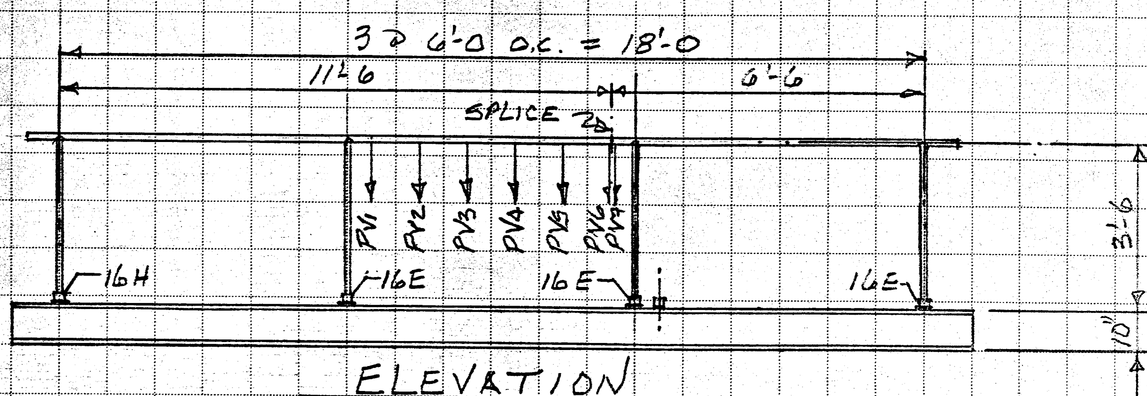
TEST No. 2

P_H	SCH 80 DEFL Δ	SCH 80 CALC Δ
200 lb	3 7/16"	1.251"
250 lb	4 7/16"	1.563"
300 lb	5 1/4"	1.876"
SCH 40	SCH 40	SCH 40
200 lb	4 5/16"	1.625"
250 lb	5 9/16"	2.030"
300 lb	8 1/4"	2.437"



TEST No. 3

P_V	LOAD	DEFL. ℄	
1	340 lb	0	
2	320 lb	1/4"	
3	320 lb	3/8"	
4	320 lb	3/8"	
5	350 lb	3/16"	
6	340 lb	0	SPLICE
7	340 lb	0	EXP. JOINT



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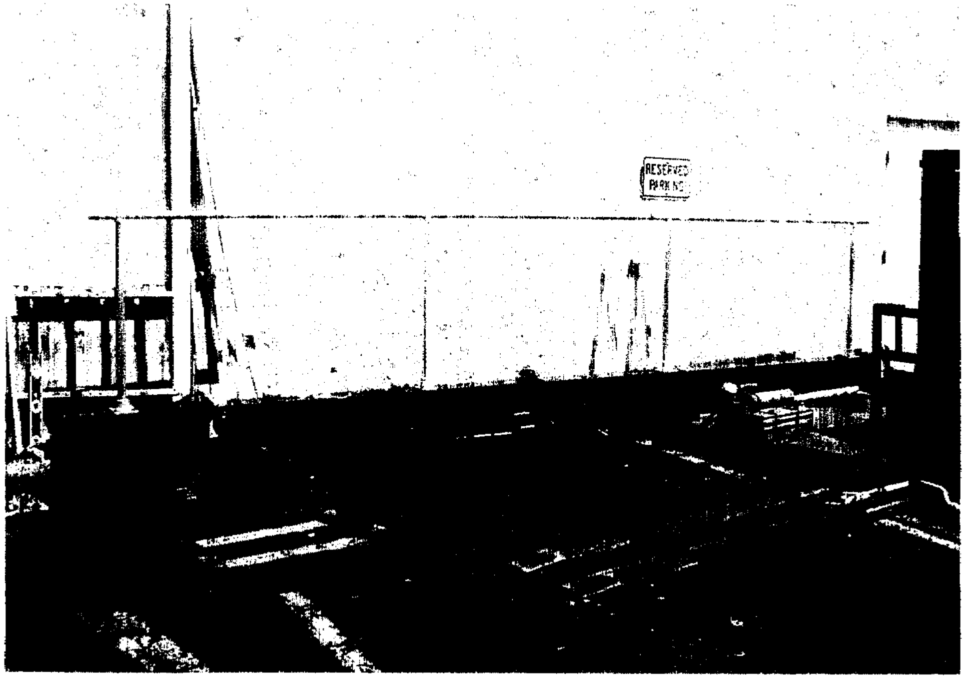

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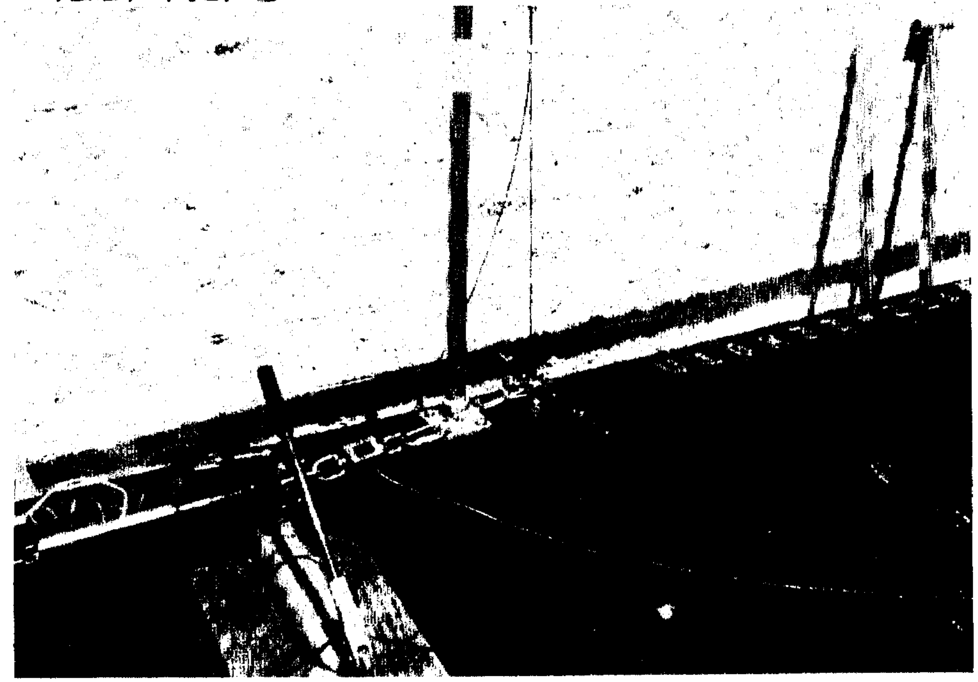

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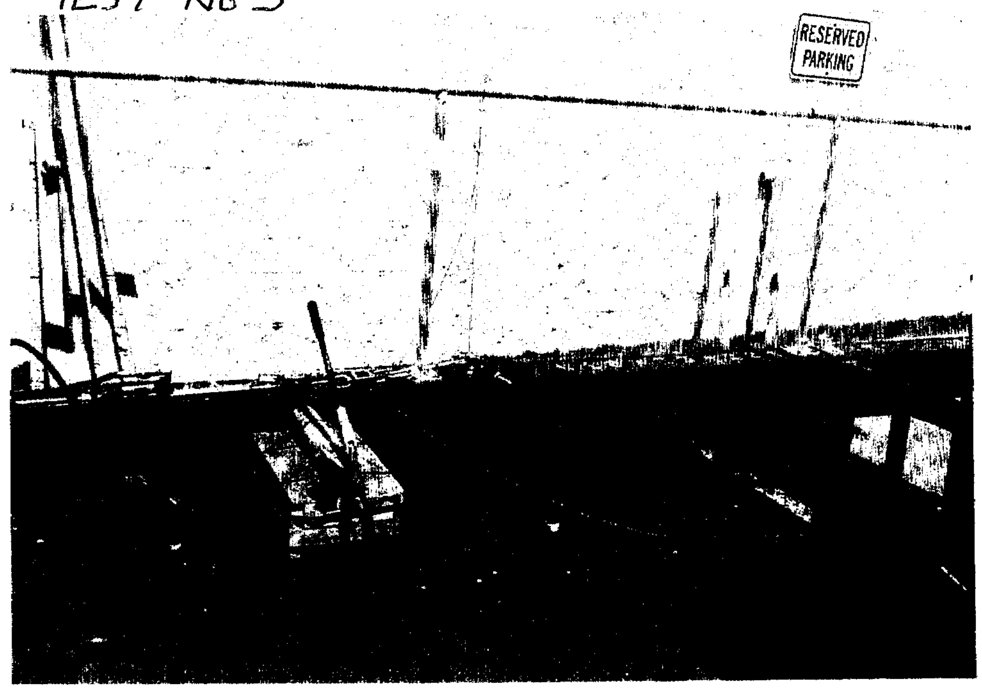

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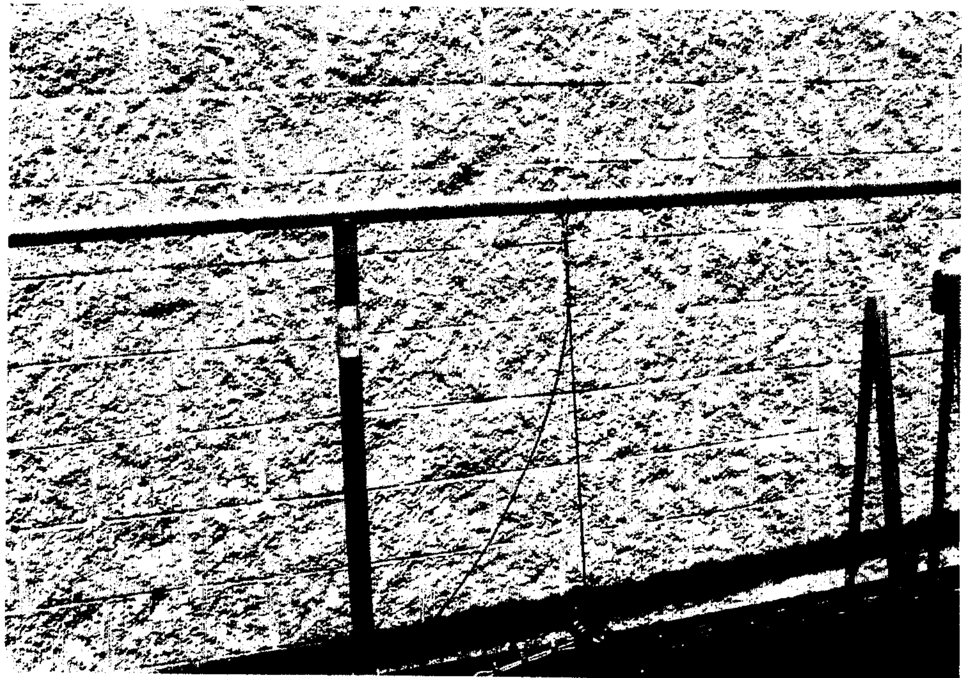

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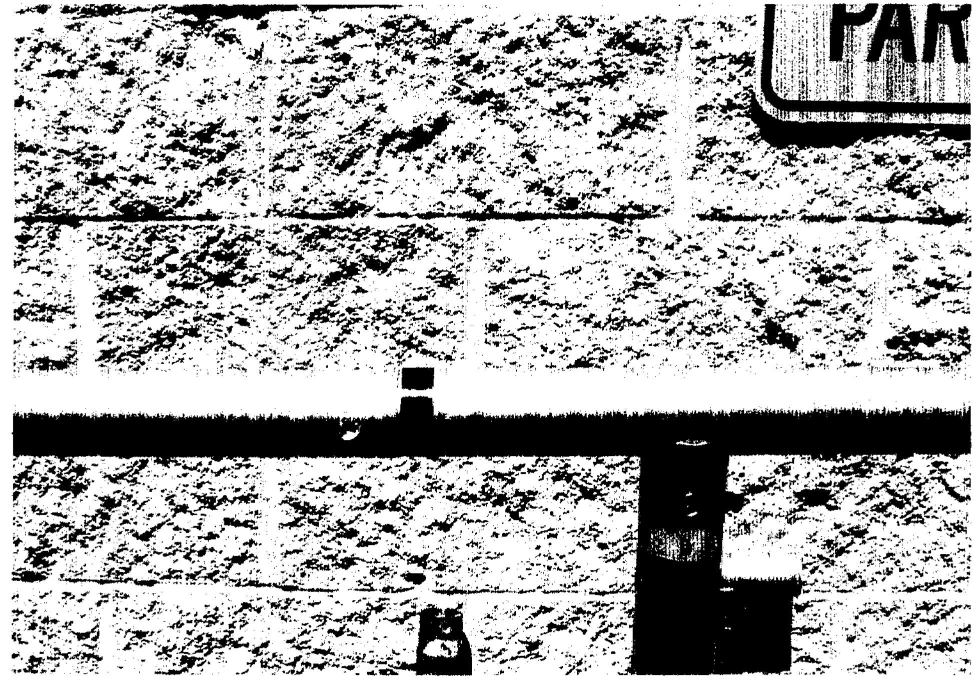

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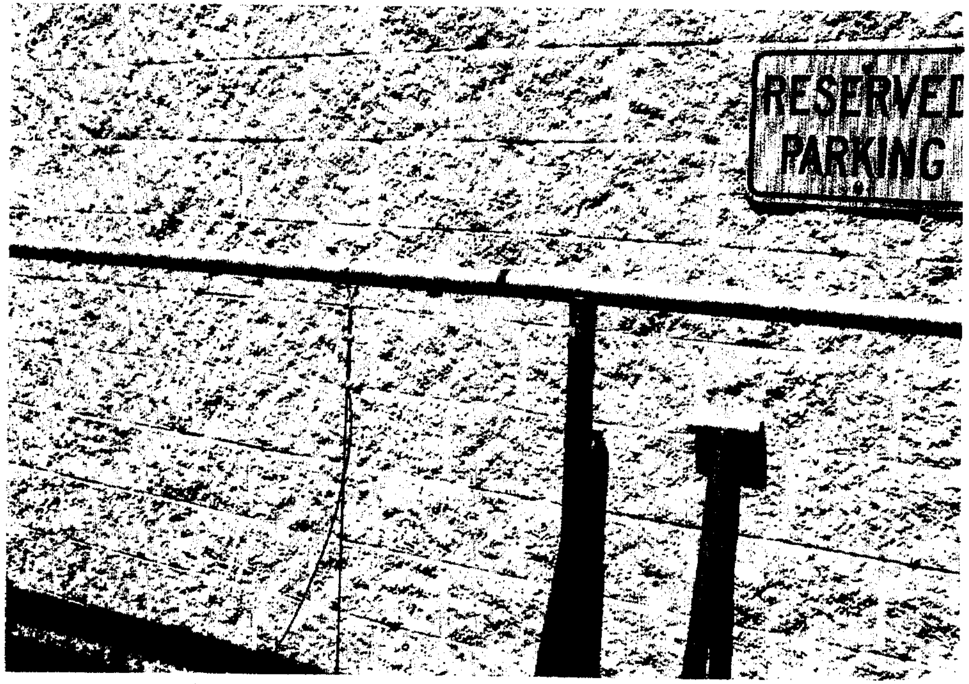

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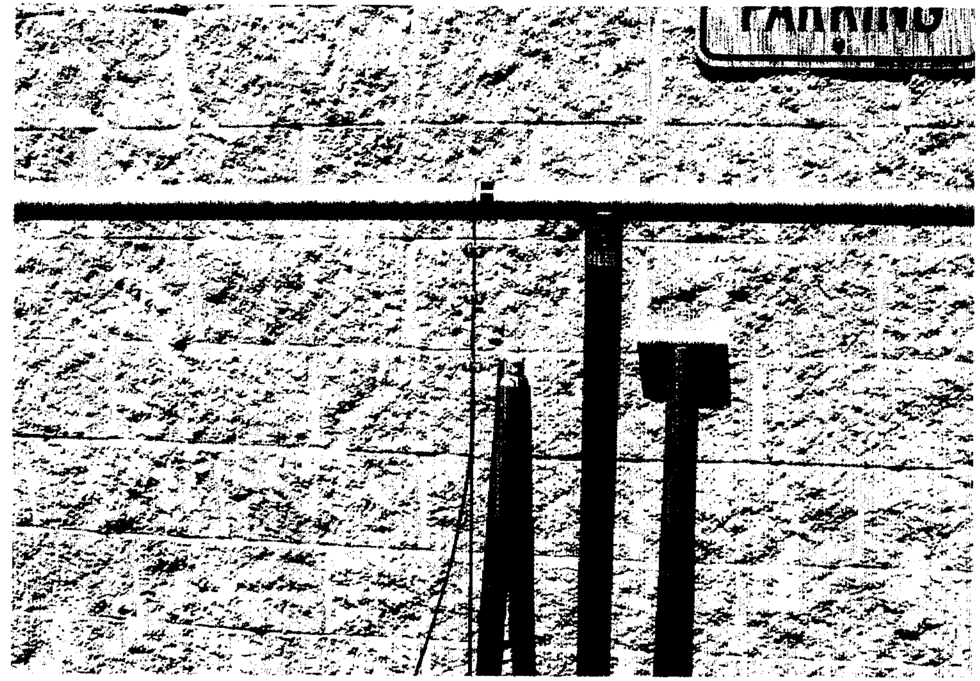

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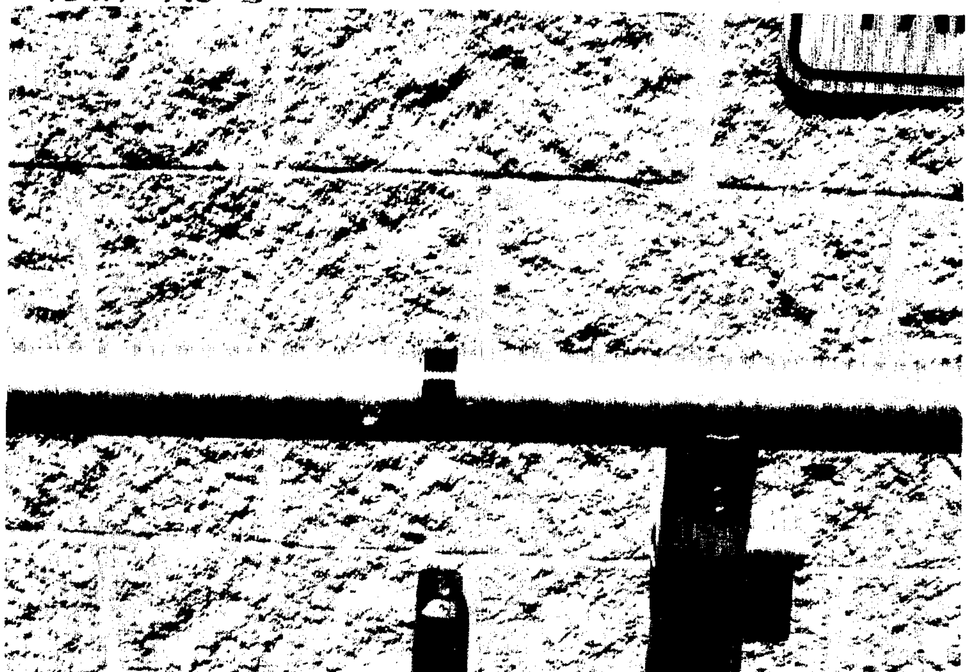

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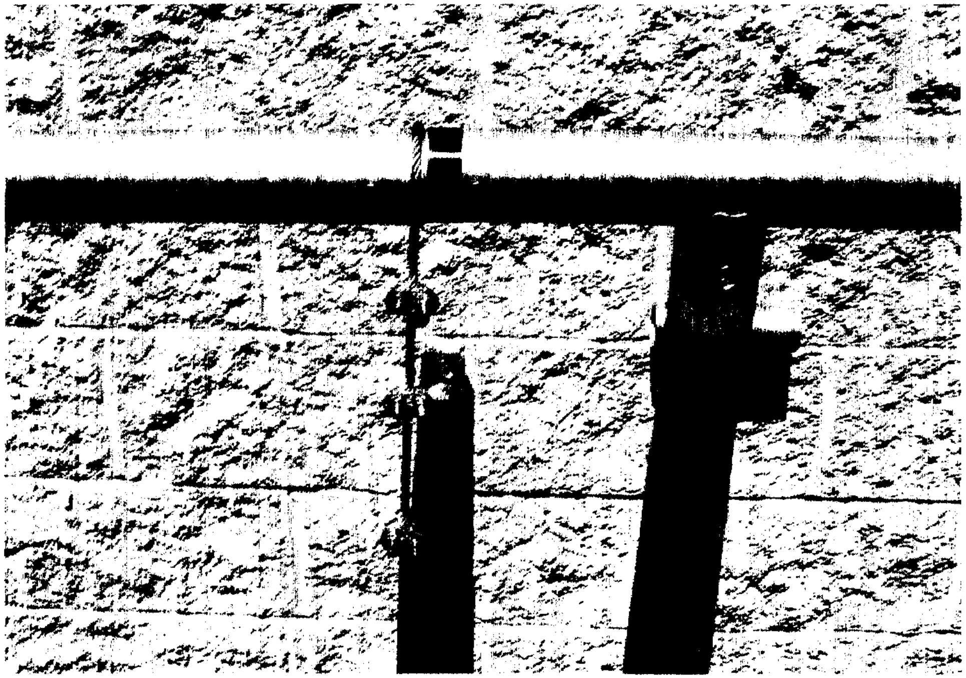

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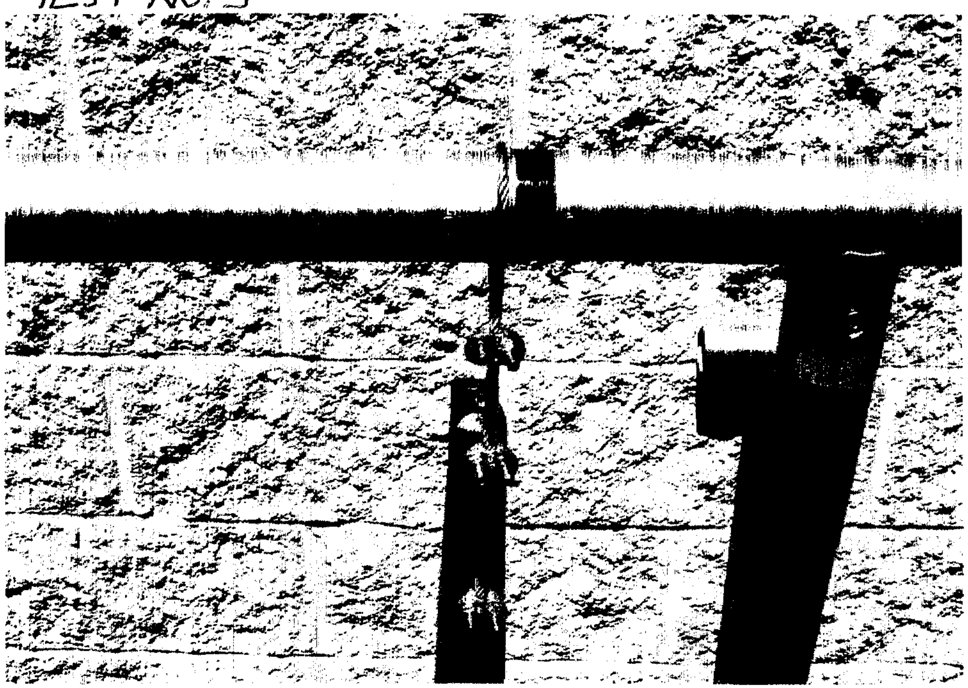

TEST No. 3

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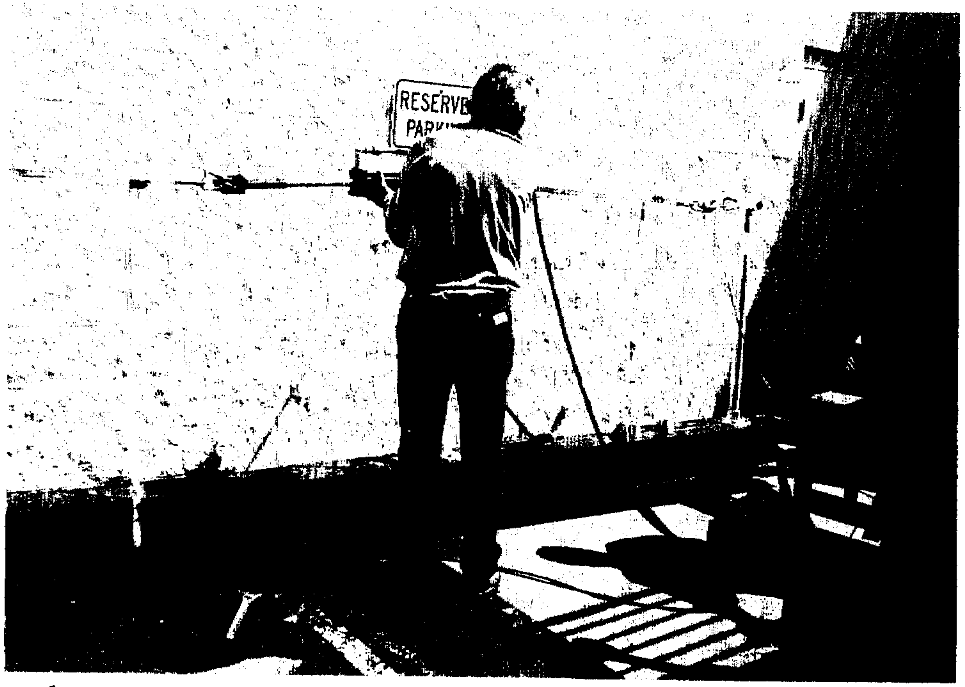

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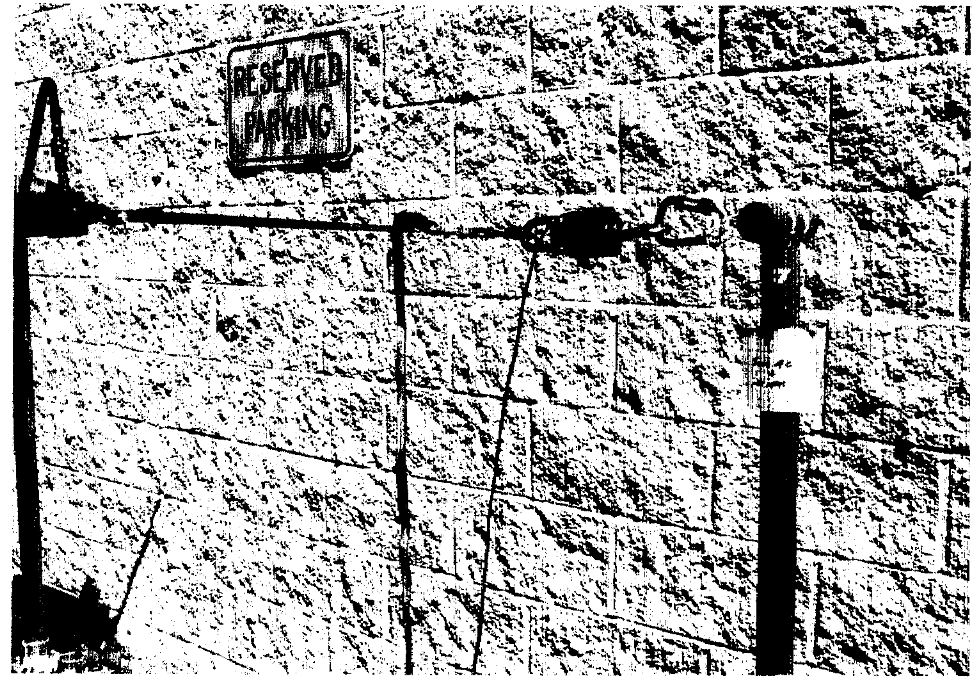

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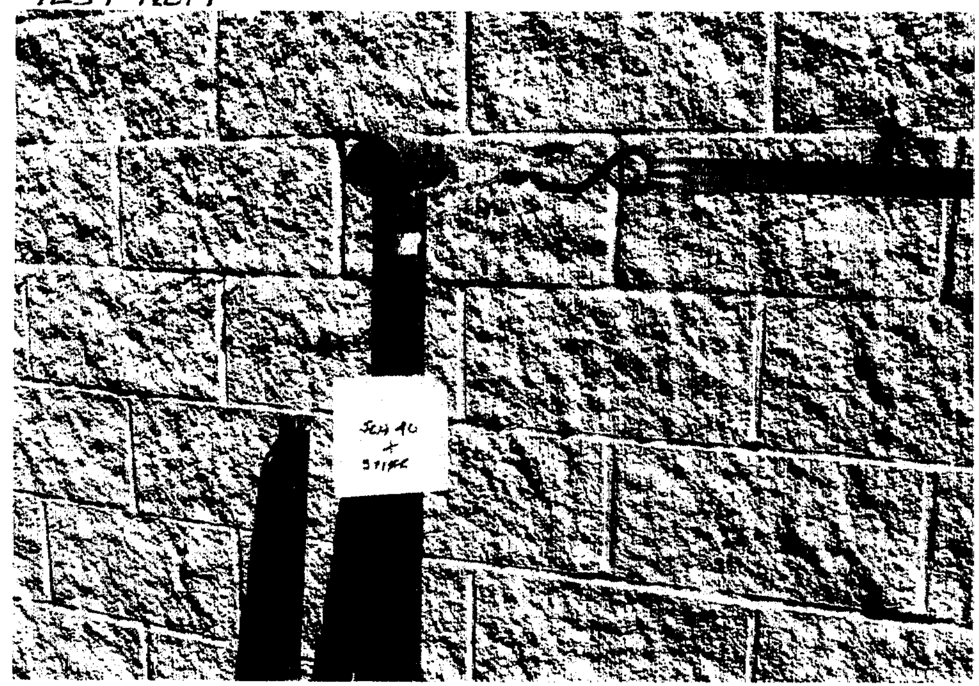

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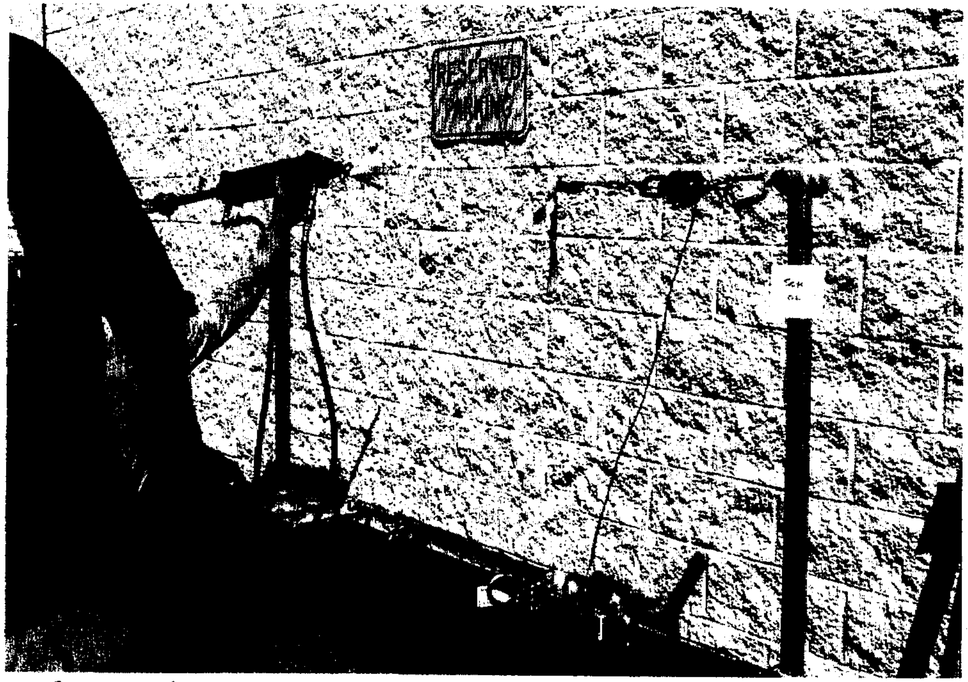

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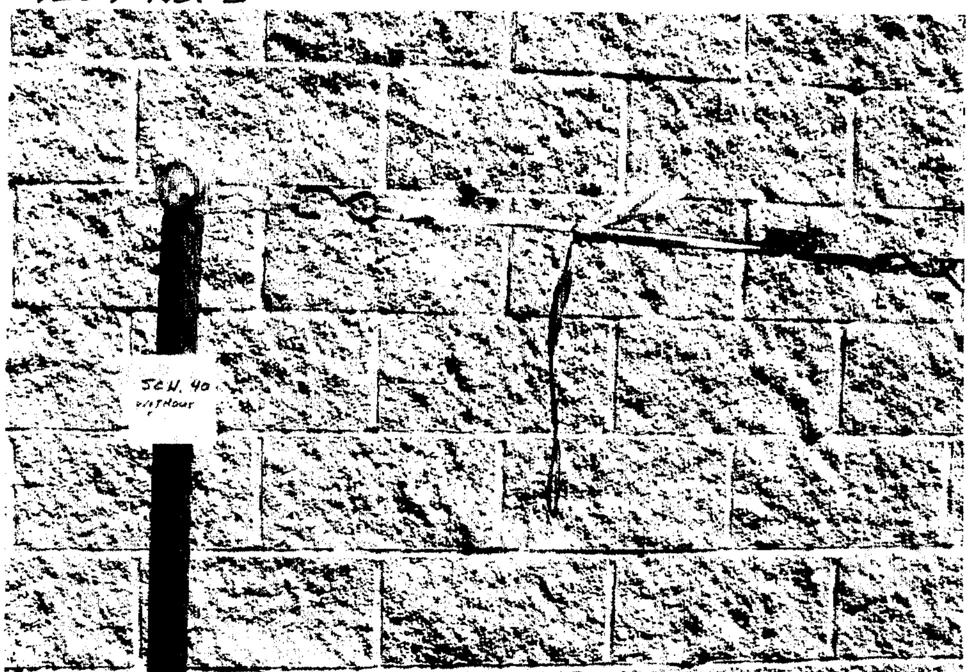

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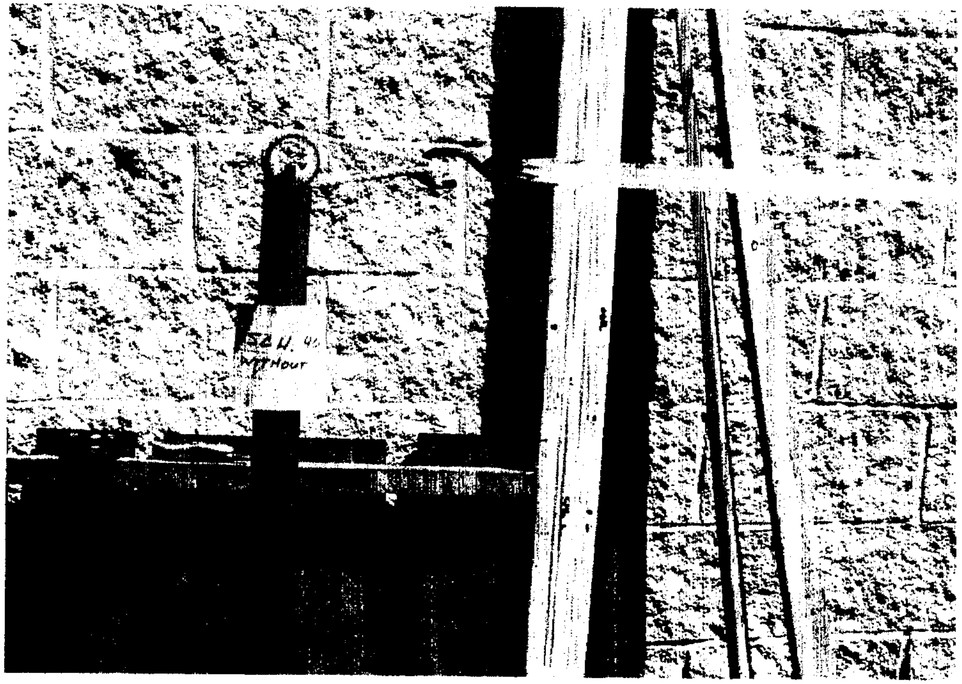

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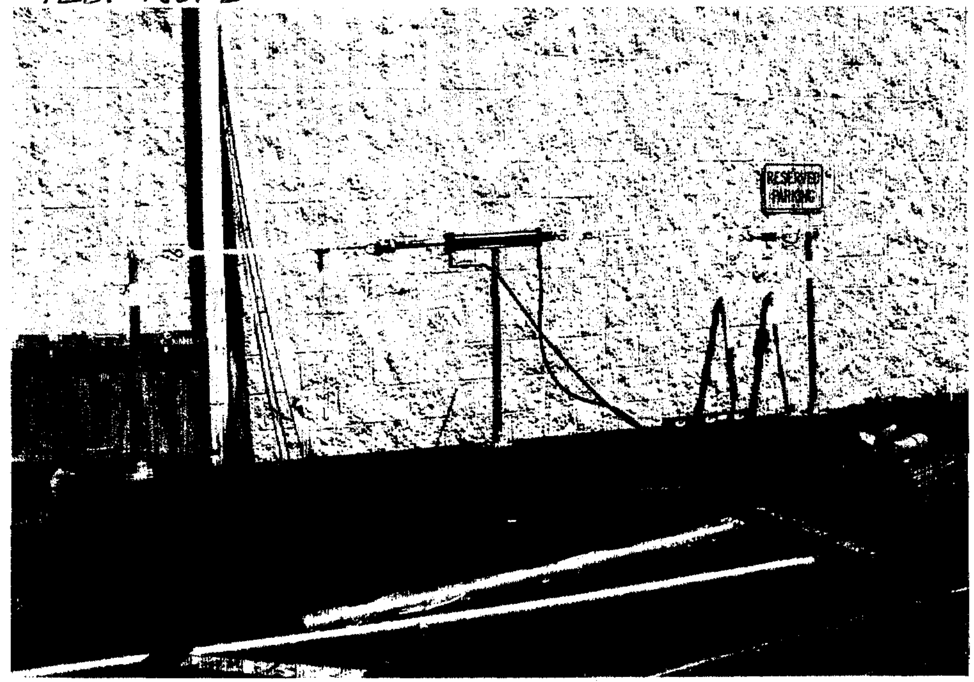

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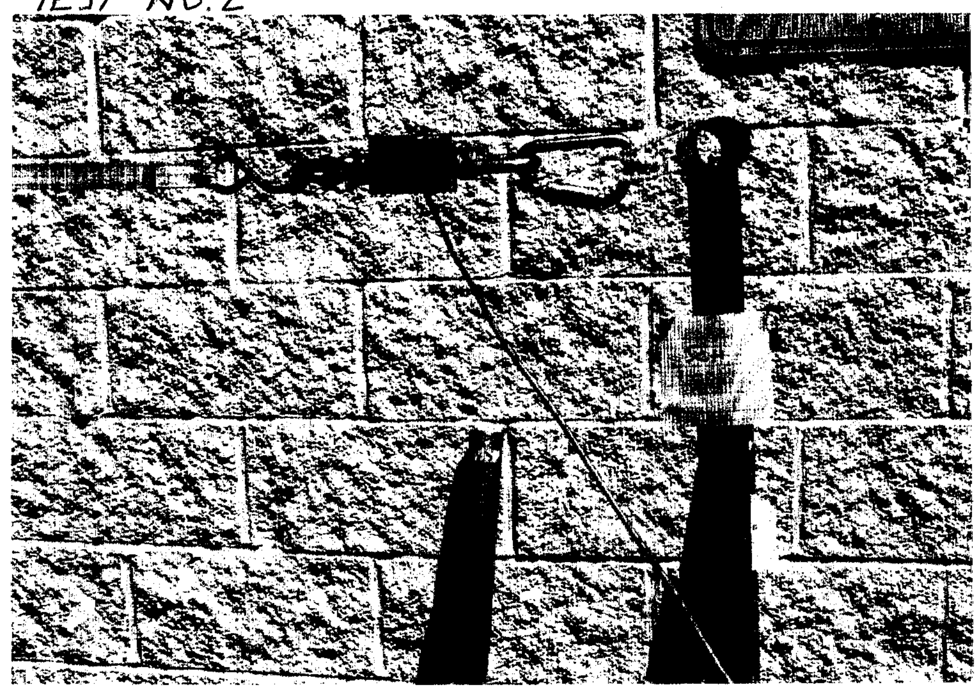
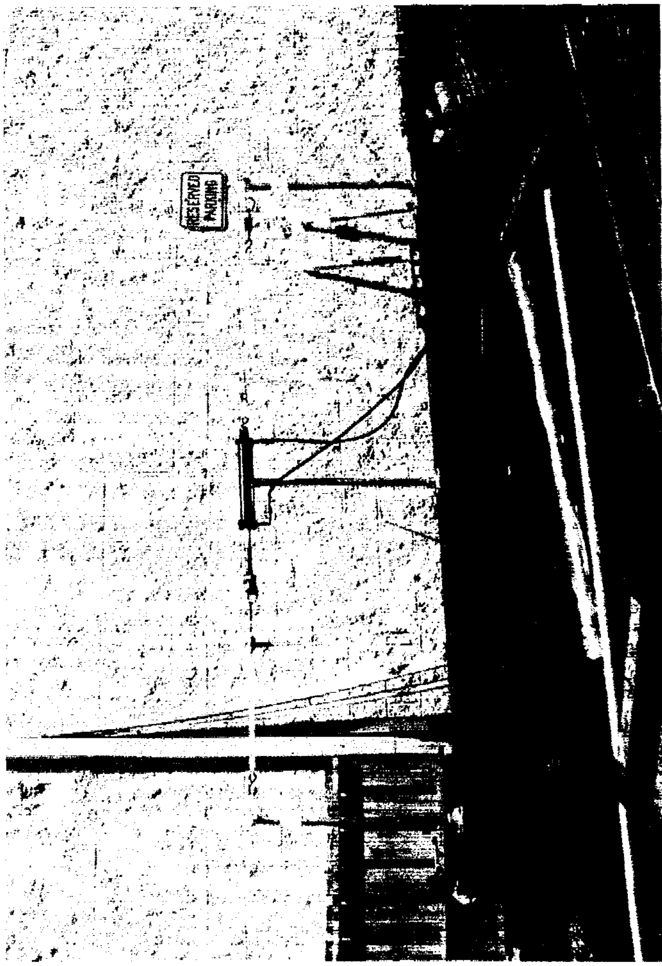
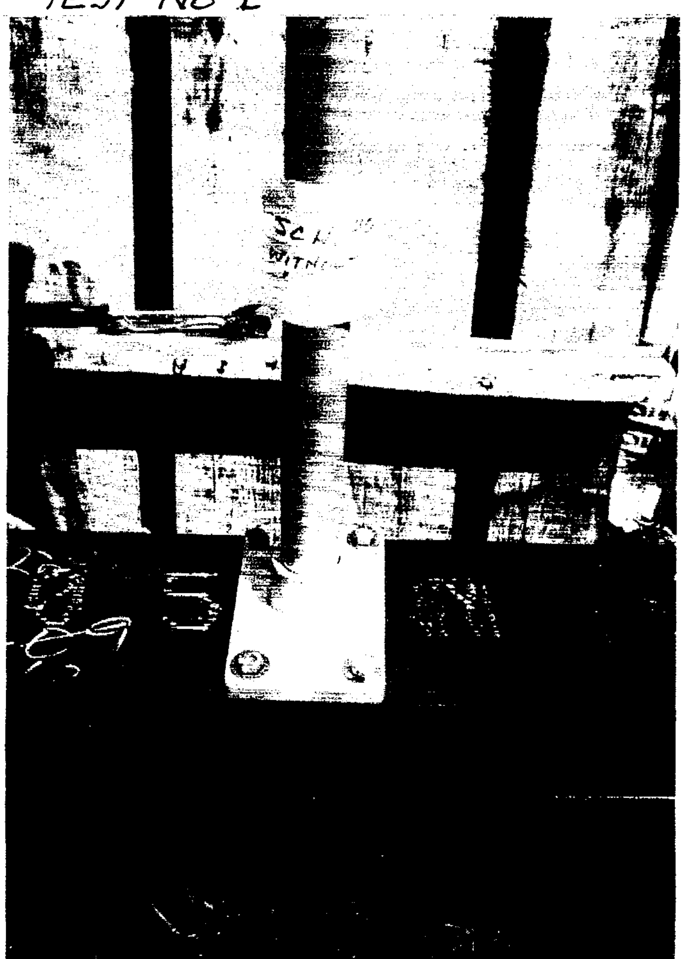




TEST No. 2

TEST No. 2

TEST No 1



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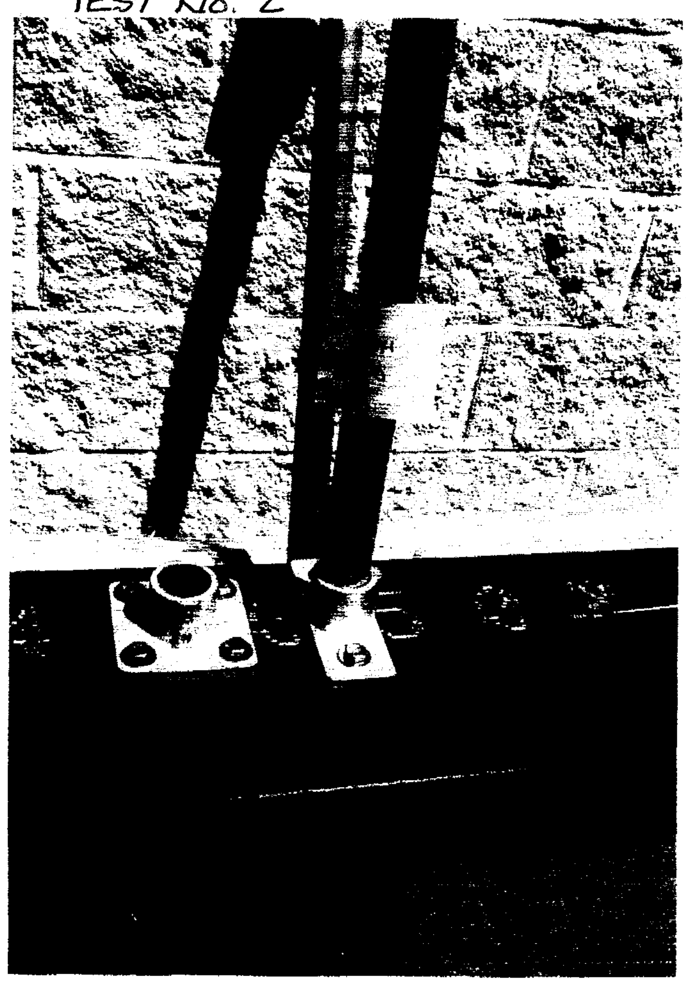

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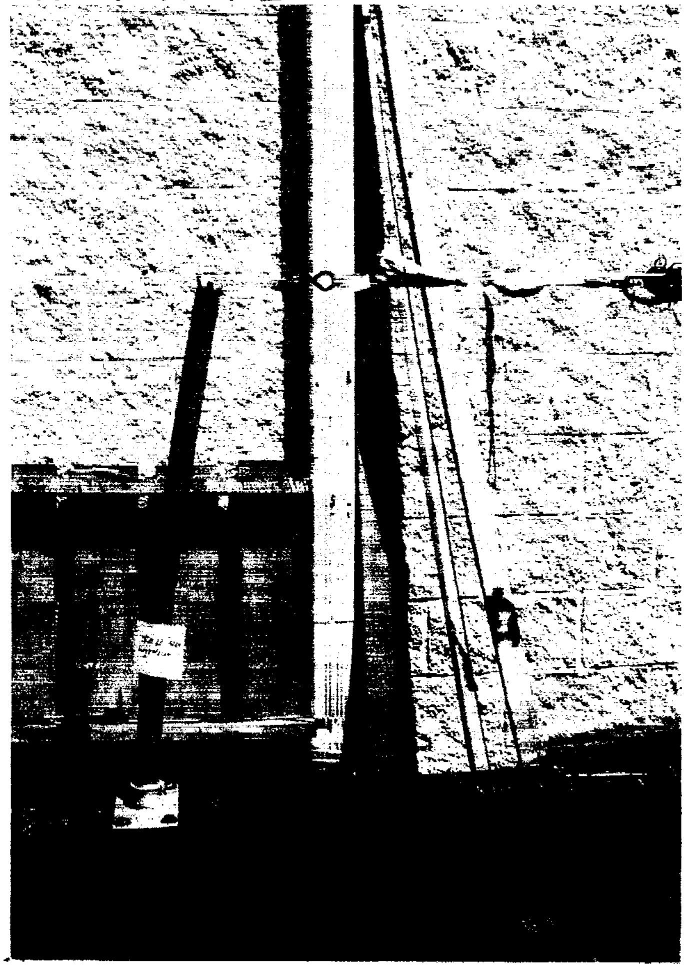


TEST No. 2

TEST No. 2

TEST No 2

ROY E. WOOTEN AND ASSOCIATES
Consulting Engineers
7585 W. Arkansas Ave., #206
Lakewood, Colorado 80232
(303) 980-8603

JOB RMR No. 1376, SAN JOSE, CA 20941
SHEET NO. 1 OF 1
CALCULATED BY REW DATE 8/12/09
CHECKED BY ________ DATE ________
SCALE ________

W.P.C.P. PHASE II DIGESTERS

DESIGN CRITERIA

CODES - IBC 2006/2003, OSHA
ASCE 7-05/02 & CALIFORNIA
BUILD CODE

LOADS
1. TOP RAILS - 50 PLF OR 200 LB.
2. MID RAILS - 200 LB.
3. CORNER RAILS - 200 lb
4. POSTS - MAX. OF 1.

MATERIALS SPECIFICATIONS
1. RAILS, POSTS & FITTINGS - 6005-T5
2. CONNECTORS & ANCHORS - T316 SS
3. CONCRETE - F'c 4000 PSI

MATERIALS PROPERTIES
SEE ATTACHED SHEETS

DESIGN - PER 2005/2000 ALUMINUM
DESIGN MANUALS - ALLOWABLE
STRESS METHOD

TOP RAILS
1½"φ SCH 40 ℓmax = 6'-0
W = 50 PLF Mw = 1/8 (50 PLF) 6'-0"² = 225 Ft·lb
P = 200 lb Mp = 1/4 (200 lb) 6'-0" = 300 Ft·lb
fb = M/S = 300 Ft·lb x 12"/1 / 0.326 IN³
= 11043 PSI < 24000 PSI ✓OK

MID RAILS
1½"φ SCH 40 ℓmax = 6'-0
P = 200 lb Mp = 1/4 (200 lb) 6'-0" = 300 Ft·lb
fb = 300 Ft·lb x 12"/1 / 0.326 IN³
= 11,043 PSI < 24000 PSI ✓OK

CORNER RAILS
1½"φ SCH 40 SEE STANDARDS 25-KD-4

POSTS
1½"φ SCH 80 6'-0 MAX SPACING
Ww = 50 PLF x 6'-0 = 300 lb ←
P = 200 lb
(A/D-1) h = 2'-5" - 2½" = 2'-2½" OR 26½"
Mw = 300 lb x 26½" = 7950 IN·lb
fb = 7950 IN·lb / 0.412 IN³
= 19296 PSI < 24000 PSI ✓OK

ANCHORAGE - 16H 8"x5" 4-½"φ TR. RODS
TREQ'D = 300 lb x 2'-5 x 12"/1 / 4⅛"
= 2110 lb OR 1055 lb/TR. ROD
SEE ATTACHED PREVIOUS SUBMITTALS
½"φ x 6" EMBED TALLOW = 2633 lb/TR ROD
F'c = 3000 PSI TALLOW = 2505 lb/TR ROD
F'c = 2400 PSI TALLOW = 2428 lb/TR. ROD
ALSO (1) 7-28-09 F'c 3000 PSI FOR 4½" & 5" EMBED
- 16E 5"x5" 4-½"φ TR RODS
TREQ'D = 300 lb x 2'-5 x 12"/1 / 4"
= 2175 lb OR 1088 lb/TR. ROD
SEE ATTACHED PREVIOUS SUBMITTALS
F'c = 3000 PSI ½"φ x 4" EMBED - TALL = 1897 lb/TR ROD
½"φ x 5" EMBED - TALL = 1955 lb/TR ROD

ROY E. WOOTEN AND ASSOCIATES
Consulting Engineers
7585 W. Arkansas Ave., #206
Lakewood, Colorado 80232
(303) 980-8603

JOB: BMR # R1376, SAN JOSE, CA 20941
SHEET NO. 1 OF 1
CALCULATED BY: REW DATE: 7-17-09
CHECKED BY: DATE: △1 7-28-09
SCALE: 1½" = 1'-0

SECONDARY CALCS FOR BASE MOUNT FITTING 16E, 5"x5" W 4-½"φ CHEM BOND ANCHORS - W_W = 50 plf x 6'-0 = 300 lb

F'c = 3000 PSI

EMBED 1. 4" M = 300 lb x 42" = 12600 in·lb

EMBED 2. 5"

---

1. 4" EMBED - T_{BASIC} = 3800 lb

   SPACING 3½" → 0.78

   EDGE DIST 2¼" → 0.645

   T_{ALL} = 3800 lb/rod x .78 x .645 = 1897 lb/ROD

   T_{ACT} = 12600 lb·in ÷ 3.99" = 3158 lb/T OR 1579 lb/T.ROD ✓ OK

2. 5" EMBED - T_{BASIC} = 4495 lb

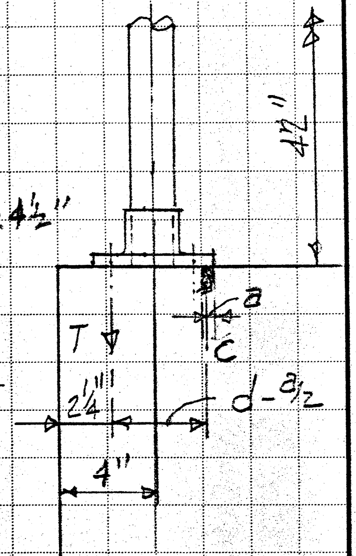
   SPACING 3½" ~ 0.75

   EDGE DIST 2¼" ~ 0.58

   T_{ALL} = 4495 x .75 x 0.58 = 1955 lb/ROD ✓ OK

   T_{ACT} = 12600 in·lb ÷ 3.99" = 3158 lb OR 1579 lb/T.ROD

$$T = C = M/(d - a/2)$$
$$= 12600 \div 3.99"$$
$$= 3158 \text{ lb}$$
$$a = 3158 / (.45 \times 3000 \text{ psi} \times 4\tfrac{1}{2}") = 0.52"$$
$$d - a/2 = 4\tfrac{1}{4} - \tfrac{0.52}{2} = 3.99"$$



$T_{△1}$ = C = M/(d - a/2)

= 42" x 200 lb / 4.15"

= 2024 lb

a = 2024 / (.45 x 3000 x 7.5") = 0.20" d - a/2 = 4.15"

1△. 4½" EMBED T_{BASIC} = 4235 lb/TR.ROD

SPACING 6¼" - 0.881

EDGE DIST 2¼" - 0.589

T_{ALL} = 4235 x 0.881 x 0.589 = 2198 lb/T.ROD

T_{ACT} = 2024 ÷ 2 = 1012 lb/TR.ROD

S.F = 2198 lb/ROD ÷ 1012 lb/ROD = 2.172

2△. 5" EMBED T_{BASIC} = 4495 lb/TR.ROD

SPACING 6¼" 0.862

EDGE DIST 2¼" 0.539

T_{ALL} = 4495 x 0.862 x 0.539 = 2088 lb/ROD

T_{ACT} = 2024 ÷ 2 = 1012 lb/ROD

S.F = 2088 ÷ 1012 = 2.063 ✓ OK

△1 FOR FITTING 16H 8"x5" W/4-½"φ CHEM BOND ANCHORS - F_H = 200 lb

1. EMBED 4½"
2. EMBED 5"

ANCHORAGE BASED ON POWERS AC100 PLUS OR POWER AC100+GOLD EPOXY ADHESIVE SYSTEM.

ROY E. WOOTEN AND ASSOCIATES
Consulting Engineers
7585 W. Arkansas Ave., #206
Lakewood, Colorado 80232
(303) 980-8603

JOB RMR No. R1376 San Jose, CA.

SHEET NO. 1 OF 1

CALCULATED BY REW DATE 7/27/09

CHECKED BY ____ DATE ____

SCALE 3/4" = 1'-0

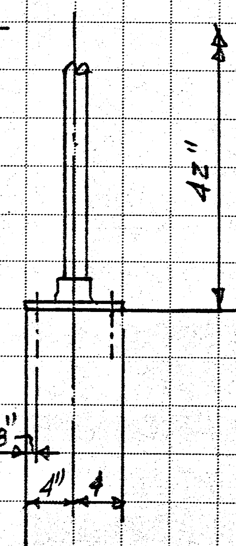
80-16H TURNED 90°

F'c = 3000psi

1. 1/2"⌀ x 4 1/2" EMBED

2. 1/2"⌀ x 5" EMBED

TREQ'D = 42" x 300 lb ÷ 7" = 1800 lb
OR 900 lb/T.ROD



1. TBASIC = 4235 lb/T.ROD
SPACING 3 1/2" · 0.74
EDGE DIST. 7/8" – NO VALUE

TALL = 4235 x 0.74 x 0
= 0

NOT ALLOWED

2. TBASIC = 4495 lb/T.ROD
SPACING = 3 1/2" · 0.70
EDGE DIST = 7/8" – NO VALUE

TALL = 4495 x 0.70 x 0.00 = 0
NOT ALLOWED

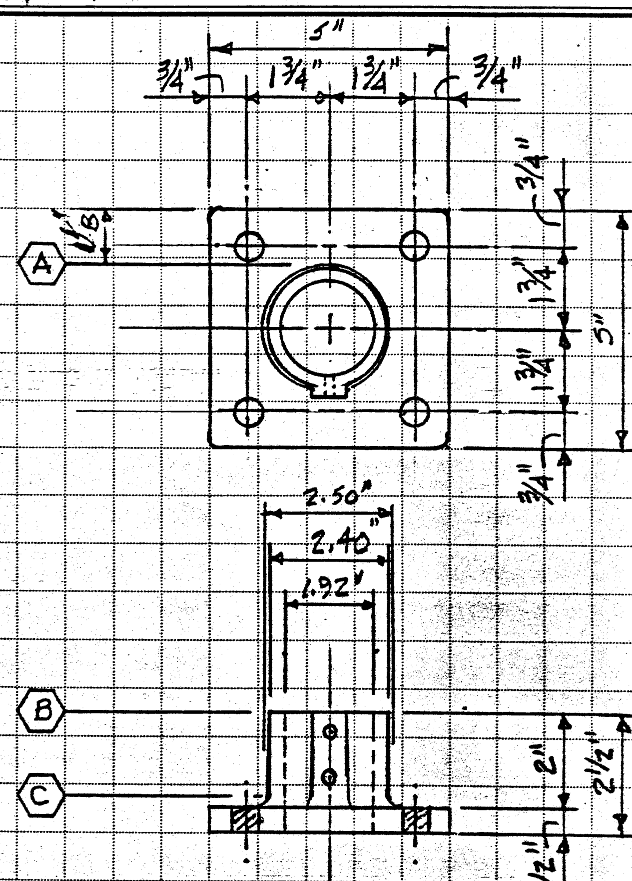
NOTE * NEEDS TO BE MIN. OF 2 1/8"
TO GET VALID CALCULABLE
LOADS.

ROY E. WOOTEN AND ASSOCIATES
Consulting Engineers
7585 W. Arkansas Ave., #206
Lakewood, Colorado 80232
(303) 980-8603

JOB ROCKY MOUNTAIN RAILINGS STANDARDS
SHEET NO. 1 OF 1
CALCULATED BY REW DATE JULY 2008
CHECKED BY R.B DATE JAN. 26, 2009
SCALE 1/4" = 1"

16 E

FOUR (4) HOLE BASE MOUNT 6105-T5



(A) PROPERTIES

$AREA = 1/2" \times 5" = 2.50\ IN^2$

$I = 1/12\,(5")(1/2")^3 = 0.05208\ IN^4$

$S = 1/6\,(5")(1/2")^2 = 0.20833\ IN^3$

$M = 0.20833\ IN^3 \times 24000\ PSI = 5000\ IN\cdot lb$

$R_C = 5000 \div 15/16" = 5333\ lb$

$P = W = 5333 \times 4\,1/16" / 42" = 516\ lb > 300\ lb$

OR 6'-0" × 50 plf = 300 lb

(B) PROPERTIES

$AREA = \pi/4\,(2.40^2 - 1.92^2) = 1.6286\ IN^2$

$I = \pi/64\,(2.40^4 - 1.92^4) = 0.9615\ IN^4$

$S = I/r_{OD} = 0.9615 \div 1.2" = 0.8013\ IN^3$

$M_R = 0.8013\ IN^3 \times 24000 = 19{,}230\ IN\cdot lb$

$P = W = 19230 / (42" - 2\,1/2") = 487\ lb > 200\ lb$

OR 6'0 × 50 plf

(C) PROPERTIES

$AREA = \pi/4\,(2.50^2 - 1.92^2) = 2.0135\ IN^2$

$I = \pi/64\,(2.50^4 - 1.92^4) = 1.2504\ IN^4$

$S = I/r_{OD} = 1.2504 / 1.25" = 1.0000\ IN^3$

$M_R = 1.000\,(24000) = 24000\ IN\cdot lb$

$P = W = 24000 \div (42 - 5/8") = 580\ lb > 200\ lb$

OR 6'0 × 50 plf.

STANDARD ANCHORS

4 - 1/2"ϕ × 3 3/4 "POWERS" WEDGE ANCHORS
PER ICC-ES ESR-1532

SPECIAL ANCHORAGE PER RMR#R1376

4 - 1/2"ϕ × 6" EMBED THREADED RODS
EPOXY BOND - POWERS AC 100 PLUS
OR POWERS AC 100 + GOLD; F'C = 4000 PSI

$T_{BASIC} = 5167\ lb/ROD$

SPACING - 3 1/2" 0.70
EDGE DIST. - 2 1/4" 0.60
= 0.42 (5167 lb) = 2170 lb/ROD

$T_{ACT} = 300\ lb \times 42" \div 4\,1/16" = 3102\ lb$

OR 1551 lb/ROD < 2170 lb/ROD

✓ OK

COLORADO REGISTERED PROFESSIONAL ENGINEER ROY E. WOOTEN 7838

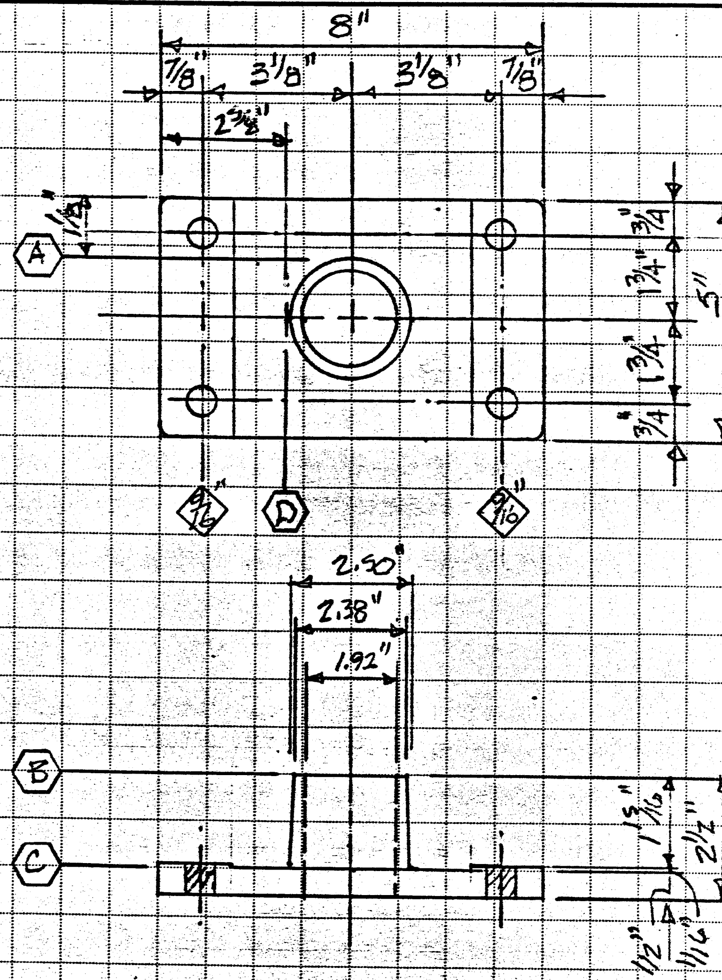
7/15/09

ROY E. WOOTEN AND ASSOCIATES
Consulting Engineers
7585 W. Arkansas Ave., #206
Lakewood, Colorado 80232
(303) 980-8603

JOB: ROCK MOUNTAIN RAILINGS STANDARDS
SHEET NO. 1 OF 1
CALCULATED BY: REW DATE: JUNE 23, 2009
CHECKED BY: RGB DATE: JUNE 29, 2009
SCALE: 1/4" = 1"

8C-16H

FOUR (4) HOLE BASE MOUNT



(A) PROPERTIES

AREA = 1/2" x 8" = 4.00 IN²
I = 1/12 (8")(1/2")³ = 0.0833 IN⁴
S = 1/6 (8")(1/2")² = 0.3333 IN³
M = 0.3333 x 24000 PSI = 8000 IN·lb
$R_{H\,MAX}$ = 8000 IN·lb ÷ 15/16" = 8533 lb
$P_{TOP\ OF\ 42"\ POST}$ = 8533 lb x 4 1/16" ÷ 42" = 825 lb

(B) PROPERTIES

AREA = π/4 (2.38² − 1.92²) = 1.5535 IN²
I = π/64 (2.38⁴ − 1.92⁴) = 0.9079 IN⁴
S = I/r_{OD} = 0.9079 ÷ 1.19" = 0.7630 IN³
M = 0.7630 IN³ x 24000 PSI = 18,310 IN·lb
$P_H = W_H$ = 18310 / (42" − 2 1/2") = 464 lb

(C) PROPERTIES

AREA = π/4 (2.50² − 1.92²) = 2.0135 IN²
I = π/64 (2.50⁴ − 1.92⁴) = 1.2504 IN⁴
S = I/r_{OD} = 1.2504 / 1.25" = 1.0003 IN³
M = 1.0003 IN³ x 24000 = 24,008 IN·lb
$P_H = W_H$ = 24008 / (42" − 1/2") = 579 lb

STANDARD ANCHORS

4 - 1/2" Φ x 3 3/4" "POWERS" WEDGE ANCHORS
PER ICC-ES-ESR-1532

RMR No 1376
SAN JOSE, CA.

(D) PROPERTIES

AREA = 1/2" x 5" = 2.00 IN²
I = 1/12 (5")(1/2")³ = 0.0528 IN⁴
S = 1/6 (5")(1/2")² = 0.2083 IN³
M = 0.2083 x 24000 PSI = 5000 IN·lb
R_{MAX} = 5000 IN·lb ÷ 2 1/2 = 2000 lb
P_H/W_H = 2000 lb x 6.98" ÷ 42" = 332 lb
✓ OK

PROBABLY SHOULD BE LOAD TESTED FOR VERIFICATION OF CALCED VALUES.

ROY E. WOOTEN AND ASSOCIATES
Consulting Engineers
7585 W. Arkansas Ave., #206
Lakewood, Colorado 80232
(303) 980-8603

JOB: ROCK MOUNTAIN RAILINGS STANDARDS
SHEET NO. 1 OF 1
CALCULATED BY: REW   DATE: JUNE 23, 2009
CHECKED BY: ______   DATE: ______
SCALE: 1/4" = 1"

80-16H

FOUR (4) HOLE BASE MOUNT

(A) PROPERTIES

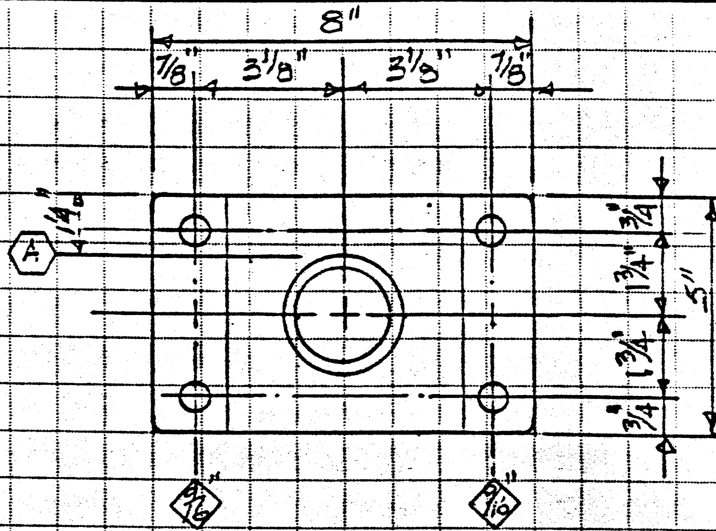
AREA = 1/2" x 8" = 4.00 IN²
I = 1/12 (8")(1/2")³ = 0.0833 IN⁴
S = 1/6 (8")(1/2")² = 0.3333 IN³
M = 0.3333 x 24000 PSI = 8000 IN·lb
$P_{H\,MAX}$ = 8000 IN·lb x 4/3 ÷ 1 3/16" = 8982 lb
$P_{TOP\ OF\ 42"\ POST}$ = 8000 IN·lb x 4/3 ÷ 42" = 254 lb

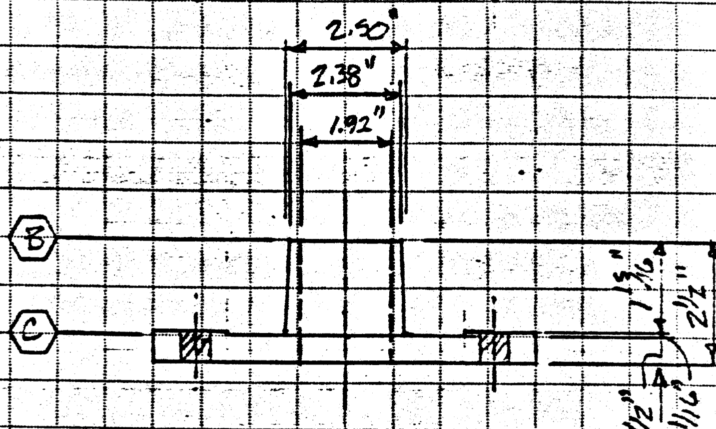
(B) PROPERTIES

AREA = π/4 (2.38² − 1.92²) = 1.5535 IN²
I = π/64 (2.38⁴ − 1.92⁴) = 0.9079 IN⁴
S = I/r_{OD} = 0.9079 ÷ 1.19" = 0.7630 IN³
M = 0.7630 IN³ x 24000 PSI = 18,310 IN·lb
$P_H = W_H$ = 18310 / (42" − 2 1/2") = 464 lb

(C) PROPERTIES

AREA = π/4 (2.50² − 1.92²) = 2.0135 IN²
I = π/64 (2.50⁴ − 1.92⁴) = 1.2504 IN⁴
S = I/r_{OD} = 1.2504 / 1.25" = 1.0003 IN³
M = 1.0003 IN³ x 24000 = 24,008 IN·lb
$P_H = W_H$ = 24008 / (42" − 1/2") = 579 lb





STANDARD ANCHORS

4 - 1/2" Φ x 3 3/4" "POWERS" WEDGE ANCHORS
PER ICC - ES - ESR - 1532

SPECIAL ANCHORAGE FOR RMR # R 1376

4 - 1/2" Φ x 6" EMBED THREADED RODS
EPOXY BOND - POWER AC 100 PLUS
OR POWERS AC 100 + GOLD; F'c = 4000 PSI

T_{BASIC} = 5270 lb/ROD
SPACING 6 1/4" 0.815 } = 0.4996 (5270 lb)
EDGE DIST 2 1/4" 0.613 }
= 2633 lb/ROD

T_{ACT} = 300 lb x 42" ÷ 4 1/8"
= 3054 lb OR 1527 lb/ROD < 2633 lb
✓ OK

COLORADO REGISTERED
ROY E. WOOTEN
7232
PROFESSIONAL ENGINEER

6/23/09

Table 3.3-1
MINIMUM MECHANICAL PROPERTIES FOR ALUMINUM ALLOYS

ALLOY AND TEMPER	PRODUCT	THICKNESS RANGE in.	F_{tu} ksi	F_{ty} ksi	F_{cy} ksi	F_{su} ksi	COMPRESSIVE MODULUS OF ELASTICITY[2] E (ksi)
5052-O	Sheet & Plate	0.006 to 3.000	25	9.5	9.5	16	10,200
-H32	Sheet & Plate	All	31	23	21	19	10,200
-H34	Cold Fin. Rod & Bar	All	34	26	24	20	10,200
-H36	Drawn Tube						
	Sheet	0.006 to 0.162	37	29	26	22	10,200
5083-O	Extrusions	up thru 5.000	39	16	16	24	10,400
-H111	Extrusions	up thru 0.500	40	24	21	24	10,400
-H111	Extrusions	0.501 to 5.000	40	24	21	23	10,400
-O	Sheet & Plate	0.051 to 1.500	40	18	18	25	10,400
-H116	Sheet & Plate	0.188 to 1.500	44	31	26	26	10,400
-H32, H321	Sheet & Plate	0.188 to 1.500	44	31	26	26	10,400
-H116	Plate	1.501 to 3.000	41	29	24	24	10,400
-H32, H321	Plate	1.501 to 3.000	41	29	24	24	10,400
5086-O	Extrusions	up thru 5.000	35	14	14	21	10,400
-H111	Extrusions	up thru 0.500	36	21	18	21	10,400
-H111	Extrusions	0.501 to 5.000	36	21	18	21	10,400
-O	Sheet & Plate	0.020 to 2.000	35	14	14	21	10,400
-H112	Plate	0.025 to 0.499	36	18	17	22	10,400
-H112	Plate	0.500 to 1.000	35	16	16	21	10,400
-H112	Plate	1.001 to 2.000	35	14	15	21	10,400
-H112	Plate	2.001 to 3.000	34	14	15	21	10,400
-H116	Sheet & Plate	All	40	28	26	24	10,400
-H32	Sheet & Plate Drawn Tube	All	40	28	26	24	10,400
-H34	Sheet & Plate Drawn Tube	All	44	34	32	26	10,400
5154-H38	Sheet	0.006 to 0.128	45	35	33	24	10,300
5454-O	Extrusions	up thru 5.000	31	12	12	19	10,400
-H111	Extrusions	up thru 0.500	33	19	16	20	10,400
-H111	Extrusions	0.501 to 5.000	33	19	16	19	10,400
-H112	Extrusions	up thru 5.000	31	12	13	19	10,400
-O	Sheet & Plate	0.020 to 3.000	31	12	12	19	10,400
-H32	Sheet & Plate	0.020 to 2.000	36	26	24	21	10,400
-H34	Sheet & Plate	0.020 to 1.000	39	29	27	23	10,400
5456-O	Sheet & Plate	0.051 to 1.500	42	19	19	26	10,400
-H116	Sheet & Plate	0.188 to 1.250	46	33	27	27	10,400
-H32, H321	Sheet & Plate	0.188 to 1.250	46	33	27	27	10,400
-H116	Plate	1.251 to 1.500	44	31	25	25	10,400
-H32, H321	Plate	1.251 to 1.500	44	31	25	25	10,400
-H116	Plate	1.501 to 3.000	41	29	25	25	10,400
-H32, H321	Plate	1.501 to 3.000	41	29	25	25	10,400
6005-T5	Extrusions	up thru 1.000	38	35	35	24	10,100
6061-T6, T651	Sheet & Plate	0.010 to 4.000	42	35	35	27	10,100
-T6, T6510, T6511	Extrusions	All	38	35	35	24	10,100
-T6, T651	Cold Fin. Rod & Bar	up thru 8.000	42	35	35	25	10,100
-T6	Drawn Tube	0.025 to 0.500	42	35	35	27	10,100
-T6	Pipe	All	38	35	35	24	10,100
6063-T5,	Extrusions	up thru 0.500	22	16	16	13	10,100
-T52	Extrusions	up thru 1.000	22	16	16	13	10,100
-T5	Extrusions	0.500 to 1.000	21	15	15	12	10,100
-T6	Extrusions & Pipe	All	30	25	25	19	10,100
6066-T6, T6510, T6511	Extrusions	All	50	45	45	27	10,100
6070-T6, T62	Extrusions	up thru 2.999	48	45	45	29	10,100
6105-T5	Extrusions	up thru 0.500	38	35	35	24	10,100
6351-T5	Extrusions	up thru 1.000	38	35	35	24	10,100
6351-T6	Extrusions	up thru 0.750	42	37	37	27	10,100
6463-T6	Extrusions	up thru 0.500	30	25	25	19	10,100
7005-T53	Extrusions	up thru 0.750	50	44	43	28	10,500

1. F_{tu} and F_{ty} are minimum specified values (except F_{ty} for 1100-H12, H14 Cold Finished Rod and Bar and Drawn Tube, Alclad 3003-H18 Sheet and 5050-H32, H34 Cold Finished Rod and Bar which are minimum expected values); other strength properties are corresponding minimum expected values.

2. Typical values. For deflection calculations an average modulus of elasticity is used; this is 100 ksi lower than values in this column.

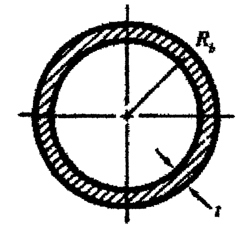


TABLE 22 – PIPES

Nominal Pipe Size	Schedule No.	Outside Diameter OD in.	Inside Diameter ID in.	Wall Thickness t in.	Weight[2] lb/ft	Area A in²	I in⁴	S in³	r in.	R_b/t
1 1/2	5	1.900	1.770	0.065	0.441	0.375	0.158	0.166	0.649	14.1
	10	1.900	1.682	0.109	0.721	0.613	0.247	0.260	0.634	8.2
	40	1.900	1.610	0.145	0.940	0.799	0.310	0.326	0.623	6.1
	80	1.900	1.500	0.200	1.26	1.07	0.391	0.412	0.605	4.3
	160	1.900	1.338	0.281	1.68	1.43	0.482	0.508	0.581	2.9
2	5	2.375	2.245	0.065	0.555	0.472	0.315	0.265	0.817	17.8
	10	2.375	2.157	0.109	0.913	0.776	0.499	0.420	0.802	10.4
	40	2.375	2.067	0.154	1.26	1.07	0.666	0.561	0.787	7.2
	80	2.375	1.939	0.218	1.74	1.48	0.868	0.731	0.766	4.9
	160	2.375	1.687	0.344	2.58	2.19	1.16	0.980	0.728	3.0
2 1/2	5	2.875	2.709	0.083	0.856	0.728	0.710	0.494	0.988	16.8
	10	2.875	2.635	0.120	1.22	1.04	0.987	0.687	0.975	11.5
	40	2.875	2.469	0.203	2.00	1.70	1.53	1.06	0.947	6.6
	80	2.875	2.323	0.276	2.65	2.25	1.92	1.34	0.924	4.7
	160	2.875	2.125	0.375	3.46	2.95	2.35	1.64	0.894	3.3
3	5	3.500	3.334	0.083	1.05	0.891	1.30	0.744	1.21	20.6
	10	3.500	3.260	0.120	1.50	1.27	1.82	1.04	1.20	14.1
	40	3.500	3.068	0.216	2.62	2.23	3.02	1.72	1.16	7.6
	80	3.500	2.900	0.300	3.55	3.02	3.89	2.23	1.14	5.3
	160	3.500	2.624	0.438	4.95	4.21	5.04	2.88	1.09	3.5
3 1/2	5	4.000	3.834	0.083	1.20	1.02	1.96	0.98	1.39	23.6
	10	4.000	3.760	0.120	1.72	1.46	2.76	1.38	1.37	16.2
	40	4.000	3.548	0.226	3.15	2.68	4.79	2.39	1.34	8.3
	80	4.000	3.364	0.318	4.33	3.68	6.28	3.14	1.31	5.8
4	5	4.500	4.334	0.083	1.35	1.15	2.81	1.25	1.56	26.6
	10	4.500	4.260	0.120	1.94	1.65	3.96	1.76	1.55	18.3
	40	4.500	4.026	0.237	3.73	3.17	7.23	3.21	1.51	9.0
	80	4.500	3.826	0.337	5.18	4.41	9.61	4.27	1.48	6.2
	120	4.500	3.624	0.438	6.57	5.59	11.7	5.18	1.44	4.6
	160	4.500	3.438	0.531	7.79	6.62	13.3	5.90	1.42	3.7
5	5	5.563	5.345	0.109	2.20	1.87	6.95	2.50	1.93	25.0
	10	5.563	5.295	0.134	2.69	2.29	8.43	3.03	1.92	20.3
	40	5.563	5.047	0.258	5.06	4.30	15.2	5.45	1.88	10.3
	80	5.563	4.813	0.375	7.19	6.11	20.7	7.43	1.84	6.9
	120	5.563	4.563	0.500	9.35	7.95	25.7	9.25	1.80	5.1
	160	5.563	4.313	0.625	11.4	9.70	30.0	10.8	1.76	4.0
6	5	6.625	6.407	0.109	2.62	2.23	11.8	3.58	2.30	29.9
	10	6.625	6.357	0.134	3.21	2.73	14.4	4.35	2.30	24.2
	40	6.625	6.065	0.280	6.56	5.58	28.1	8.50	2.25	11.3
	80	6.625	5.761	0.432	9.88	8.40	40.5	12.2	2.19	7.2
	120	6.625	5.501	0.562	12.6	10.7	49.6	15.0	2.15	5.4
	160	6.625	5.187	0.719	15.7	13.3	59.0	17.8	2.10	4.1

Table 2-20
ALLOWABLE STRESSES FOR BUILDING TYPE STRUCTURES

6005-T5 Extrusions up through 1.000 in. thick
6105-T5 Extrusions up through 0.500 in. thick

White bars apply to unwelded metal
Shaded bars apply to weld-affected metal

For tubes with circumferential welds, Sections 3.4.10, 3.4.12, and 3.4.16.1 apply for $R_b/t < 20$

Type of Stress	Type of Member or Element		Sec. 3.4.	Allowable Stress	
TENSION, axial	Any tension member	gross section net section	1	21 19	12.5
TENSION IN BEAMS, extreme fiber, net section	Flat elements in uniform tension		2	19	8
	Round or oval tubes		3	24	9
	Flat elements in bending in their own plane, symmetric shapes		4	28	10
BEARING	On rivets and bolts		5	39	25
	On flat surfaces and pins and on bolts in slotted holes		6	26	16

Type of Stress	Type of Member or Element	Sec. 3.4.	Allowable Stress, $S \leq S_1$	S_1	Allowable Stress, $S_1 < S < S_2$	S_2	Allowable Stress, $S \geq S_2$
COMPRESSION IN COLUMNS, axial	All columns	7	–	0	$20.2 - 0.126\ kL/r$	66	$51100\ /(kL/r)^2$
			–	0	$7.4 - 0.034\ kL/r$	144	$51100\ /(kL/r)^2$
COMPRESSION IN COLUMN ELEMENTS, gross section	Flat elements supported on one edge – columns buckling about a symmetry axis	8	21	2.4	$23.1 - 0.787\ b/t$	10	$154\ /(b/t)$
			8	3.8	$8.7 - 0.224\ b/t$	19	$85\ /(b/t)$
	Flat elements supported on one edge – columns not buckling about a symmetry axis	8.1	21	2.4	$23.1 - 0.787\ b/t$	12	$1970\ /(b/t)^2$
			8	3.8	$8.7 - 0.224\ b/t$	26	$1970\ /(b/t)^2$
	Flat elements supported on both edges	9	21	7.6	$23.1 - 0.247\ b/t$	33	$491\ /(b/t)$
			8	12	$8.7 - 0.070\ b/t$	62	$271\ /(b/t)$
	Flat elements supported on one edge and with stiffener on other edge	9.1	see Part IA Section 3.4.9.1				
	Flat elements supported on both edges and with an intermediate stiffener	9.2	see Part IA Section 3.4.9.2				
	Curved elements supported on both edges	10	21	1.4	$22.1 - 0.799\ \sqrt{R_b/t}$	141	$3190\ /\left(\frac{R_b}{t}\right)\left(1 + \frac{\sqrt{R_b/t}}{35}\right)^2$
			8	6.6	$8.6 - 0.275\ \sqrt{R_b/t}$	450	$3190\ /\left(\frac{R_b}{t}\right)\left(1 + \frac{\sqrt{R_b/t}}{35}\right)^2$

COMPRESSION IN BEAMS, extreme fiber, gross section	Single web shapes	11	21	21	$23.9 - 0.124\ L_b/r_y$	79	$87000\ /(L_b/r_y)^2$
			8	26	$8.8 - 0.034\ L_b/r_y$	172	$87000\ /(L_b/r_y)^2$
	Round or oval tubes	12	25	29	$39.3 - 2.70\ \sqrt{R_b/t}$	81	Same as
			9	62	$15.2 - 0.764\ \sqrt{R_b/t}$	184	Section 3.4.10
	Solid rectangular and round sections	13	28	14	$40.5 - 0.927\ \frac{d}{t}\sqrt{\frac{L_b}{d}}$	29	$11400\ /\left(\frac{d}{t}\right)^2\frac{L_b}{d}$
			10	19	$13.7 - 0.182\ \frac{d}{t}\sqrt{\frac{L_b}{d}}$	50	$11400\ /\left(\frac{d}{t}\right)^2\frac{L_b}{d}$
	Tubular shapes	14	21	123	$23.9 - 0.238\ \sqrt{\frac{2L_bS_c}{\sqrt{I_yJ}}}$	1680	$23600\ /\frac{2L_bS_c}{\sqrt{I_yJ}}$
			8	190	$8.8 - 0.065\ \sqrt{\frac{2L_bS_c}{\sqrt{I_yJ}}}$	8070	$23600\ /\frac{2L_bS_c}{\sqrt{I_yJ}}$
COMPRESSION IN BEAM ELEMENTS, (element in uniform compression), gross section	Flat elements supported on one edge	15	21	6.5	$27.3 - 0.930\ b/t$	10	$182\ /(b/t)$
			8	9	$10.3 - 0.265\ b/t$	14	$101\ /(b/t)$
	Flat elements supported on both edges	16	21	21	$27.3 - 0.292\ b/t$	33	$580\ /(b/t)$
			8	29	$10.3 - 0.083\ b/t$	62	$320\ /(b/t)$
	Curved elements supported on both edges	16.1	25	2.1	$26.2 - 0.944\ \sqrt{R_b/t}$	141	$3780\ /\left(\frac{R_b}{t}\right)\left(1+\frac{\sqrt{R_b/t}}{35}\right)^2$
			9	8.2	$10.1 - 0.325\ \sqrt{R_b/t}$	450	$3780\ /\left(\frac{R_b}{t}\right)\left(1+\frac{\sqrt{R_b/t}}{35}\right)^2$
	Flat elements supported on one edge and with stiffener on other edge	16.2	see Part IA Section 3.4.16.2				
	Flat elements supported on both edges and with an intermediate stiffener	16.3	see Part IA Section 3.4.16.3				
COMPRESSION IN BEAM ELEMENTS, (element in bending in own plane), gross section	Flat elements supported on tension edge, compression edge free	17	28	9.1	$40.5 - 1.41\ b/t$	19	$4930\ /(b/t)^2$
			10	12	$13.7 - 0.277\ b/t$	33	$4930\ /(b/t)^2$
	Flat elements supported on both edges	18	28	48	$40.5 - 0.270\ h/t$	75	$1520\ /(h/t)$
			10	65	$13.7 - 0.053\ h/t$	129	$881\ /(h/t)$
	Flat elements supported on both edges and with a longitudinal stiffener	19	28	110	$40.5 - 0.117\ h/t$	173	$3500\ /(h/t)$
			10	150	$13.7 - 0.023\ h/t$	300	$2040\ /(h/t)$
SHEAR IN ELEMENTS, gross section	Unstiffened flat elements supported on both edges	20	12	36	$15.8 - 0.101\ h/t$	64	$38700\ /(h/t)^2$
			4.5	50	$6.0 - 0.029\ h/t$	139	$38700\ /(h/t)^2$
	Stiffened flat elements supported on both edges	21	12	–	12	66	$53200\ /(a_e/t)^2$
			4.5	93	$8.2 - 0.039\ a_e/t$	139	$53200\ /(a_e/t)^2$