CC PRE-AMP PLATFORM: STRUCTURAL ANALYSIS

Steven Sakla
June 9,1994

Approved:

D0 Engineering Note: 3740.210-EN-406

INTRODUCTION

The structure in question is an existing personnel access platform located in the D-Zero Assembly Building. This platform is used to access the pre-amplifiers located on the central calorimeter. The platform will need to be shortened to a "fold-out" length of 36 in. due to some modifications recently made to the detector. The purpose of this note is to determine whether this modification affects the safety and the rated load of the platform.

Three of the load carrying members were analyzed; the gusset supports, the hinge supports, and the hinge pins. The long and short beams which make up the platform's flooring were not analyzed (see pg. 1). The long beams will not be affected by this modification because there is no change in the length of their moment arms. The short beams will be affected, but will see a smaller bending stress because of the decrease in the length of their moment arms. Any weld results previously found will also not be affected.

ANALYSIS

The first member analyzed was the gusset support. This supporting member was statically indeterminate. The reaction forces as shown on pg. 2 are: $A_x=B_x=3594$ lbs. and $A_y+B_y=800$ lbs. The gusset was divided into three sections: A, B, and C which were all analyzed separately. Maximum bending and transverse shear stresses were calculated for each of the three sections. Section C was analyzed by defining the area, moment of inertia, and the moment as a function of x since these three values changed with the position at which the member was being analyzed. The maximum bending and transverse shear stresses were calculated as x varied from x=0 to x=33.5 by using a Fortran program. The maximum bending stress was 10,005 psi. and the maximum shear stress was 2403 psi. According to AISC specifications 1.5.1.4 and 1.5.1.2, respectively, the maximum allowable bending stress is equal to 0.66 x (yield stress)= 23.8 ksi. and the maximum allowable shear stress is equal to (0.40)x(yield stress) =14.4 ksi.

The next member analyzed was the hinge which is welded to the gusset support. Both the upper and lower hinges were analyzed. The maximum bending stress calculated was 22,986 psi. (upper hinge), the maximum normal stress was 7663 psi. (upper hinge), and the maximum shear stress was 640 psi.

(upper hinge). For a combined loading (compressive and bending stress), AISC specification 1.6.1 states that the sum of the ratios of the computed axial stress to 0.6 times the yield stress and the computed bending stress (in the x and y directions) to the allowable bending stress must be less than or equal to one. Both parts of the hinge met this criteria. The upper and lower hinges welded to the support bridge were also analyzed. The maximum normal stress for this member was 8170 psi. (upper hinge), the maximum bending stress was 8710 psi. (lower hinge), and the maximum shear stress was 2734 psi (lower hinge). Both parts of this hinge also met AISC specifications. The lower pin connecting the two parts of the hinge has a maximum shear stress of 15,504 psi which is below the maximum allowable stress of 18.7 ksi.

CONCLUSION

According to the calculations performed, this platform should still be safe after it's length is shortened to 36 in. provided the maximum load stays under 800 lbs. It also is within the allowable limits for normal, bending, and shear stress according to standards devised by the American Institute of Steel Construction.

SUMMARY

MEMBER	MAX. NORMAL STRESS	MAX. BENDING STRESS	MAX. SHEAR STRESS	PASS AISC SPECS.
Gusset Support	-	10,005 psi	2,403 psi	YES
Upper Hinge Welded to Gusset	7,663 psi	22,986 psi	640 psi	YES
Lower Hinge Welded to Gusset	3,832 psi	11,497 psi	0	YES
Upper Hinge Welded to Support Bridge	8,170 psi	7,756 psi	2,733 psi	YES
Lower Hinge Welded to Support Bridge	7,663 psi	8,710 psi	2,734 psi	YES
Upper Hinge Pin	-	-	14,015 psi (nominal)	YES
Lower Hinge Pin	-	-	15,504 psi (nominal)	YES

*F_y=36 ksi.

ALLOWABLE STRESSES:

Normal: $F_n=0.45F_y=16.2$ ksi
Bending: $F_b=0.66F_y = 23.8$ ksi.
Shear: $F_v=0.40F_y = 14.4$ ksi.
Shear (pin): $F_v=0.22(85 \text{ ksi.})=18.7$ ksi.
Combined (Shear & Bending): $(f_a/0.60F_y) + (f_{bx}/F_{bx}) + (f_{by}/F_{by}) \leq 1.0$

where f_a=calculated normal stress, F_y=yield stress
f_b=calculated bending stress, F_b=allowable bending stress

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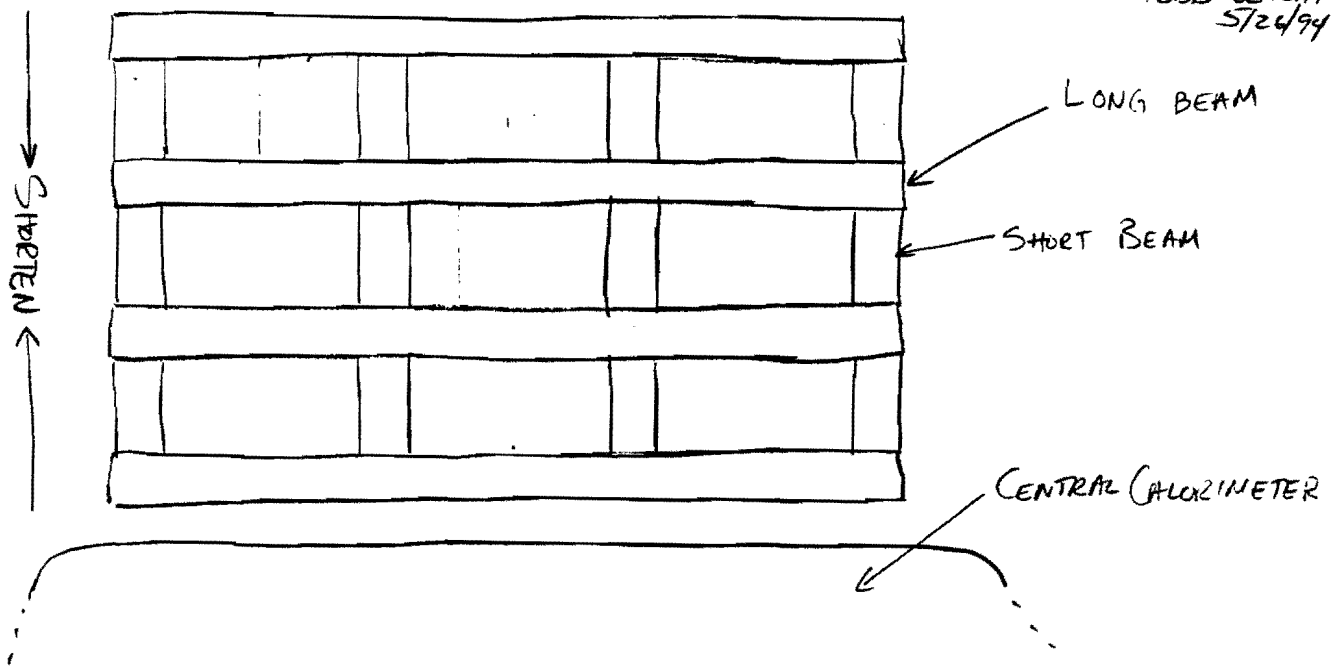
SUBJECT	NAME	
PLATFORM ANALYSIS	STEVE SAKLA	
	DATE 6-9-94	REVISION DATE

CHECKED: TODD LEICHT 5/26/94



- STRESSES IN THE LONG BEAMS WILL NOT CHANGE DUE TO SHORTENING OF THE PLATFORM

- STRESSES IN THE SHORT BEAM WILL NOT EXCEED ORIGINAL CALCULATIONS & WILL PROBABLY EVEN DECREASE. SINCE BENDING STRESS IS $\sigma = \frac{Mc}{I}$, c & I WILL REMAIN CONSTANT & THE BENDING MOMENT WILL DECREASE SINCE THE MOMENT ARMS WILL BE SHORTER.

- WELD ANALYSES WILL NOT CHANGE EITHER.

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SUBJECT: GUSSETT SUPPORT ANALYSES

NAME: STEVE SAKIA

DATE: 6-9-94

REVISION DATE:

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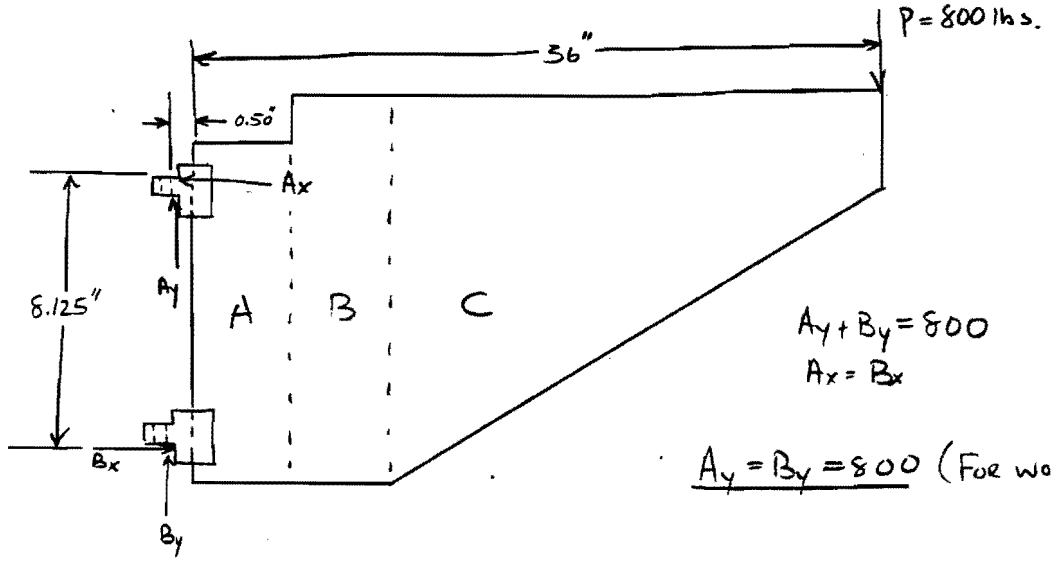


$A_y + B_y = 800$

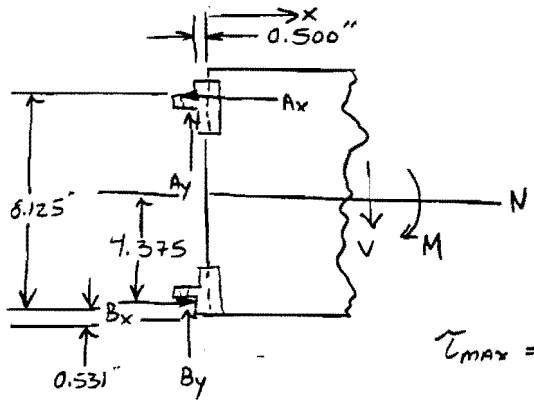
$A_x = B_x$

$\underline{A_y = B_y = 800}$ (FOR WORST CASE)

$\Sigma M_B = 36.5P - 8.125 A_x = 0$

$\underline{A_x = 3594 \text{ lb.}}$ $\underline{B_x = 3594 \text{ lbs.}}$

SECTION A:



$V = A_y + B_y = \underline{800 \text{ lbs.}}$

$M = -(\cancel{A_y + B_y})(x + 0.5) + B_x(4.375) + A_x(3.75)$ (800)

$= (3594)(3.75 + 4.375) - 400 - \cancel{800x}$ (0)

$= 28{,}801$ lb-in @ $x = 0$

$\sigma_{MAX} = \dfrac{(28{,}801 \text{ lb-in})(4.91 \text{ in})}{19.6833 \text{ in}^4} = \underline{\underline{7{,}185 \text{ psi}}}$

$\tau_{MAX} = \dfrac{1.5V}{A} = \dfrac{1200}{(0.25)(9.8125)} = \underline{\underline{490 \text{ psi}}}$

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SUBJECT	NAME STEVE SAKLA			
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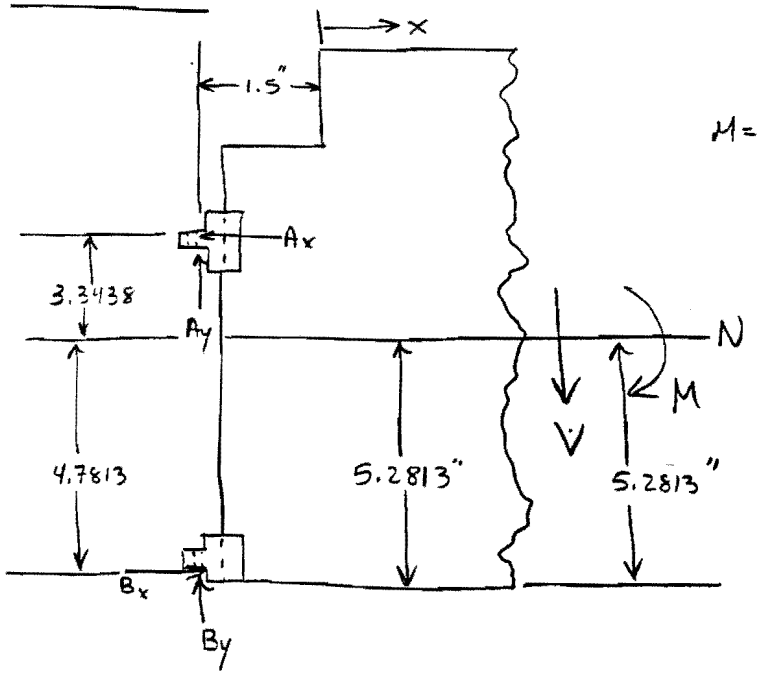
SECTION B:



$V = A_y + B_y = 800$ lbs.

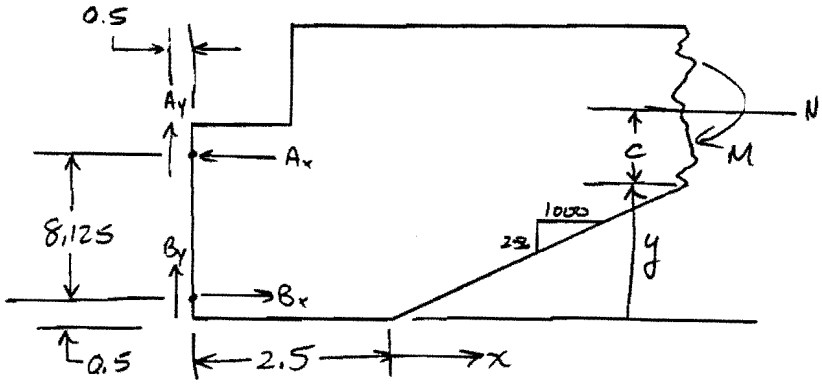
$M = A_x(3.3438 + 4.7813) - 800(1.5 + \cancel{x})^{0}$

$= 28{,}016$ lb-in @ $x=0$

$$\sigma_{MAX} = \frac{(28016 \text{ lb-in})(5.2813 \text{ in})}{24.5504 \text{ in}^4} = \underline{\underline{6027 \text{ psi}}}$$

$$\tau_{MAX} = \frac{1200 \text{ lb}}{(0.25)(10.5625)} = \underline{\underline{454 \text{ psi}}}$$

SECTION C:



$y = 0.2556x$

$c = \frac{1}{2}(10.5625 - y) = 5.28 - 0.1278x$

$A_y + B_y = 800$ lb.

$A_x = B_x = 3594$ lb.

$M = B_x(\cancel{c} + y - 0.5) - (A_y + B_y)(x+3) - A_x(\cancel{c} + y - 8.625)$

$= -0.5B_x + 8.625A_x - 2400 - 800x$

$= 8.125A_x - 2400 - 800x$

$= 26801 - 800x$ lb-in

$V = \underline{800 \text{ lb.}}$

$$\sigma = \frac{(26801 - 800x)(5.28 - 0.1278x)}{24.55 - 1.7813x + 0.043x^2 - 0.0003479x^3}$$

$I = \frac{1}{12}(0.25)(2c)$

$$\tau_{MAX} = \frac{1.5V}{A} = \frac{1200 \text{ lb.}}{(0.25)(2c)} = \frac{1200}{\frac{1}{2}(5.28 - 0.1278x)}$$

$= \underline{\underline{2403 \text{ psi}}}$

$\sigma_{MAX} = \underline{\underline{10{,}005 \text{ psi}}}$ @ $x = 28$ in

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SUBJECT: HINGE (WELDED TO GUSSET)

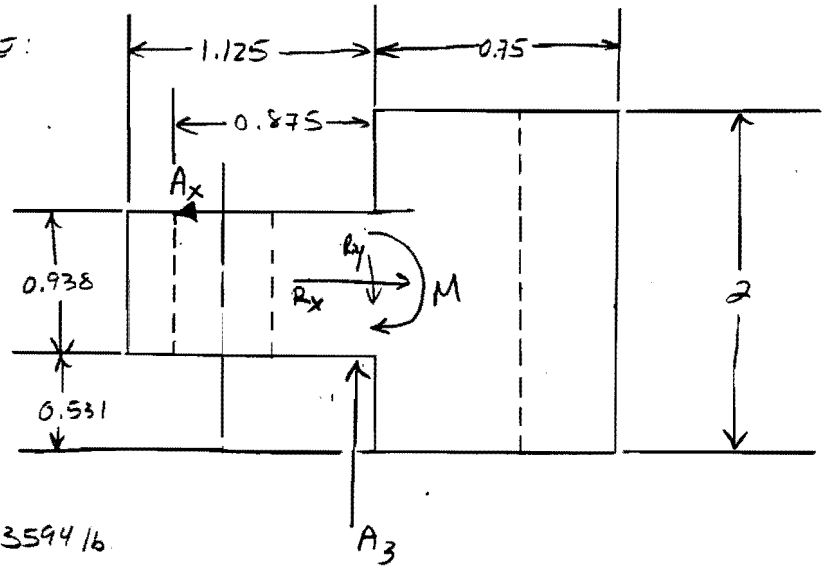
NAME: STEVEN SAKUA

DATE: 6-9-94

REVISION DATE:

CHECKED: TODD LEICHT 5/26/94

UPPER HINGE:

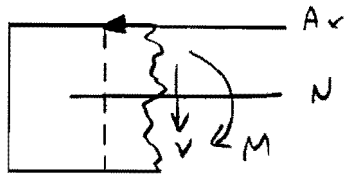


$R_x = A_x = 3594$ lb

$R_y = A_y = 800$ lb

$$\Sigma M_{A_3}: 0.375 R_y + 0.469 R_x - 0.938 A_x + M = 0$$

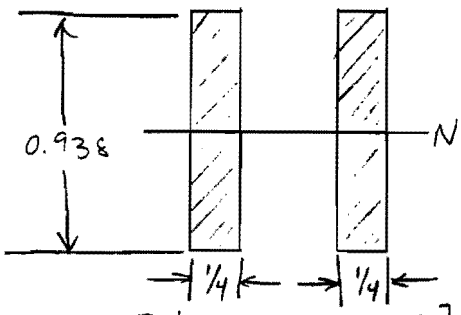
$$M = \underline{1386 \text{ lb-in}}$$



$M = 0.469 A_x = 1686$ lb-in

$$\sigma_{MAX} = \frac{(1686 \text{ lb-in})(0.469 \text{ in})}{0.0344 \text{ in}^4}$$

$$= \underline{\underline{22{,}986 \text{ psi}}}$$



$$I = 2\left[\tfrac{1}{12}(0.25)(0.938^3)\right]$$

$$= \underline{0.0344 \text{ in}^4}$$

$$\sigma_N = \frac{P}{A} = \frac{3594 \text{ lb}}{2(0.25)(0.938)} = \underline{\underline{7{,}663 \text{ psi}}}$$

$$\tau = \underline{\underline{\emptyset}}$$

SUBJECT

NAME: STEVE SAKUA

DATE: 6-9-94 | REVISION DATE

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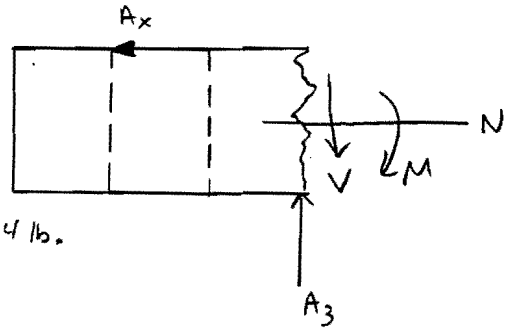
$V = A_3 = 800\ lb.$



$M = 0.469\ A_x = 1686\ lb\text{-}in$

$A_x = 3594\ lb.$

$\sigma_{max} = \dfrac{(1686\ lb\text{-}in)(0.469\ in)}{\frac{1}{12}(1)(0.938^3)}$

$= \underline{11{,}497\ psi}$

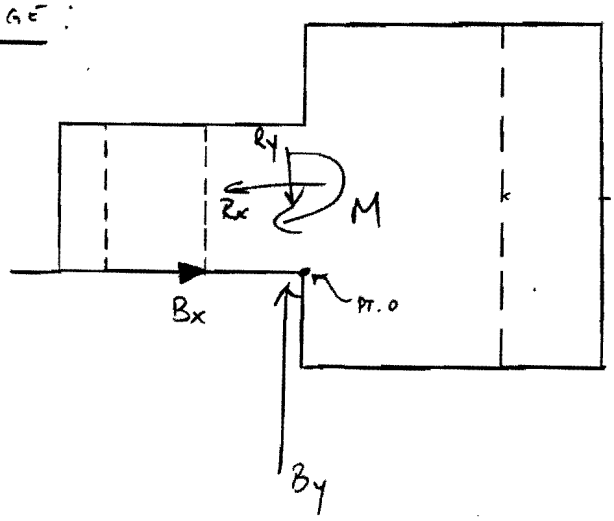
$Q = (0.2345)(0.2345)(1)$

$= 0.0550\ in^3$

$\sigma_n = \dfrac{3594\ lb.}{0.938\ in^2} = \underline{3832\ psi}$

$\tau = \dfrac{(800\ lb.)(0.0550\ in^3)}{1/12\ (1)(0.938^3)(1)} = \underline{640\ psi}$

LOWER HINGE:

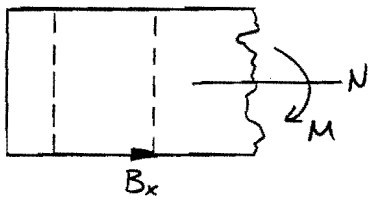


$R_x = B_x = 3594\ lb.$

$R_y = B_y = 800\ lb.$

$\Sigma M_o: \ M - 0.469\ R_x = 0$

$M = \underline{1686\ lb\text{-}in}$



$M = 0.469 B_x = 1686\ lb\text{-}in$

$\sigma_{max} = \underline{11497\ psi}$

$\sigma_n = \underline{3832\ psi}$

$\tau = \emptyset$

SUBJECT: HINGE (WELDED TO SUPPORT BRIDGE)

NAME: STEVE SAKLA
DATE: 6-9-94
REVISION DATE:
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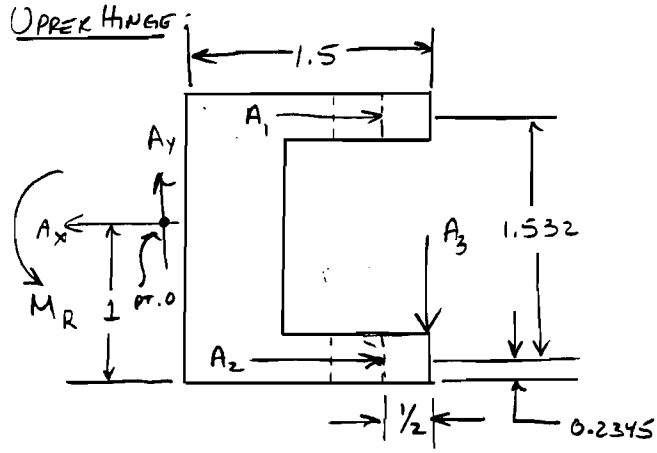
UPPER HINGE:

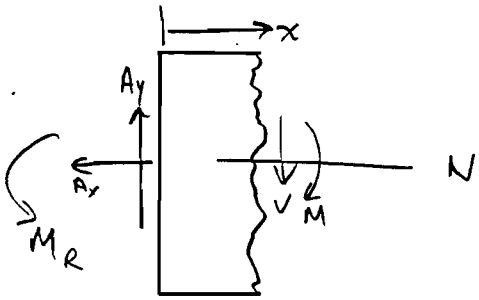


$A_1 = 2754$ lb.
$A_2 = 842$ lb.
$A_3 = 800$ lb.

$A_y = A_3 = 800$ lb
$A_x = A_1 + A_2 = 3587$ lb.

ΣM_o: $M_R + A_2(0.7655) - A_1(0.7655) - A_3(1.5) = 0$

$M_R = 2657$ lb-in



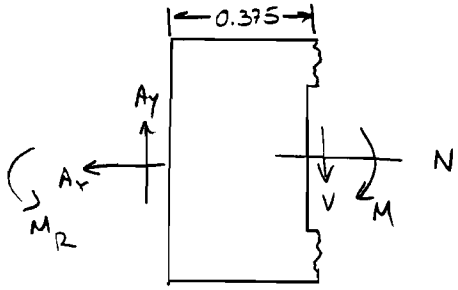
$V = A_y = 800$ lb.

$M = M_R - A_y(\cancel{x})^0$ $\quad 0 \le x \le 0.375$

$M = M_R = 2657$ lb-in

$$\sigma_{max} = \frac{(2657 \text{ lb-in})(1 \text{ in})}{\frac{1}{12}(1)(2^3)} = \underline{3986 \text{ psi}}$$

$$\tau_{max} = \frac{1.5(800)}{(1)(2)} = \underline{600 \text{ psi}} \qquad \sigma_n = \frac{3587 \text{ lb}}{2 \text{ in}^2} = \underline{1794 \text{ psi}}$$



$M = 2657$ lb-in $\qquad V = 800$ lb.

$$I = \frac{1}{12}\left[(1)(2^3) - (1)(1.063^3)\right] = 0.5666 \text{ in}^4$$

$$\sigma_{max} = \frac{(2657 \text{ lb-in})(1 \text{ in})}{0.5666 \text{ in}^4} = \underline{4690 \text{ psi}}$$

$$\sigma_n = \frac{3587 \text{ lb.}}{0.938 \text{ in}^2} = \underline{3824 \text{ psi}} \qquad \tau_{max} = \frac{1.5(800)}{(2 - 1.063)} = \underline{1281 \text{ psi}}$$

SUBJECT

NAME STEVE SAKLA
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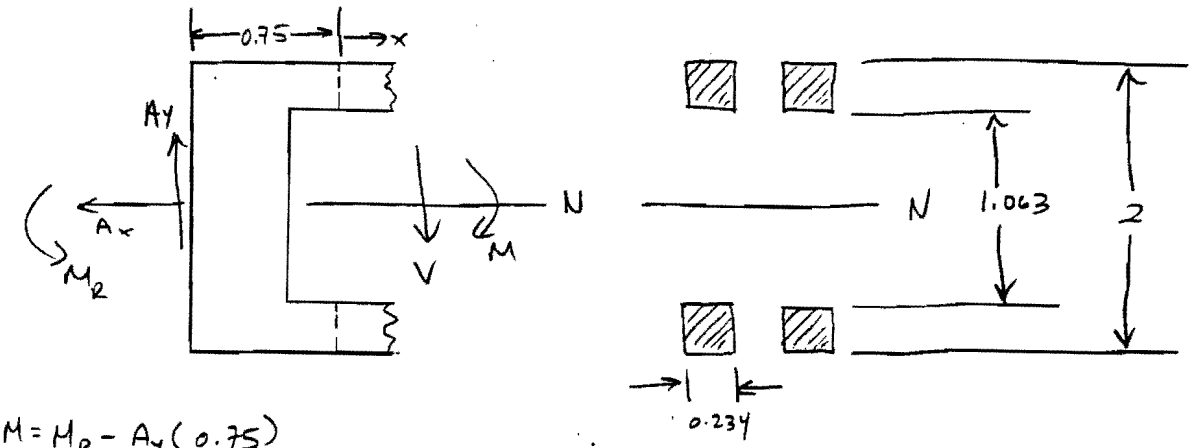

$M = M_R - A_y(0.75)$

$= 2657 - 800(0.75)$

$= 2057$ lb-in

$V = 800$ lb.

$$I_N = 2\left[\frac{1}{12}(0.234)(2^3) - \frac{1}{12}(0.234)(1.063^3)\right]$$

$$= 0.2652 \text{ in}^4$$

$$A = 4(0.234)(0.469) = 0.439 \text{ in}^2$$

$$\sigma_{max} = \frac{(2057 \text{ lb-in})(1 \text{ in})}{0.2652 \text{ in}^4} = \underline{\underline{7{,}756 \text{ psi}}}$$

$$\tau_{max} = \frac{1200 \text{ lb.}}{0.439 \text{ in}^2} = \underline{\underline{2733 \text{ psi}}}$$

$$\sigma_n = \frac{3587 \text{ lb.}}{0.439 \text{ in}^2} = \underline{\underline{8170 \text{ psi}}}$$

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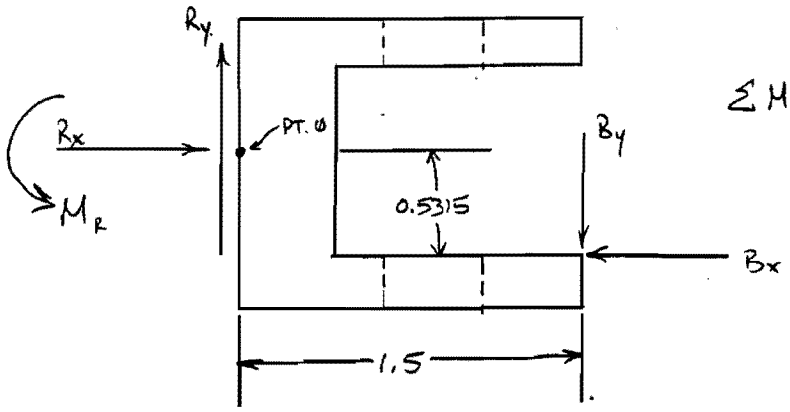
LOWER HINGE:

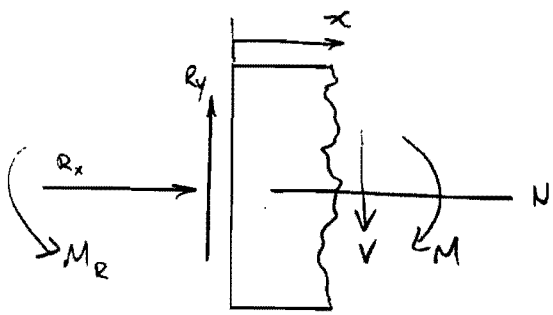
$R_y = B_y = 800\,lb.$

$R_x = B_x = 3594\,lb$



ΣM_o: $M_R - 1.5B_y - 0.5315\,B_x = 0$

$M_R = \underline{3110\,lb\text{-}in}$



$0 \le x \le 0.375$

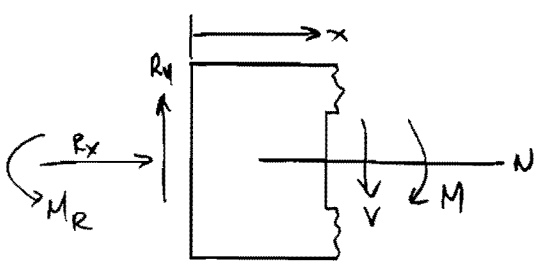
$M = M_R - R_y \cancel{x}^{\,0}$ $\qquad V = R_y = \underline{800\,lb}$

$M = M_R = 3110\,lb\text{-}in$

$$\sigma_{MAX} = \frac{(3110\,lb\text{-}in)(1\,in)}{\frac{1}{12}(1)(2^3)\,in^4} = \underline{\underline{4665\,psi}}$$

$$\tau_{MAX} = \frac{1.5(800)\,lb.}{2\,in^2} = \underline{\underline{600\,psi}}$$

$$\sigma_n = \frac{R_x}{2\,in^2} = \underline{\underline{1797\,psi}}$$



$0.375 \le x \le 0.75$

$I = \underline{0.566\,in^4}$

$V = \underline{800\,lb.}$ $\qquad M = M_R - R_y(0.375)$

$= \underline{2810\,lb\text{-}in}$

$$\sigma_{MAX} = \frac{(2810\,lb\cdot in)(1\,in)}{0.566\,in^4} = \underline{\underline{4965\,psi}}$$

$$\sigma_n = \frac{R_x}{0.938\,in^2} = \underline{\underline{3832\,psi}}$$

$$\tau_{MAX} = \frac{1.5(800)\,lb.}{0.938\,in^2} = \underline{\underline{1279\,psi}}$$

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	STEVE SAKLA	
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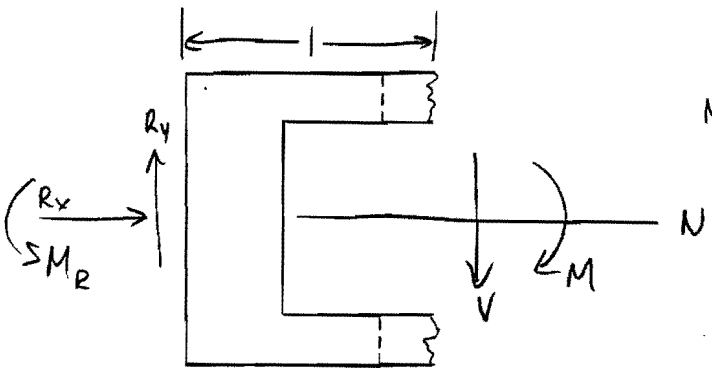
TODD LEICHT
5/26/94



$I = 0.2652 in^4$

$V = R_y = \underline{800 lb.}$

$M = M_R - R_y = 3110 - 800 = \underline{2310 \text{ lb-in}}$

$$\sigma_{MAX} = \frac{(2310 \text{ lb-in})(1 in)}{0.2652 in}$$

$$\sigma_{MAX} = \underline{8710 \text{ psi}}$$

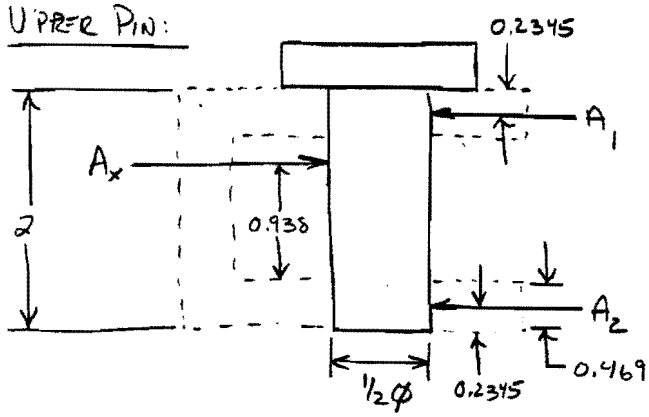
$$\sigma_n = \frac{3594 \text{ psi}}{0.469 in^2} = \underline{\underline{7,663 \text{ psi}}}$$

$$\tau_{MAX} = \frac{1200 \text{ lb.}}{0.439 in^2} = \underline{\underline{2734 \text{ psi}}}$$

SUBJECT: HINGE PIN

NAME: STEVEN SAKLA
DATE: 6-9-94
REVISION DATE:
CHECKED: TODD LEICHT 5/26/94

UPPER PIN:



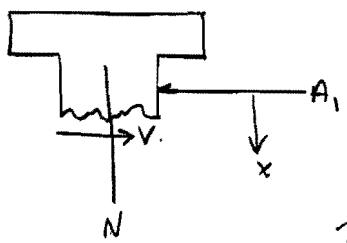
$A_x - A_1 - A_2 = 0$

ΣM_{A_x}: $0.3585 A_1 = 1.1725 A_2$

$A_1 = 3.2706 A_2$

$3594 - 4.2706 A_2 = 0$

$A_1 = 2754$ lb. $A_2 = 842$ lb.

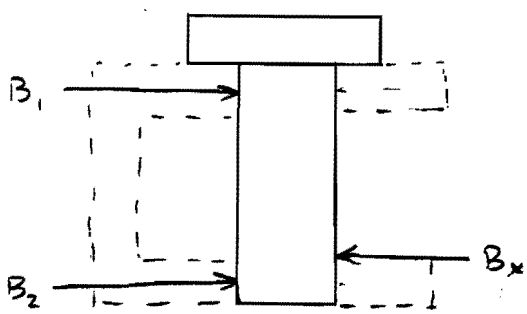


$V = A_1 = 2752$ lb.

$A = \frac{\pi d^2}{4} = 0.1963 in^2$

$\tau_{NOM} = \frac{2752 lb}{0.1963 in^2} = 14{,}015 psi$

LOWER PIN:



$B_x = 3594$ lb

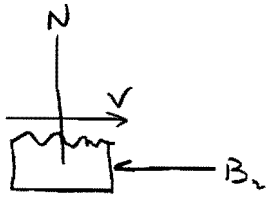
ΣM_{B_x}: $0.2345 B_2 = 1.2965 B_1$

$B_2 = 5.5288 B_1$

$B_1 + B_2 = B_x = 3594$

$B_1 = 550$ lb. $B_2 = 3044$ lb.

* SAME DIMENSIONS AS UPPER PIN



$V = B_2$

$\tau_{NOM} = \frac{V}{A} = \frac{3044 lb.}{0.1963 in^2} = 15{,}504 psi$

$A = \frac{\pi d^2}{4} = 0.1963 in^2$

SUBJECT: AISC SPECIFICATIONS

NAME: STEVE SAKLA

DATE: 6-9-94 | REVISION DATE:

CHECKED: TODD LEICHT 5/26/94

ALLOWABLE BENDING STRESS: $F_b = 0.66\,F_y = 23.8\text{ ksi}$ ($F_y = 36\text{ ksi}$)

ALLOWABLE SHEAR STRESS: $F_v = 0.40\,F_y = 14.4\text{ ksi}$

ALLOWABLE COMBINED LOADING: $\dfrac{f_a}{0.60F_y} + \dfrac{f_{bx}}{F_{bx}} + \dfrac{f_{by}}{F_{by}} \leq 1$

GUSSET: $F_b = 10{,}005\text{ psi} \leq 23.8\text{ ksi}$ ✓

$F_v = 2403\text{ psi} \leq 14.4\text{ ksi}$ ✓

HINGE (WELDED TO GUSSET): $F_b = 22{,}986\text{ psi} \leq 23.8\text{ ksi}$ ✓

$F_v = 640\text{ psi} \leq 14.4\text{ ksi}$ ✓

$$\frac{7{,}663}{0.6\,(36{,}000)} + \frac{22{,}986}{36{,}000} = 0.9933 \leq 1 \checkmark$$

HINGE (WELDED TO SUPPORT BRIDGE): $F_b = 8{,}710\text{ psi} \leq 23.8\text{ ksi}$ ✓

$F_v = 2{,}734\text{ psi} \leq 14.4\text{ ksi}$ ✓

$$\frac{8170}{0.6(36{,}000)} + \frac{8710}{36{,}000} = 0.6202 \leq 1 \checkmark$$

PIN: $F_v = 15{,}504\text{ psi} \leq 0.22\,(85\text{ ksi}) = 18.7\text{ ksi}$ ✓

* F = Allowable Stress
f = Calculated Stress

**********BENDING STRESS (PSI) AS A FUNCTION OF X**********

x=	0.5000000	stress=	5817.911
x=	1.500000	stress=	5928.270
x=	2.500000	stress=	6042.484
x=	3.500000	stress=	6160.721
x=	4.500000	stress=	6283.149
x=	5.500000	stress=	6409.942
x=	6.500000	stress=	6541.272
x=	7.500000	stress=	6677.314
x=	8.500000	stress=	6818.232
x=	9.500000	stress=	6964.186
x=	10.50000	stress=	7115.319
x=	11.50000	stress=	7271.751
x=	12.50000	stress=	7433.572
x=	13.50000	stress=	7600.825
x=	14.50000	stress=	7773.482
x=	15.50000	stress=	7951.436
x=	16.50000	stress=	8134.452
x=	17.50000	stress=	8322.131
x=	18.50000	stress=	8513.850
x=	19.50000	stress=	8708.673
x=	20.50000	stress=	8905.241
x=	21.50000	stress=	9101.626
x=	22.50000	stress=	9295.028
x=	23.50000	stress=	9481.528
x=	24.50000	stress=	9655.464
x=	25.50000	stress=	9808.680
x=	26.50000	stress=	9929.071
x=	27.50000	stress=	9998.222 ← σ_{MAX}
x=	28.50000	stress=	9986.627
x=	29.50000	stress=	9843.925
x=	30.50000	stress=	9473.969
x=	31.50000	stress=	8660.011
x=	32.50000	stress=	6746.609
x=	33.50000	stress=	18.57320

**********SHEAR STRESS (PSI) AS A FUNCTION OF X**********

x=	0.5000000	stress=	460.1139
x=	1.500000	stress=	471.6703
x=	2.500000	stress=	483.8222
x=	3.500000	stress=	496.6168
x=	4.500000	stress=	510.1064
x=	5.500000	stress=	524.3494
x=	6.500000	stress=	539.4106
x=	7.500000	stress=	555.3627
x=	8.500000	stress=	572.2870
x=	9.500000	stress=	590.2751
x=	10.50000	stress=	609.4309
x=	11.50000	stress=	629.8716
x=	12.50000	stress=	651.7311
x=	13.50000	stress=	675.1624
x=	14.50000	stress=	700.3414
x=	15.50000	stress=	727.4711
x=	16.50000	stress=	756.7874
x=	17.50000	stress=	788.5657
x=	18.50000	stress=	823.1299
x=	19.50000	stress=	860.8630
x=	20.50000	stress=	902.2216
x=	21.50000	stress=	947.7549
x=	22.50000	stress=	998.1284
x=	23.50000	stress=	1054.157
x=	24.50000	stress=	1116.850
x=	25.50000	stress=	1187.472
x=	26.50000	stress=	1267.628
x=	27.50000	stress=	1359.388
x=	28.50000	stress=	1465.470
x=	29.50000	stress=	1589.509
x=	30.50000	stress=	1736.488
x=	31.50000	stress=	1913.418
x=	32.50000	stress=	2130.492
x=	33.50000	stress=	2403.124 ← τ_{MAX}