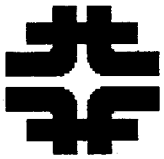


Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-300 Date: 7 JAN 2011

Project Internal Reference:

Project: NOvA

Title: Near Detector 10 ton Block Support Bracket

Author(s): K. Beczkiewicz

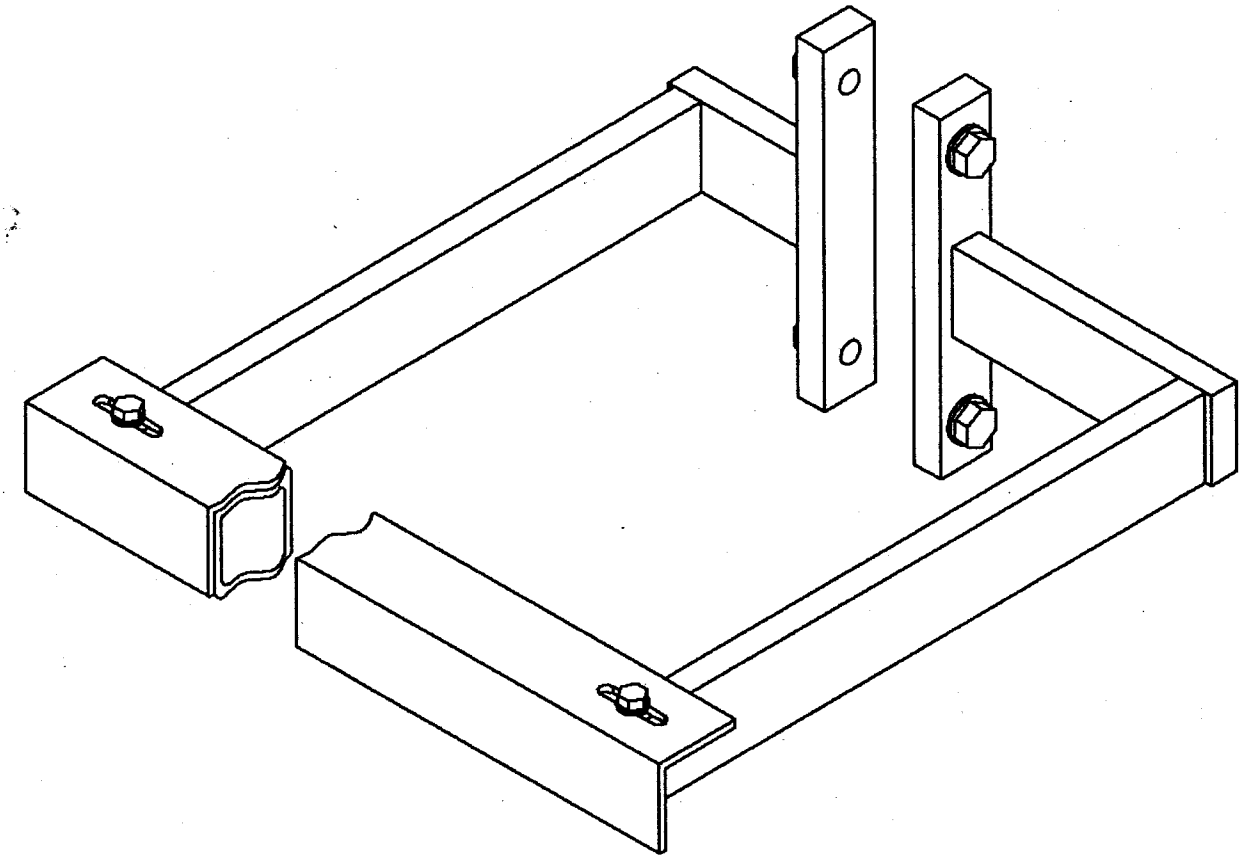
Reviewer(s):

Key Words: NOvA, Near Detector, Block Support

Abstract Summary: The following note determines the stresses and deflections that will occur in a support bracket and whether or not those values fall within allowable ranges. The block, which weighs roughly 10 tons, is to be moved using a forklift.

Applicable Codes:

Support Bracket



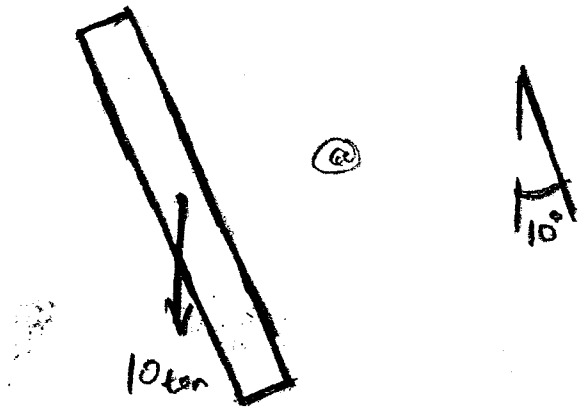
The design of the support bracket consists of the following parts:

- 2: 1" x 2" x 12" bars
- 1: 1" x 3" x 5.5" bar
- 1: 1" x 3" x 10" bar
- 2: 1" x 3" x 23" bars
- 3" x 3" x 0.25" Structural steel tubing
- L3 x 3 x ¼ x 120" LG

All parts are assumed to be ASTM A36 structural steel. The structural steel tubing is bolted to the angle. The 1"x 2"x 12" bar is bolted to the steel block using ¾"-10 bolts (A307 assumed). The 1" x 3" x 5.5"/10" bars are welded to the 1" x 3" x 23" bars using ¼" fillet welds (E70xx weld metal assumed). They are welded to the 1" x 2" x 12" bars using ½" fillet welds.

When the block is being transported on the forklift, it is assumed that the largest angle that would occur relative to the mast of the forklift is 10°. The values in this note are calculated using the resultant forces assuming that this is the case.

DESIGN ANALYSIS

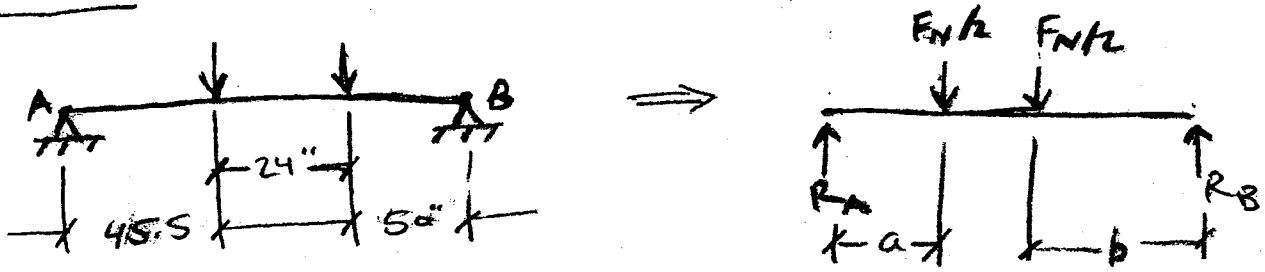


$F_N = (20{,}000 \text{ lbs}) \sin(10°)$

$= 3473 \text{ lbs}$

CENTER OF PL ASSUMED TO BE CENTERED ON FORKS OF FORKLIFT; L 3x3x½ IS NOT CENTERED ON FORKLIFT

ANGLE



$$R_A = \frac{P}{\ell}(\ell - a + b)$$

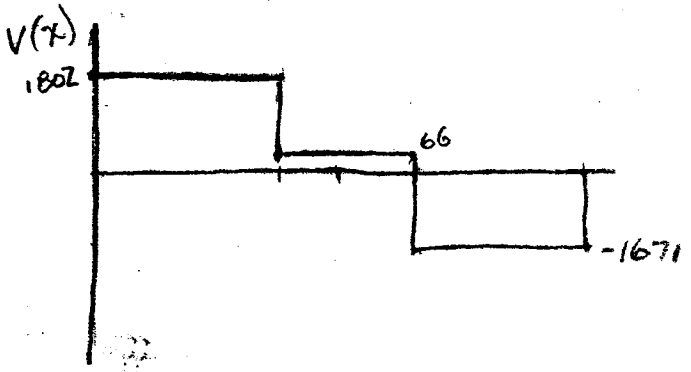
$$= \left(\frac{1736 \text{ lbs}}{119.5 \text{ in}}\right)(119.5 \text{ in} - 45.5 \text{ in} - 50 \text{ in})$$

$R_A = 1802 \text{ lbs.}$

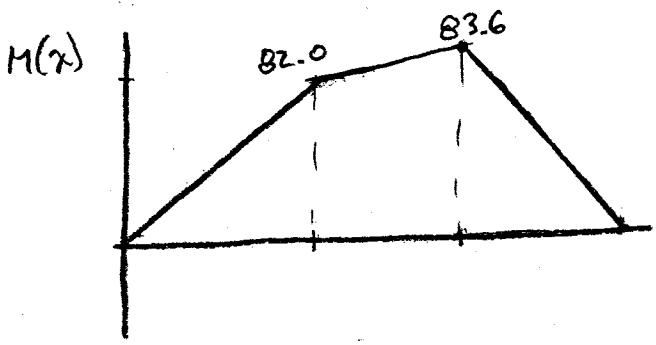
$$R_B = \frac{P}{\ell}(\ell - b + a)$$

$$= \left(\frac{1736 \text{ lbs}}{119.5 \text{ in}}\right)(119.5 \text{ in} - 50 \text{ in} + 45.5 \text{ in})$$

$R_B = 1671 \text{ lbs}$



$$V = (1802)\langle x\rangle^0 + (-1736)\langle x-45.5\rangle^0 + (-1736)\langle x-69.5\rangle^0$$



$$M(x) = (1802)\langle x\rangle^1 + (-1736)\langle x-45.5\rangle^1 + (-1736)\langle x-69.5\rangle^1$$

$$EI\theta = \int M(x)\,dx$$

$$EI\theta = \left(\frac{1802}{2}\right)\langle x\rangle^2 + \left(\frac{-1736}{2}\right)\langle x-45.5\rangle^2 + \left(\frac{-1736}{2}\right)\langle x-69.5\rangle^2 + C_1$$

$$EI\delta = \int EI\theta\,dx$$

$$EI\delta = \left(\frac{1802}{6}\right)\langle x\rangle^3 + \left(\frac{-1736}{6}\right)\langle x-45.5\rangle^3 + \left(\frac{-1736}{6}\right)\langle x-69.5\rangle^2 + C_1x + C_2$$

FOR $\delta(0)=0$, $C_2=0$

$\delta(119.5)=0$,

$$-C_1(119.5) = \left(\frac{1802}{6}\right)\langle 119.5\rangle^3 + \left(\frac{-1736}{6}\right)\langle 119.5-45.5\rangle^3 + \left(\frac{-1736}{6}\right)\langle 119.5-69.5\rangle^3$$

$$C_1 = -3\times10^6$$

$\delta = \delta_{MAX}$ WHEN $\theta = 0$

$$EI\theta = 0 = \left(\frac{1802}{2}\right)\langle x\rangle^2 + \left(\frac{-1736}{2}\right)\langle x-45.5\rangle^2 + \left(\frac{-1736}{2}\right)\langle x-69.5\rangle^2 + -3\times10^6$$

$EI\theta = 0$ WHEN $x = 59.26$

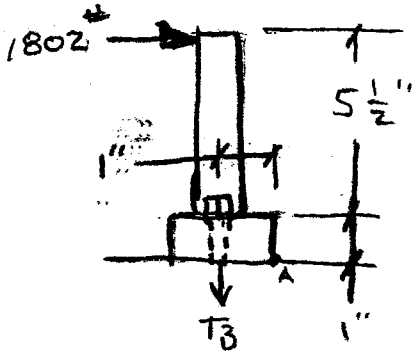
$$\delta_{MAX}(59.26) = \frac{1}{EI}\left[\left(\frac{1802}{6}\right)\langle 59.26\rangle^3 + \left(\frac{-1736}{6}\right)\langle 59.26-45.5\rangle^3 + -3\times10^6(59.26)\right]$$

$$|\delta_{MAX}| = 0.91 \text{ in.}$$

TENSION IN BOLTS

3/4" - 10 BOLTS (x2) A307 (ASSUMED)

1" x 3" x 5½"



$M_A = 0 = (-1802 \text{ lbs})(6\frac{1}{2} \text{ in.}) + (T_B)(1 \text{ in})$

$T_B = \frac{(1802 \text{ lbs})(6\frac{1}{2} \text{ in})}{(1 \text{ in.})}$

$T_B = 11.7 \text{ kips}$

$F_A = \frac{T_B}{2A}$

$F_A = \frac{11.7 \text{ kips}}{2(\pi(\frac{0.75}{2})^2)}$

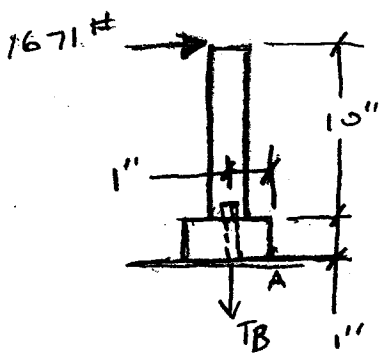
$F_A = 13.3 \text{ ksi}$

$F_Y = 0.75(45 \text{ ksi}) = 33.8 \text{ ksi}$

$13.3 \text{ ksi} < 33.8 \text{ ksi}$

OK

1" x 3" x 10"



$M_A = 0 = (-1671 \text{ lbs})(11 \text{ in.}) + (T_B)(1 \text{ in.})$

$T_B = \frac{(1671 \text{ lbs})(11 \text{ in.})}{(1 \text{ in.})}$

$T_B = 18.4 \text{ kips-in.}$

$F_A = \frac{T_B}{2A}$

$F_A = \frac{18.4 \text{ kips-in.}}{2(\pi(\frac{0.75}{2})^2)}$

$F_A = 20.8 \text{ ksi}$

$20.8 \text{ ksi} < 33.8 \text{ ksi}$

OK

SHEAR STRESS : BOLTS & PLATE

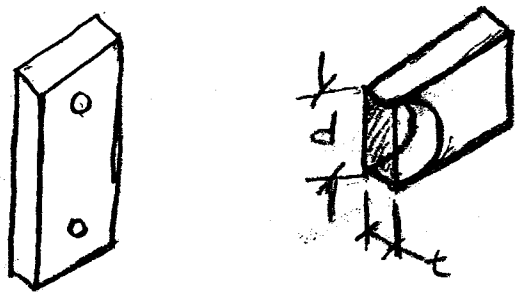


PLATE (L)

$$V_{P,L} = \frac{P_L}{A}$$

$P_L = 1802$ lbs

$A = td = (1\text{ in.})(0.75\text{ in.})$

$$V_{P,L} = \frac{1802\text{ lbs}}{(1\text{ in.})(0.75\text{ in})}$$

$V_{P,L} = 2.4$ ksi

$F_y = 21$ ksi

2.4 ksi < 21 ksi OK

BOLT (L)

$$V_{B,L} = \frac{P_L}{A}$$

$P_L = 1802$ lbs

$A = 2(\pi r^2) = 2\pi\left(\frac{0.75\text{ in}}{2}\right)^2$

$$V_{B,L} = \frac{1802\text{ lbs}}{0.883\text{ in}^2}$$

$V_{B,L} = 2.04$ ksi

$F_y = 0.75(24\text{ ksi}) = 18$ ksi

2.04 ksi < 18 ksi OK

PLATE (R)

$$V_{P,R} = \frac{P_R}{A}$$

$P_R = 1671$ lbs

$A = td = (1\text{ in.})(0.75\text{ in})$

$$V_{P,R} = \frac{1671\text{ lbs}}{(1\text{ in.})(0.75\text{ in})}$$

$V_{P,R} = 2.23$ ksi

$F_y = 21$ ksi

2.23 ksi < 21 ksi OK

BOLT (R)

$$V_{B,R} = \frac{P_R}{A}$$

$P_R = 1671$ lbs

$A = 2(\pi r^2) = 2\pi\left(\frac{0.75\text{ in}}{2}\right)^2$

$$V_{B,R} = \frac{1671\text{ lbs}}{0.883\text{ in}^2}$$

$V_{B,R} = 1.89$ ksi

$F_y = 18$ ksi

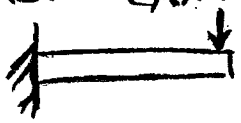
1.89 ksi < 18 ksi OK

STRESS & DEFLECTION IN 1"x3" BEAMS

- 2 SEPARATE LENGTHS

  5 ½", 10"

- BASIC CANTILEVER



1"x3"x5½"

$$\delta_{MAX} = \frac{PL^3}{3EI}$$

P = 180.2 lbs
L = 5½ in.
E = 29x10⁶ psi
$I = \frac{1}{12}bh^3 = \frac{1}{12}(3in.)(1in.)^3$
$= 0.25 in.^4$

$\delta_{MAX} = 0.014$ in.

$$\sigma_{MAX} = \frac{My}{I}$$

$M = (180.2 lbs)(5.5 in.)$
$= 9.91$ kips-in
$y = 0.5$ in.

$$\sigma_{MAX} = \frac{(9910 lbs \cdot in)(0.5 in)}{(0.25 in^4)}$$

$\sigma_{MAX} = 19.8$ ksi

$F_y = 0.6 \cdot (36 ksi) = 21.6$ ksi

19.8 ksi < 21.6 ksi OK

1"x3"x10"

$$\delta_{MAX} = \frac{PL^3}{3EI}$$

P = 167 lbs
L = 10 in.
E = 29x10⁶ psi
$I = 0.25 in.^4$

$\delta_{MAX} = 0.077$ in.

$$\sigma_{MAX} = \frac{My}{I}$$

$M = (167 lbs)(10 in)$
$= 16.7$ kips-in.

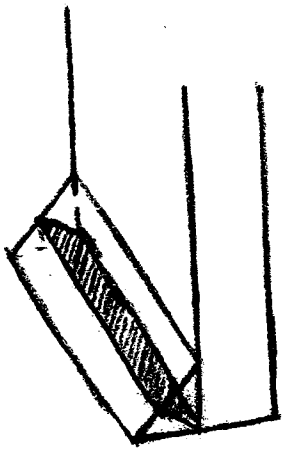
$$\sigma_{MAX} = \frac{(16.7 kips \cdot in)(0.5 in)}{(0.25 in^4)}$$

$\sigma_{MAX} = 33.4$ ksi

$F_y = 21.6$ ksi

33.4 ksi > 21.6 ksi
TOO HIGH

SHEAR & TENSION IN WELDS



CRIT. THROAT AREA (SHEAR)

$A = 0.707 w \ell$

$w = 0.5$ in

$\ell = 2\times(1\text{ in.}) + 2\times(3\text{ in})$

$\ell = 8$ in.

$A = 0.707(0.5\text{ in})(8\text{ in.})$

$A = 2.83\text{ in}^2$

ALLOWABLE SHEAR STRESS

$V_{ALLOW} = 0.3(70\text{ksi})$

$= 21$ ksi

$V_L = \frac{1802\text{ lbs}}{2.83\text{ in}^2} = 0.64$ ksi

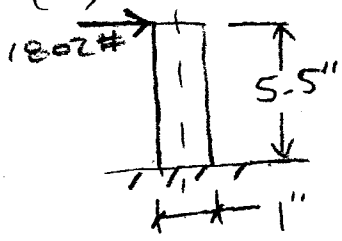
$V_R = \frac{1671\text{ lbs}}{2.83\text{ in}^2} = 0.59$ ksi

(L) 0.64 ksi < 21 ksi OK

(R) 0.59 ksi < 21 ksi OK

MOMENTS ACTING ON WELDS

(L)



MOMENT $= (1802\#)(5.5\text{ in.})$

$= 9.91$ kips·in.

MAX TENSION @ 0.5 in FROM CENTER

$T_{MAX} = \frac{9.91\text{kips-in}}{0.5\text{ in}} = 19.8$ kips

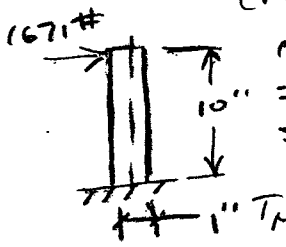
$V_{ACTUAL} = \frac{19.8\text{ kips}}{0.707(0.5\text{in})(3\text{in}+0.5\text{in}+0.5\text{in})}$

$V_{ACTUAL} = 14.0$ ksi

$V_{ALLOW} = 0.3\cdot 70\text{ksi} = 21$ ksi

$14.0\text{ksi} < 21\text{ksi}$ OK

(R)



MAX. MOMENT $= (1671\text{ lbs})(10\text{in})$

$= 16.7$ kips-in

$T_{MAX} = \frac{16.71\text{ kips-in}}{0.5\text{ in}}$

$= 33.4$ kips

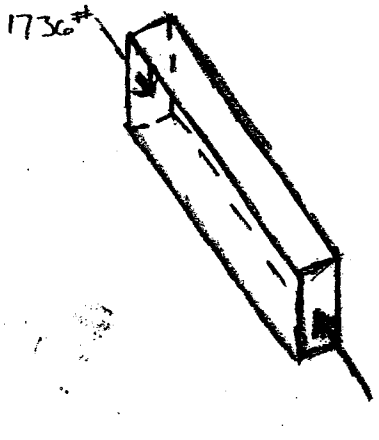
$V_{ACTUAL} = \frac{33.4}{0.707(0.5\text{in})(3\text{in}+.5\text{in}+.5\text{in}}$

$= 23.6$ ksi

$23.6\text{ ksi} > 21\text{ ksi}$ TOO HIGH

THE ABOVE VALUE FOR ALLOWABLE SHEAR IS A CONSERVATIVE VALUE.

COMPRESSION IN 1" x 3" x 23"



$$C_L = \frac{P_L}{A} \qquad P_L = 1802 \text{ lbs}, \quad A = 3 in^2$$

$$C_L = \frac{1802 \text{ lbs}}{3 in^2}$$

$$\boxed{C_L = 0.601 \text{ ksi}}$$

$$C_R = \frac{P_R}{A}$$

$$P_R = 1671 \text{ lbs}, \quad A = 3 in^2$$

$$C_R = \frac{1671 \text{ lbs}}{3 in^2}$$

$$\boxed{C_R = 0.557 \text{ ksi}}$$