Fermilab

Particle Physics Division

Mechanical Department Engineering Note

Number: MD-ENG-329 Date: April 6, 2011

Project:

Project Internal Reference:

Title: E906 Beam Dump Shielding Cave Revised Layout 4- 6-2011

Author(s): R. J. Woods

Reviewer(s): Dave Pushka

Key Words: E906, Beam Dump, Shielding Cave

Abstract/Summary:

This note analyzes another revision to the block layout for the shield block cave. The top upstream blocks have been rearranged as shown in "View A" on page 8 of this note. Four horizontal "H" blocks and two horizontal "G" blocks are cantilevered out 54 inches. These blocks are supported by a horizontal layer of "H" blocks on the far upstream end of the cave. The calculations on pages 1 and 2 prove that the supporting "H" blocks can safely carry the imposed loads.

Two 9 inch layers of steel beams, 18 inches wide, are located directly under the supporting "H" blocks. These blocks are shown in blue in "View A". The calculations on page 3 show that these solid steel beams can safely carry the total load from above.

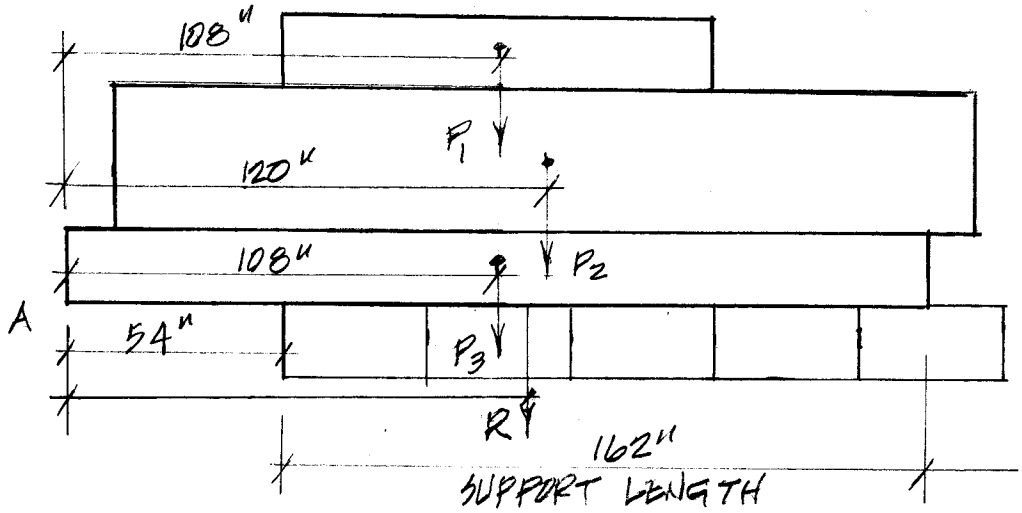
Pages 4 through 7 include the calculations for the horizontal "H" blocks which are supported by 6 inches of steel shim blocks placed on top of the magnet. These "H" blocks will cantilever 18.625 inches on the upstream end as shown in "View B" on page 8. These calculations show that the "H" blocks can safely carry the loads from above.

Applicable Codes:

Building Code Requirements for Structural Concrete (ACI 318-02), American Concrete Institute, Farmington Hills, Michigan.

Manual of Steel Construction ASD, American Institute of Steel Construction, Chicago, Illinois, ~~Sixth~~ 9th Edition, 1989

FOR 12" WIDTH:
(SEE VIEW A, PAGE 8)



		DISTANCE FROM "A"	P x d
P_1 =	2025#	108	218700
P_2 =	8100#	120	972000
P_3 =	4050#	108	437400
	14175 = R	TOTAL	1628100

RESULTANT DISTANCE FROM "A" = 1628100/14175 = 114.9"

DISTRIBUTION OF LOAD OVER 162" BEARING LENGTH:

$$14175 = \frac{162(y_1+y_2)}{2}$$

$$175 = y_1 + y_2$$

$$175 - y_1 = y_2$$

DISTANCE FROM LEFT EDGE OF BEARING AREA TO R =
114.9 - 54 = 60.9" ∴ DIST. FROM R TO RIGHT
EDGE = 162 - 60.9 = 101.1"

$$101.1 = \frac{162(2y_1 + 175 - y_1)}{3(175)}$$

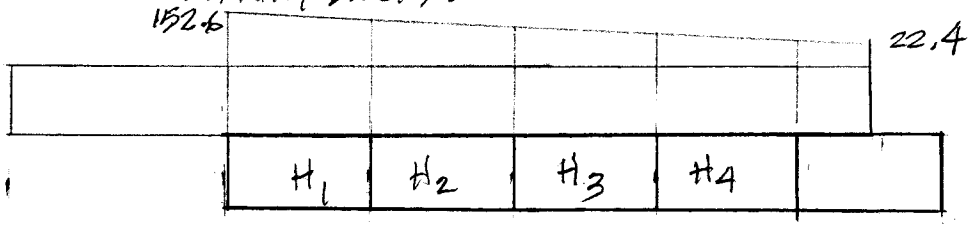
$$53077.5 = 324y' + 28350 - 162y'$$

$$24727.5 = 162y'$$

$$152.6 = y_1$$

$$22.4 = y_2$$

"H" BEARING BLOCKS:



RATE OF LOAD DECREASE $= (152.6 - 22.4)/162$
$= 0.804$ #/IN

$152.6 - 36(0.804) = 123.7$
$123.7 - 36(0.804) = 94.75$
$94.75 - 36(0.804) = 65.8$
$65.8 - 36(0.804) = 36.9$
$36.9 - 18(0.804) = 22.4$

LOAD ON $H_1 = \frac{36(152.6+123.7)}{2} = 4973.4$ #/FT

LOAD ON $H_2 = \frac{36(123.7+94.75)}{2} = 3932.1$ #/FT

LOAD ON $H_3 = \frac{36(94.75+65.8)}{2} = 2889.9$ #/FT

SERVICE LOAD MOMENT ON BLOCK H_1:

SPAN = 113"

$w = 150/1728(18 \times 36) + 4973.4/12$
$= 56.25$ #/IN $+ 414.45$ #/IN
$= 470.7$ #/IN

$M = 470.7(113)^2/8$
$= 751296$ #-IN

$M_u = M \times 1.4 = 751296(1.4) = 1051814$ #-IN

ALLOWABLE MOMENT FOR "H" BLOCK:

$f'_c = 5000$ PSI $f_y = 60{,}000$ PSI
$h = 18"$ $b = 36"$ $L = 113"$ $A_s = 4$-#6 BARS $= 4(0.44) = 1.76$ IN^2

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{1.76(60)}{0.85(5)(36} = 0.690$

$M_u = \phi A_s f_y (d - a/2)$
$= 0.9(1.76)(60)(15.25 - 0.690/2) = 1417$ K-IN
$= 1{,}417{,}000$ #-IN
$> 1{,}051{,}814$ #-IN OK

SHEAR @ SUPPORT:

$R = 470.7(113)/2 = 26595\#$

$R_u = 26595(1.4) = 37232\# = V_u$

$V_c = 2\sqrt{f'_c}\, b_w d$

$= 2\sqrt{5000}(36)(15.25)$

$= 77640$ psi

$V_n = V_c$

$\phi V_n \geq V_u$

$0.75(77640) \overset{?}{\geq} 37232$

$58230 > 37232$ ok

CHECK STEEL BEAMS

SIZE = 18" WIDE x 9" DEEP

$S_x = 18(9)^2/6 = 243\ IN^3$

$M = 751296 + 18(9)/144(490)(113)^2/8$

$= 1{,}631{,}156$ #-IN

$f_b = 1631156/243 = 6713$ psi

$F_b = 0.75\,F_y$ (AISC F2-1, p. 5-48)

$= 0.75(36) = 27$ KSI

$= 27{,}000$ psi > 6713 psi ok

$F_v = 0.40\,F_y$ (AISC F4-1, p. 5-49)

$= 0.40(36) = 14.4$ KSI

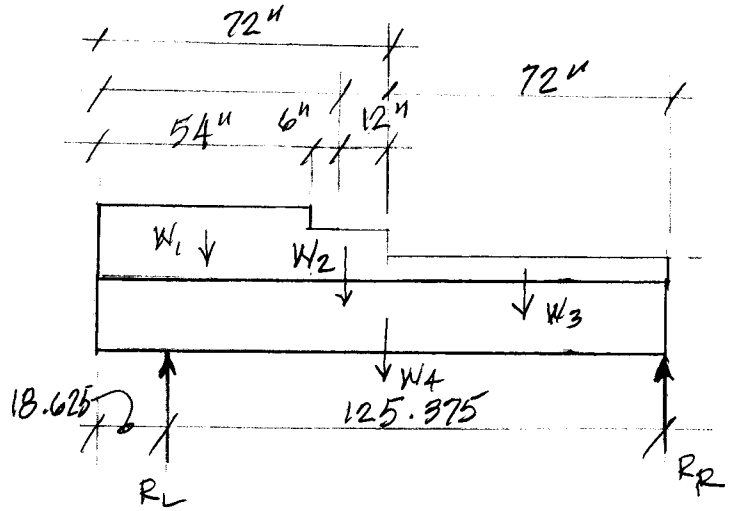
$= 14{,}400$ psi

$f_v = (26595 + 9(18)/144(490)(113/12\times 2))/9(18)$

$= 29190\#/162\ IN^2$

$= 180$ psi $< 14{,}400$ psi ok

CHECK "J" BLOCK @ CENTER OF DUMP OVER MAGNET:
(SEE VIEW B, PAGE 2)



$$w_1 = (18+18+36)(150)/1728 + 18(490)/1728$$
$$= 11.35\ \#/IN^2$$
$$11.35\,(36") = 408\ \#/IN$$

$$w_2 = 18\,(150)/1728 + 18(490)/1728$$
$$= 6.67\ \#/IN^2$$
$$6.67(36") = 240\ \#/IN$$

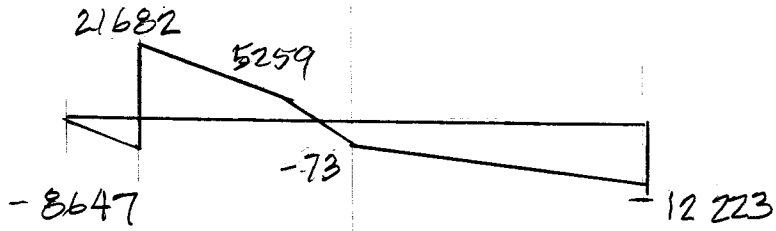
$$w_3 = 36\,(150)/1728$$
$$= 3.125\ \#/IN^2$$
$$3.125\,(36") = 112.5$$

$$w_4 = 18(150)/1728 = 1.5625\ \#/IN^2$$
$$1.5625(36") = 56.25$$

$$W_1 = 408(54) = 22032\ \#$$
$$W_2 = (6+12)(240) = 4320\ \#$$
$$W_3 = 72(112.5) = 8100\ \#$$
$$W_4 = 144(56.25) = 8100\ \#$$

$$R_L = \frac{72(8100) + 72/2(8100) + (72+18/2)(4320) + (72+18+54/2)(22032)}{125.375}$$
$$= 30329\ \#$$

$$R_R = \frac{(\frac{54}{2} - 18.625)(22032) + 44.375(4320) + 89.375(8100) + 53.375(8100)}{125.375}$$
$$= 12223\ \#$$



$M_{CANT} = 18.625(8647)/2$
$= 80\,525$ #-IN

$M_{u\,CANT} = 80\,525\,(1.4) = 112\,735$ #-IN

$M_{SPAN} = \frac{(21682+5259)(35.375)}{2} + 17.75(5259)/2 - 112\,735$
$= 410\,458$ #-IN

$M_{u\,SPAN} = 410\,458\,(1.4) = 574\,641$ #-IN

CAPACITY OF "J" BLOCK BASED ON TOP REINF. (WEAK AXIS BENDING)

$f'_c = 5000$ psi $f_y = 60{,}000$ psi $h = 18''$ $b = 36''$ $L = 144''$

$A_s = 3$-#6 BARS $= 3(0.44) = 1.32$ IN^2

$d = 18 - 2.75 = 15.25$

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{1.32(60)}{0.85(5)(36)} = 0.518$

$M_u = \phi A_s f_y (d - a/2) = 0.9(1.32)(60)(15.25 - \frac{0.518}{2})$
$= 1069$ K-IN
$= 1{,}069{,}000$ #-IN $> 112\,735$ #-IN <u>ok</u>

CAPACITY OF "J" BLOCK BASED ON BOTTOM REINF. (WEAK AXIS BENDING)

$f'_c = 5000$ psi $f_y = 60{,}000$ psi $h = 18''$ $b = 36''$ $L = 144''$

$A_s = 4$-#6 BARS $= 4(0.44) = 1.76$ IN^2

$d = 18 - 2.75 = 15.25''$

$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{1.76(60)}{0.85(5)(36)} = 0.690$

$M_u = \phi A_s f_y (d - a/2) = 0.9(1.76)(60)(15.25 - \frac{0.690}{2})$
$= 1417$ K-IN
$= 1\,417\,000$ #-IN $> 574\,614$ #-IN <u>ok</u>

CHECK SHEAR

$R = 30329$ $V_u = 1.4(30329) = 42\,460$ #

$V_c = 2\sqrt{f'_c}\, b_w d = 2\sqrt{5000}\,(36)(15.25) = 77\,640$ #

$V_n = V_c$

$\phi V_n \geq V_u$?

$0.75(77640) \overset{?}{\geq} 42\,460$

$58\,230 > 42\,460$ <u>ok</u> J BLOCK <u>ok</u>

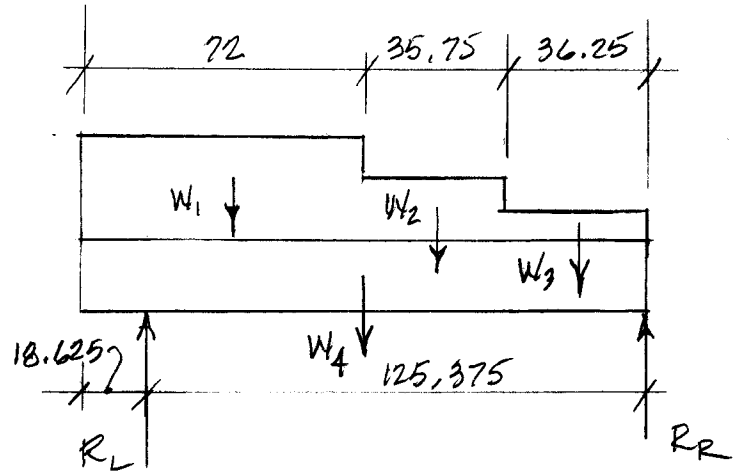
E906 BEAM DUMP

SHIELDING CAVE

R. J. Woods

APR. 11, 2011

CHECK "J" BLOCK @ CENTER OF DUMP @ EDGE OF MAGNET



$$W_1 = \frac{18(150) + 18(150) + 36(150) + 18(490)}{1728} = 11.35$$

$11.35(36") = 408\ \#/IN$

$$W_2 = \frac{18(150) + 36(150) + 18(150) + 36(150)}{1728} = 9.375$$

$9.375(36") = 337.5\ \#/IN$

$$W_3 = \frac{36(150) + 18(150)}{1728} = 4.6875$$

$4.6875(36) = 168.75\ \#/IN$

$$W_4 = 18(150)/1728 = 1.5625$$

$1.5625(36 = 56.25\ \#/IN$

$W_1 = 408(72) = 29376\#$

$W_2 = 337.5(35.75) = 12066\#$

$W_3 = 168.75(36.25) = 6117\#$

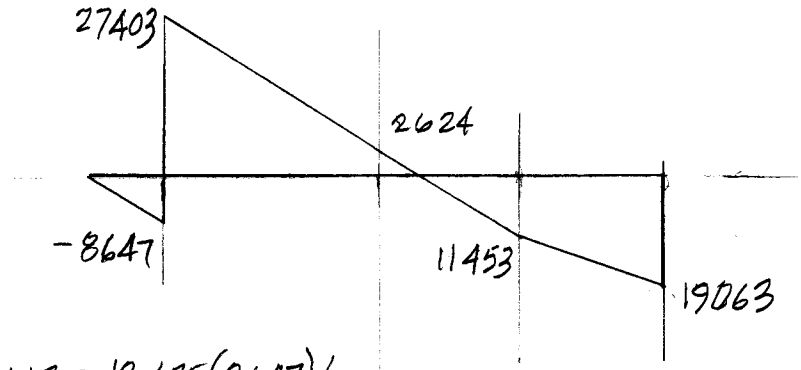
$W_4 = 144(56.75) = 8100\#$

$$R_L = \frac{(72 + 72/2)\,29376 + (35.75/2 + 36.25)(12066) + 36.25/2\,(6117) + 72(8100)}{125.375}$$

$= 36{,}050\#$

$$R_R = \frac{17.375(29376) + 71.25(12066) + 107.25(6117) + 53.375(8100)}{125.375}$$

$= 19609\#$



$M_{CANT} = 18.625(8647)/2$
$= 80525$ #-IN

$M_{u\,CANT} = 1.4(80525) = 112735$ #-IN $< 1{,}069{,}000$ #-IN

$M_{SPAN} = \frac{72(27403+2624)}{2} + \frac{6.66(2624)}{2} - 8647(18.625)/2$
$= 1009185$ #-IN

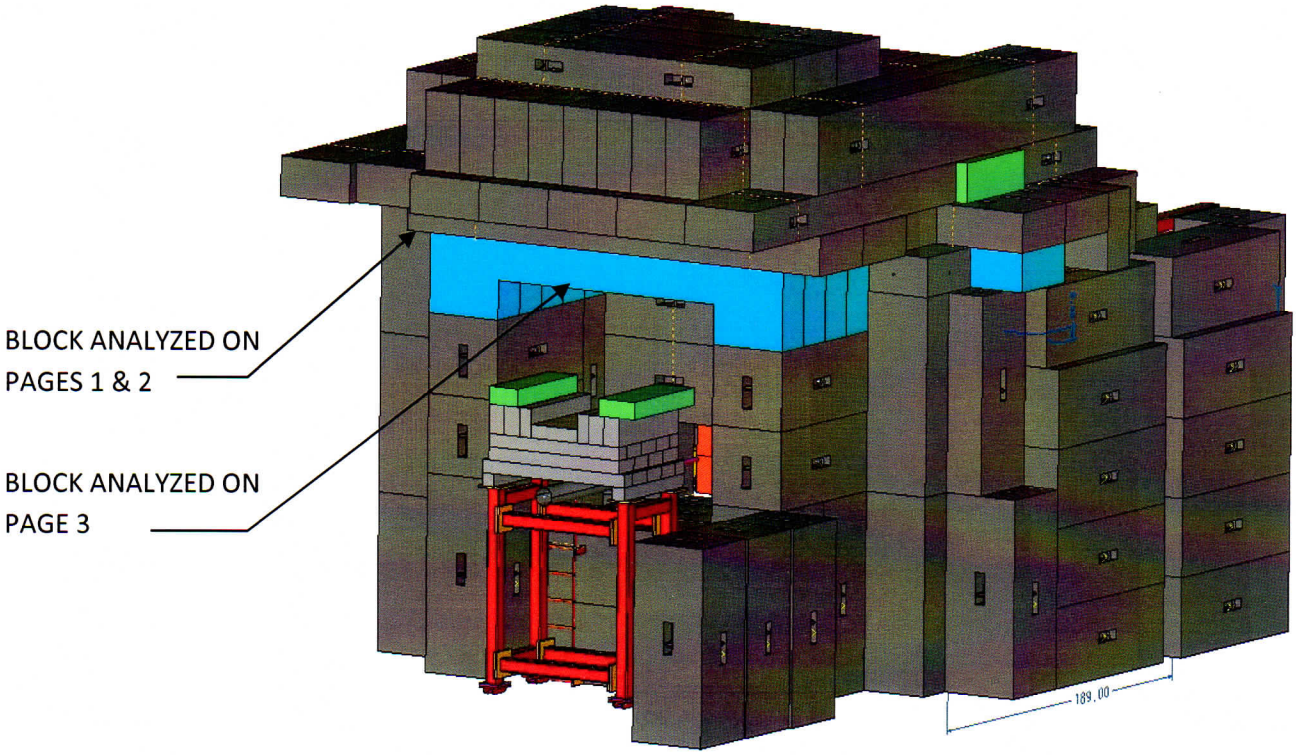
$M_{u\,SPAN} = 1.4(1009185)$
$= 1412859$ #-IN > 1417000 ok

CHECK SHEAR:

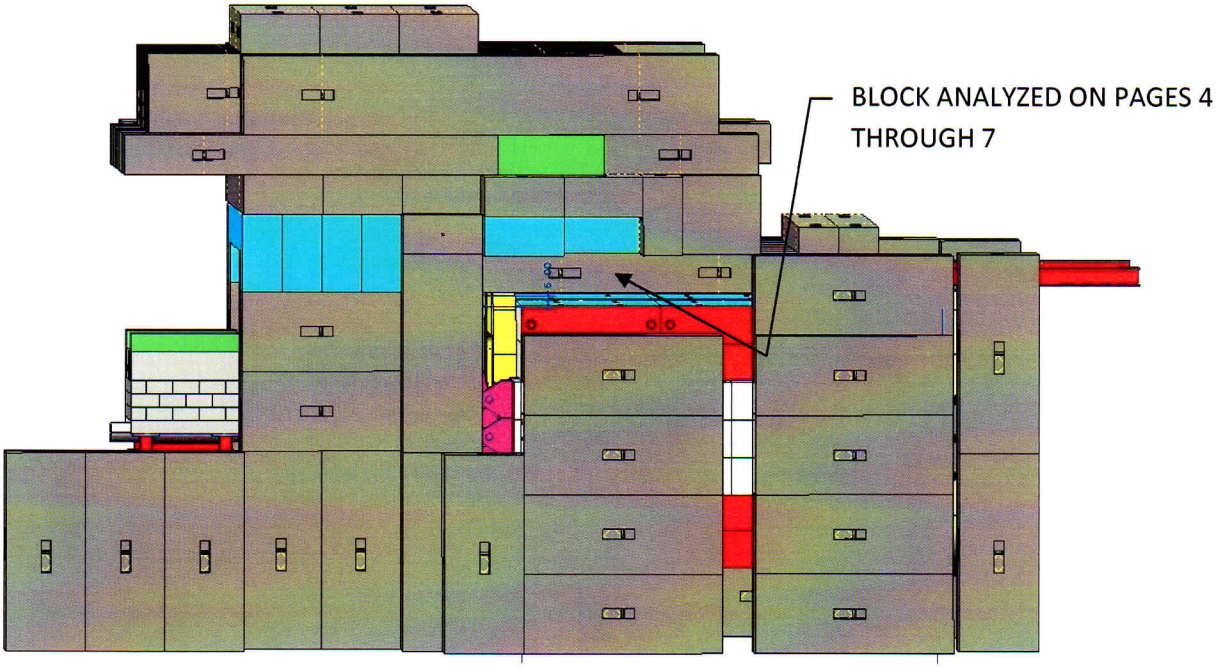
$R = 36050$# $V_u = 1.4(36050)$
$= 50470$

$\phi V_n \overset{?}{\geq} V_u$
$0.75(77640) \geq 50470$
$58230\# > 50470\#$ ok

E 906 SHIELDING CAVE



VIEW A



VIEW B