# Fermilab

## Particle Physics Division
## Mechanical Department Engineering Note

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Title: Structural Calculations & Analysis of the "R" Shielding Block Subjecting the New Loading Configurations in the Numi Target Hall

Author(s): Edward Chi

Reviewer(s): Zhijing Tang

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Abstract Summary:

The new loading configurations have increased the loads applying to the "R" concrete shielding block in the Numi target hall area. The discussions have studied the maximum calculated moment and the maximum shear strength versus the allowable moment and the allowable shear strength. All the subjecting boundary conditions have presented through the calculations.

Applicable Codes:

"Building Code Requirements for Reinforced Concrete" ACI 318 – 89

"Design of Concrete Structures" 7th edition, 1964 by George Winter

## ***Structural Calculations and Analysis of the "R" Shielding Block Subjecting the New Loading Configurations in the Numi Target Hall***

The new layout proposal for the 2010 shutdown of the Numi target hall area is presenting the increased loads with the new T-blocks configurations. It is necessary to have further study and discussion of the structural behaviors of the "R" shielding block regarding the new loading case.

**The design Criteria and the Boundary Conditions**:

The following 2D drawing is the current "Numi Target Hall Layout Proposal Post 2010 Shutdown".

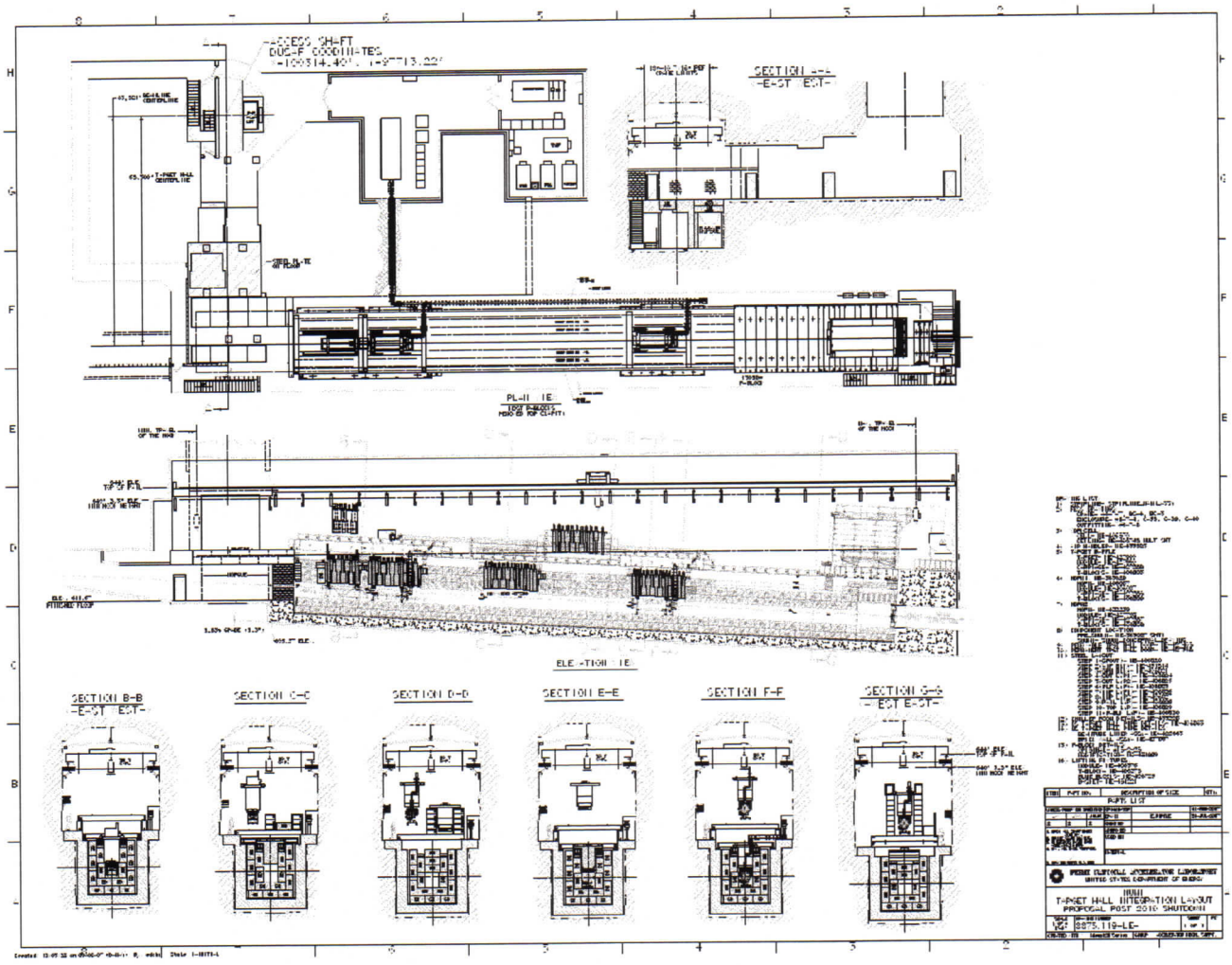


Figure 1, 2D drawing of the Numi Target Hall Layout Proposal Post 2010 Shutdown

The section D-D from figure 1 is the most critical configuration which for the single R block subjecting the increased load. It is necessary to have further more detailed discussion and study. Figure 2 from page 2 is the zoomed view of section D-D of the figure 1.

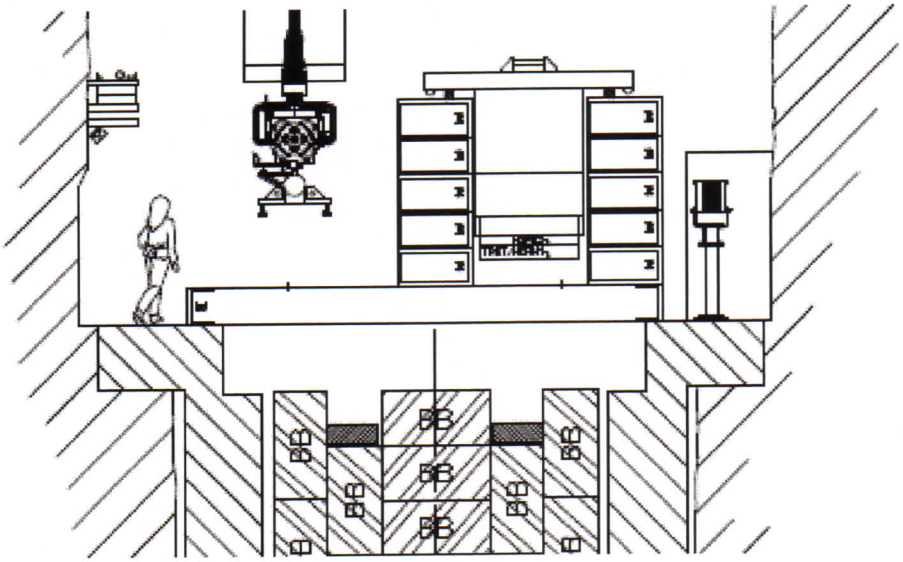

Figure 2, Zoomed view of the section D-D from the 2d drawing of figure1.

From the figure 2, it is found that the "R" block with 18" in high, 230" in length and 36" in width simply supports two sets of R blocks, each set has 5 R block run in transverse direction (Z), there are ~11 T-Blocks sits in the top of the two sets of the R blocks which runs in z direction.

Figure 3 is the section of the "R" shield block from the FESS drawing 13-2-25, SC-1. The effective depth of the shield block section d can be defined as:

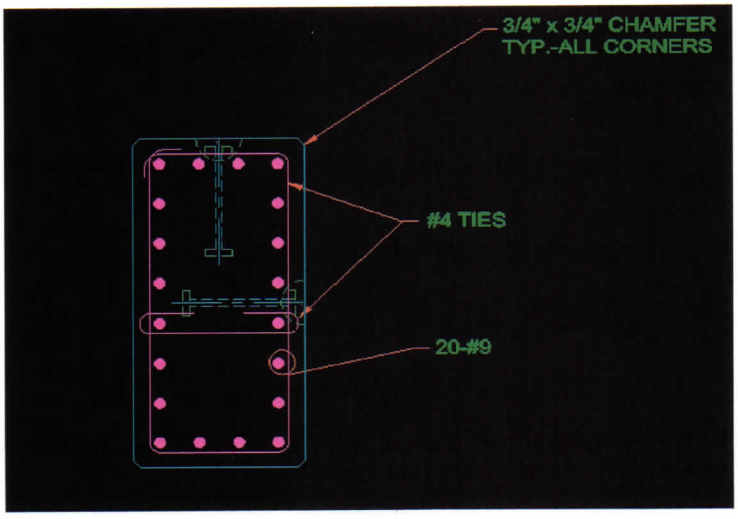


Figure 3, Section of the "R" shield block from the FESS drawing 13-2-25, SC-1

$d = 18" - 1.50" - 0.5" - 1.128"/2 = 15.436"$

Per section 7.7.1 of ACI 318 – 89

It also found out:

$b_w = 36.0$ in, web width

$A_s = 8 \times A_{bar} = 8 \times 1.0\ in^2 = 8.0\ in^2$

area of the reinforcing bar

From the configuration of figure 2, a force distribution diagram was generated as showing from figure 4.

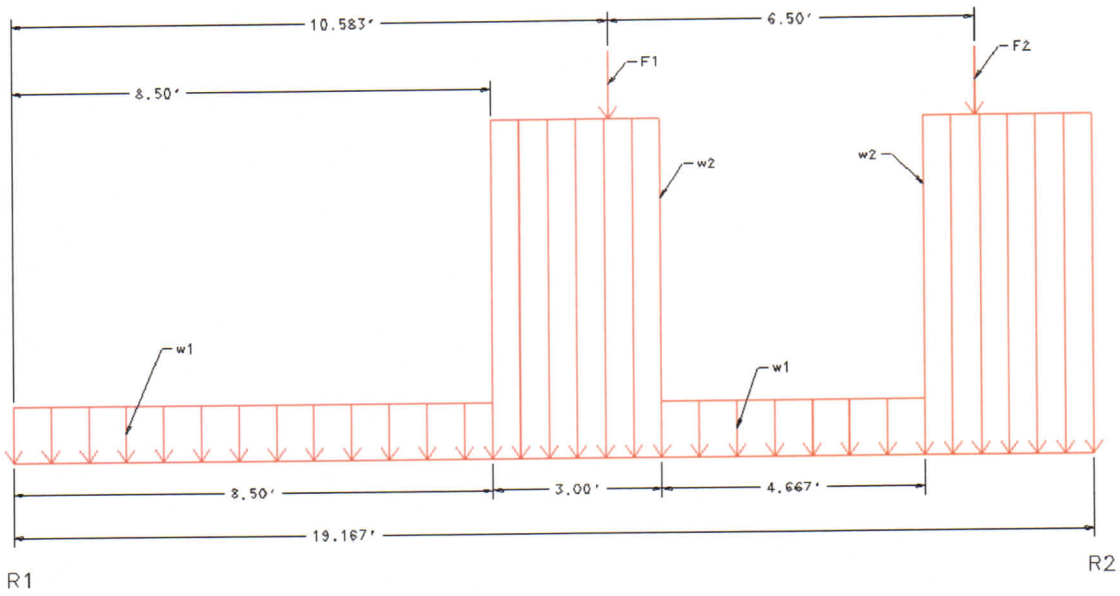


Figure 4, The force distribution diagram for the loading case of figure 2.

In order to analysis/calculate the load case as showing from figure 4, we must make some assumptions and define the boundary conditions:

1. R Shielding Block spec: See drawing #13-2-25, SC-1, dated on 12-05-2002.
2. The load factor for the dead load (DL) is 1.4, for the live load (LL) is 1.7. (See section 9.2.1 of ACI 318-89)
3. Concrete shield block "R" weights: 150 lbs/ft$^3$,
   Factored DL: 150 lbs/ft$^3$ x 1.4 = 210 lbs/ft$^3$,
   210 lbs/ft$^3$ x 3.0 ft x 1.5 ft = 945 lbs/ft for the "R" shield block
   Uniformly distributed live load: 100 lbs/ft$^2$.
   Factored LL: 100 lbs/ft$^2$ x 1.7 = 170 lbs/ft$^2$,
   170 lbs/ft$^2$ x 3.0 ft = 510 lbs/ft for the "R" shield block
   Total load to the "R" shield block = 1.4 DL + 1.7 LL = 1,455 lbs/ft
4. The weight from the two 5 stacked R blocks treated as the dead load (DL). where the DL = 5 x 945 lbs/ft = 4,725 lbs/ft

5. The concentrated load from T-Blocks /Horns treated as live load (LL).
   Total load from the T-Blocks/Horn is about 150,000 lbs distributed over R blocks in Z direction (230"), each side has 75,000 lbs. Those lead to:
   $F_1 = F_2 = (75{,}000 \text{ lbs} / 230 \text{ in}) \times 36 \text{ in} \times 1.7 = 19{,}958 \text{ lbs.}$
6. $f_y = 60{,}000$ psi, $\mathbf{f'_c} = 5{,}000$ psi (See drawing 13-2-25, SC-1)
7. The reduction factor $\mathbf{\Phi} = 0.90$ for the allowable moment $M_u$,
   The reduce factor $\mathbf{\Phi} = 0.85$ for the allowable shear strength $V_c$

From the above assumptions and the boundary conditions, it is found out that:

$w_1 = 1{,}455$ lbs/ft
$w_2 = 1{,}455$ lbs/ft + 4,725 lbs/ft = 6,180 lbs/ft
$F_1 = F_2 = 19{,}958$ lbs.
L = 230" = 19.167'

**The Allowable Moment and Shear Force VS. the Applied Mom. and Shear Force**:

$R2 = [(8.5 \text{ ft} \times w_1 \times 4.25 \text{ ft}) + (10.583 \text{ ft} \times F_1) + (3 \text{ ft} \times w_2 \times 10 \text{ ft}) + (4.667 \text{ ft} \times w_1 \times 13.8335 \text{ ft}) + (17.083 \text{ ft} \times F_2) + 3 \text{ ft} \times w_2 \times 17.667 \text{ ft})] \div L$
$= (52{,}562 + 211{,}216 + 185{,}400 + 93{,}936 + 340{,}943 + 327{,}546)$ lbs-ft $\div$ 19,167 ft
$= 63{,}213$ lbs.

$R1 = [(3.0 \text{ ft} \times w_2 \times 1.5 \text{ ft}) + (2.084 \text{ ft} \times F_2) + (4.667 \text{ ft} \times w_1 \times 5.3335 \text{ ft}) + (3.0 \text{ ft} \times w_2 \times 9.167 \text{ ft}) + (8.584 \text{ ft} \times F_1) + 8.5 \text{ ft} \times w_1 \times 14.917 \text{ ft})] \div L$
$= (27{,}810 + 41{,}592 + 36{,}217 + 169{,}956 + 171{,}319 + 184{,}486)$ lbs-ft $\div$ 19,167 ft
$= 32{,}941$ lbs.

Figure 5 is the shear force diagram of the "R" shielding block under the boundary conditions as it defined from section D-D of figure 1.

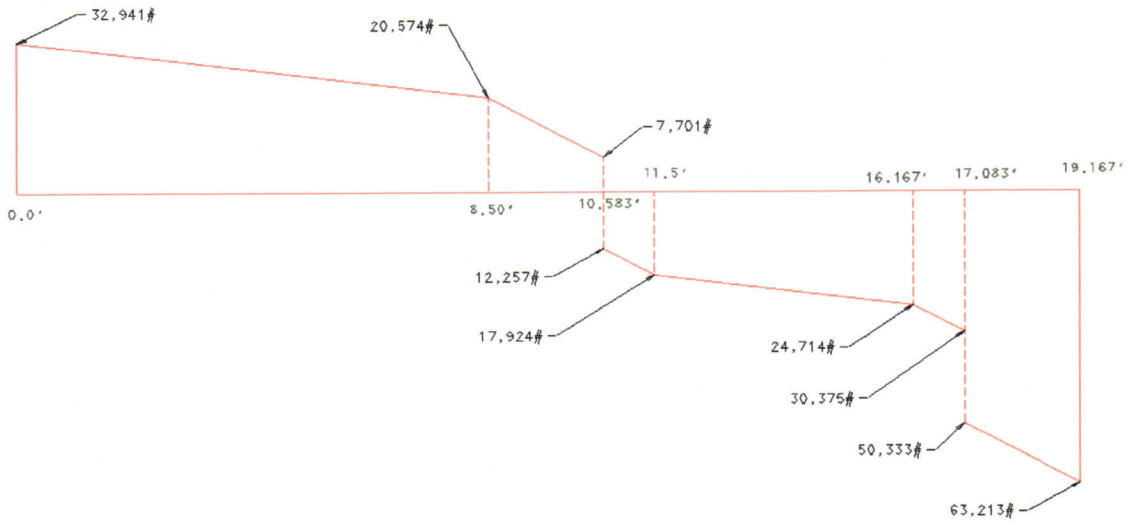


Figure 5. Shear force diagram of the "R" block under the B.C of the section D-D.

Using the shear force diagram to find out the maximum calculated moment $\mathbf{M_{max\text{-}cal}}$:

$\mathbf{M_{max\text{-}cal}}$ = ((32,941 + 20,574) lbs x 8.50 ft ÷ 2) + ((20,574 + 7,701)lbs x 2.083 ft ÷ 2)
= **256,867 lbs-ft**

Per section 11.1.3.1 of the ACI 318-89, the maximum factored shear force $\mathbf{V_{u\text{-}cal}}$ is located a distance "d" from the face of the support:

$\mathbf{V_{u\text{-}cal}}$ = 63,213 lbs – (15.436/12) ft x 6,180 lbs/ft = **55,264 lbs**

Find the allowable moment $\mathbf{M_u}$ and the shear strength $\mathbf{V_c}$ (shear strength provided only by concrete) of the "R" shielding block:

$\mathbf{M_u = \Phi}$ [$A_s f_y$ (d – a/2)] (See section 9.2.1, ACI 318-89)
= 0.90 x [8.0 $in^2$ x 60,000 psi x (15.436 in – 3.137/2 in)]
= 5,990,760 lbs-in = **499,230 lbs-ft**
where $a = \mathbf{A_s f_y} / 0.85\ \mathbf{f'_c b_w}$ = (8.0 $in^2$ x 60,000 psi) / 0.85 x (5,000 psi x 36 in)
= 3.137 in, the depth of the stress block

$\mathbf{V_c = \Phi}\ 2\ (\mathbf{f'_c})^{1/2}\ \mathbf{b_w}\ d$ (See section 11.3.1.1 of ACI 318-89)
= 0.85 x 2 x $(5{,}000)^{1/2}$ psi x 36 in x 15.436 in
= **66,799 lbs**.

Since:
$\mathbf{M_{max\text{-}cal}}$ = 256,867 lbs-ft < $\mathbf{M_u}$ = 499,230 lbs-ft
$\mathbf{V_{u\text{-}cal}}$ = 55,264 lbs. < $\mathbf{V_c}$ = 66,799 lbs.

**Conclusions:**

The calculations for the allowable moment $\mathbf{M_u}$ and allowable shear strength $\mathbf{V_c}$ are very conservative approach for the reason of the simplicity. However, both the applied calculated moment $\mathbf{M_{max\text{-}cal}}$ and the applied calculated shear strength $\mathbf{V_{u\text{-}cal}}$ are less than the allowable moment and shear strength respectively as shown from the above calculations.

To this end, the current specifications of the concrete shielding block "R" is satisfactory subjecting the increased loads as it defined from the section D-D of the Numi target hall layout proposal post 2010 shutdown (as shown from figure 1).

Notes:

1. Go to link: \\blue1\PPD_Users\edchi\ANU\layout for the pdf version drawing of figure 1.
2. See figure 6 for the attached electronic copy of the drawing of 13-2-25, SC-1. Otherwise, go to \\fesserver1\FESS_Archive\13\2\25\6 - Design Documents\6c - Drawings for the full size of the drawing.

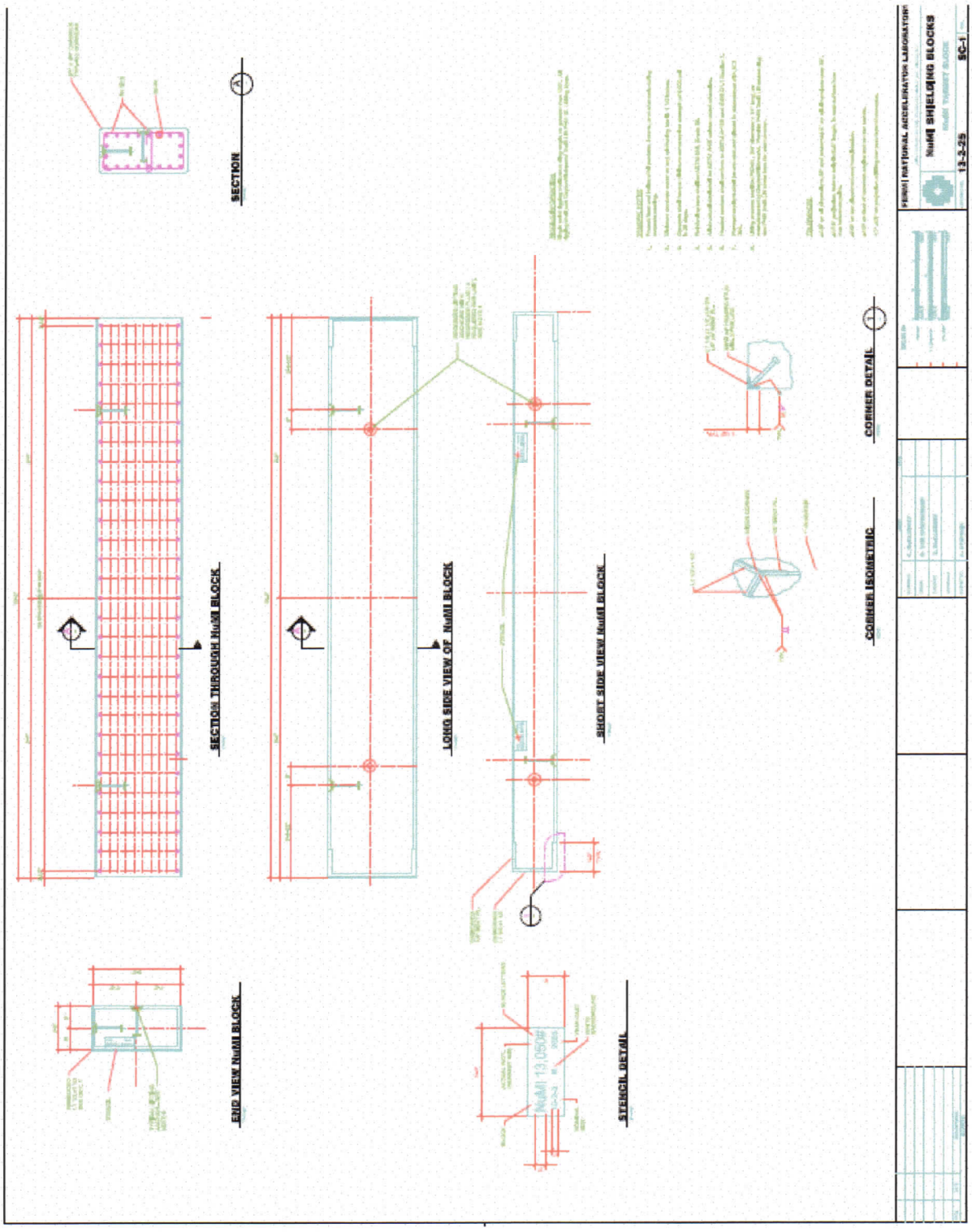


Figure 6. "R" Concrete Shielding Block drawing - #13-2-25, SC-1