Take Heart School

Migori, Kenya

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Advised By:
Kevin Dong
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ABSTRACT:

Journeyman International, also known as JI, is a non-profit organization that groups together design and construction students with organizations looking to build humanitarian projects around the world. This pairing is beneficial for both the organization because they get free design and construction expertise, as well as for the students who get real-world experience.

The Take Heart School is a planned school and grounds for the region of Migori Kenya. Take Heart Africa is a fair trade store with all profits going to help the impoverished communities of Kenya. The three-acre site will have a school with eight classrooms, offices, a library, a cafeteria, and housing for students and visitors. It is located near a small village which it is intended to serve. The design team included Janelle Tatari, a Cal Poly Architecture student, who completed the architectural work for the twelve buildings. Spencer Mishky, a Cal Poly Construction Management student, did the construction development work. David Corona, a Cal Poly Architectural Engineering, designed the structural system for the eight classroom school building. As well as myself who designed the structural system for the library and office building. Throughout this process, I was advised by ARCE professor Kevin Dong. The project was completed over the course of the 2020/2021 school year with the majority of the architectural design being completed in the fall and winter, and the structural and construction design being completed in the spring. This report will focus on the research, assumptions, structural design process, and lessons learned from the design experience.
PROJECT DESCRIPTION:

As stated before the project is located in rural Kenya, within the Migori region. The site is a three-acre sloped site, with a road that leads to the property line, but no driveway running through the property. The surrounding landscape consists of mostly short brush and grasslands, as well as rural farms. Walking distance from the site is a village, whose people the project is meant to serve. The project itself will consist of twelve buildings. There will be four dormitory-style buildings. These will be used to house visitors and guest lecturers, displaced women, and their children, and young adults aged 18-22 because the Kenyan government no longer provides free housing to people of that age range. There will be four communal/multi-purpose spaces. These will be used as places for guest presentations and events, as well as space for the residents to relax and gather. There will be a cafeteria that will serve the residents as well as the students from the local village who are attending school. The school building will have eight classrooms, and next door there will be a library building with facility
offices attached. The clients came provided two design requirements. They wanted to maximize the views out to the west, as well as provide outdoor spaces for people on-site to gather and use.
DESIGN PROCESS:

Because of the location of the site, many design assumptions were made beginning with the site. The site was assumed a risk category II and site class of D because a soils report was not provided. In order to get an Sds, a location other than Mogori Kenya had to be assumed. The location of the California capital was used, as it is likely a similar seismic region. Using this information, and info conducted by another firm the site was assigned an Sds of 0.51.

A 5 PSF dead load, and a 15 PSF live load, were assumed for the vertical loading. A 20 PSF wind load on the building was also assumed. Some design thought had to be made regarding the materiality of the building. After speaking with an architect from Kenya, we determined that the availability of construction materials is limited. For the gravity system, the architect suggested that we use steel decking as the main roofing material, steel wide flange for the joist/girder system, and CMU pilasters and steel columns to transfer the roof load into the ground. In the lateral direction, reinforced masonry shear walls were used because there is skilled labor available in that trade, and both CMU and No. 4 rebar is available. We were not able to determine the most common CMU sizes in Kenya, so we opted to use the standard 8”x8”x16” block.
The gravity design was fairly straightforward, although there were some considerations made about the forty-foot girder, that required some extra design consideration. The decking was sized as twenty gauge deep VERCOR deck. This is a fairly standard deck in the U.S., and it was assumed that this or a similar deck can be found and purchased in Kenya. The joists were spaced at ten feet on center and sized to be W8x10’s. These framed into girders that were split up into different length pieces. The first being a twenty-foot girder, which a single joist point load in the center. This was sized to be a W12x14. The second span was thirty feet with two point loads applied at ten feet and twenty feet across. This was sized to be a W12x26. The architect designed the building to have a ten-foot cantilever, that provides shade outside of the building. In order to have it cantilever, we needed to use a forty-foot girder. This length however would be hard to transport along dirt roads and lift once on site. Because of these challenges, I decided to offer two design options for the remaining forty-foot length. The first being a forty-foot girder that would be able to support the cantilever. This was sized at W12x40. The other option is a thirty-foot girder, and then a ten-foot girder with a column at the end instead of a cantilever. By providing these two options the contractor and owner can make a decision on what they would like to use. The columns were placed on a grid, and along wall lines, as to not inhibit open space. The CMU pilasters are 16”x16” with 4 N.o. 4 rebar vertically. The steel columns however
required a few more design considerations. Here in the United States, most columns would be sized as HSS squares, however, the availability of materials is limited in Kenya, and so I designed the columns twice, once using the HSS and once using lower grade 36ksi pipe. The low-grade pipes are easier to find in locations with scarce materials and seemed like a good choice as a substitute for the HSS. Understanding that this was a school, and would have young kids playing about, I wanted to ensure that the columns would not deflect if students were climbing them. To do this the columns were designed with a 500 lb lateral force applied at the center. Two-column heights were designed. With the ten-foot column being sized at HSS 4x4x1/8 or 3’ STD pipe, and the sixteen-foot column being sized at HSS 4x4x3/16 or 4’ STD pipe.

The lateral design was more straightforward. The building was designed to have two reinforced masonry shear walls in the east-west direction, and three in the north-south. Once the lateral forces were determined, I focused on the thirteen-foot shear wall running in the east-west
direction. The wall proved to be of interest because it had three openings, one door, and two windows. The wall was checked for both in-plane and out of plain loading. And it was determined that N.o. 4’s at 32in on center each way would suffice as the standard spacing of rebar. It is important to note that if this building was being built in the US, the spacing of 32in on center would not be permitted, and would need to be brought down to 24in. Because the out-of-plane loading is larger around the openings, the rebar must be spaced at 16in on center when framing openings. The calculations were preliminary, and the next steps would be to start developing the connections needed for construction.
LESSONS LEARNED:

I had three main takeaways from this project. The first being the importance of communication and professional relationships. Before beginning this project I had a friendship and working relationship with the Construction Management student on the team Spencer Mishky. Throughout the process, my communication with him was much easier than the communication I had with Janelle Tatari, the Architect. When I had a question for Spencer, I would just drop him a text or give him a call. I typically had the question answered within a few hours. When I had a question for Janelle I would have to schedule a zoom call with her, and typically get it answered within two days. Communication is key to getting a project done well and in a timely manner. As I begin work in August I will be sure to foster all of my professional relationships, as well as work hard to communicate clearly and effectively with all people working on the project.

I also learned that the client does not always know what they want. The three primary requirements the clients wanted were eight classrooms, being able to see the view to the west, and being able to utilize outdoor space. This is very little to go on, and I learned that it is our job as design professionals to ask the correct questions of the client to help them understand what they want and need.

I finally learned that designing here in the United States we have a luxury of goods. I can size almost anything out of my design manuals and know that it can be ordered and delivered to the site. That is just not the case in other countries. The design of buildings in many countries is limited by the materials present. This was a new challenge for me to design with, but one that I found offered interesting problems that were a joy to solve.
Take Heart School Project

Journeyman International

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S.1

ROOF FRAMING PLAN
Roof Loading:
This will likely be a bare bones roof, with no fire proofing, and very light MEP. We will use 5 PSF for Dead Load in case lighting, or solar is added.

Dead Load: 5PSF
Live Load: 15PSF

Total Load: 20PSF

Metal Roof Deck Selection:

Use 20 Gage Deep VERCOR Deck spanning 10 ft

VERCO Catalog Page 148
Design Int. Joist

\[ DL = 5 \text{ PSF} \quad W = \left(1.2(5 \text{ PSF}) + 1.6(15 \text{ PSF})\right)10' = 300 \text{ PLF} \]

\[ LL = 15 \text{ PSF} \quad W = \left(15 \text{ PSF} + 15 \text{ PSF}\right)10' = 200 \text{ PLF} \]

\[ MU = \frac{WL^2}{8} = \frac{300 \text{ PLF}(26)^2}{8} = 25.35 \text{ k} = MU \]

\[ Vu = \frac{WL}{2} = \frac{300 \text{ PLF}(26)}{2} = 3.9k = Vu \]

\[ Lb = 0 \quad \phi b = .9 \]

\[ Z_{xreg} = \frac{MU}{\phi Vu} = \frac{25.35k}{.9(50 \text{ k} \text{ in}^3)} = 6.76 \text{ in}^3 = Z_{xreg} \]

\[ \frac{L}{240} = \frac{5WL^4}{384EI} \Rightarrow I = \frac{300 \text{ PLF} \times 26^3}{384 \times 8 	imes 10^6} \]

\[ J_{reg} = \frac{3.125(2)(26)^3(12 \frac{3}{8})}{29 	imes 10^6} = 6.54 \text{ in}^4 = I_{reg} \]

Choose \( W \ 8 \times 10 \)

\[ I_x = 30.8 \text{ in}^4 > 6.54 \text{ in}^4 = I_{reg} \checkmark \]

\[ \phi b M_{px} = 32.9k > 25.35k = Mu \checkmark \]

\[ \phi v V_{hx} = 40.2k > 3.9k = Vu \checkmark \]

\[ Z_x = 8.87 \text{ in}^3 > 6.76 \text{ in}^3 = Z_{xreg} \checkmark \]

**USE W 8 \times 10 \** Joists
Design Int 20' Girder

DL = 50 PSF
LL = 150 PSF

P = [(5 + 1516(15)]10'(20') = 7.8 k
P = (5 + 15)10 (20') = 5.2 k

M_U = \frac{P \cdot L}{4} = \frac{7.8k(20')}{4} = 39 k-ft = M_U

V_U = \frac{P \cdot L}{2} = 7.8k(20') = 3.9 k = V_U

L = 0 \quad \theta = 0

Z_{x_{req}} = \frac{M_U}{48EI} = \frac{39k(12)}{48(50k68)} = 10.4 \text{ in}^4 = Z_{x_{req}}

Z_{x_{req}} = \frac{P L^3}{48EI} = \frac{5(800)(20')(12^3)}{29,000 \times 10^6} = 51.64 \text{ in}^4 = I_{req}

Choose: W 1214

I_x = 38.6 \text{ in}^4 > 51.64 \text{ in}^4 = I_{req} \checkmark

\phi L M_{px} = 65.3 k > 39 k = M_U \checkmark

\phi V_{nx} = 64.3 k > 3.9 k = V_U \checkmark

Z_x = 17.4 \text{ in}^3 > 10.4 \text{ in}^3 \checkmark

USE W 12x14 FOR 20' SPAN
Design Int 30' Span

PL = 5 PSF  \[ P = \left( \frac{12(5) + 1.4(15)}{10} \right) \left( \frac{26}{2} \right) = 7.8k \]

LL = 15 PSF  \[ P_i = (5 + 15)(10)(26) = 5.21k \]

Mu = P(a) = 7.8k(10) = 78k" = Mu

Vu = P = 7.8k = Vu

Lb = 0  \[ \phi b = 0.9 \]

I \[ x_{req} = \frac{Mu}{\phi b A_y} = \frac{78k}{0.9(50)} = 20.8in^3 = I_{x req} \]

\[ L = \frac{Pa}{24EI} \left( 3L^2 - 4a^2 \right) = \frac{10Pa}{E} \left( \frac{5L^2 - 4a^2}{3} \right) \]

I \[ vec = \frac{10(5200)(10')(12')}{29 \times 10^6 (30')} \left( 3(30')^2 - 4(10')^2 \right) = 198in^4 \]

Choose: W 12x26

I_x = 204in^4 > 198in^4 = I_{x req} \checkmark

\[ \phi b M_{x}\max = 140k" > 78k" = Mu \checkmark \]

\[ \phi b V_{ux} = 84.2k > 7.8k = Vu \checkmark \]

\[ I_x = 37.2in^3 > 20.8in^3 = I_{x req} \checkmark \]

USE W 12x26 FOR 30' SPAN
Design of Int 40' Girder

DL = 5PSF
LL = 15PSF
P1 = [1.2*5PSF+1.6*15PSF]*10'*26' = 7.8K
P2 = [1.2*5PSF+1.6*15PSF]*5'*26' = 3.9K

\[ \text{Mu} = 65K' \]

\[ \text{Vu} = 9.1K \]

Per IBC TABLE 1604.3
Deltau = L/180
Per footnote I for cantilever L shall be taken as twice the length of the cantilever
Deltau = 20'*12in/ft/180 = 1.33"

\[ \text{Lb} = 0 \]
\[ \text{Phib} = .9 \]
\[ \text{Zxreq} = \frac{\text{Mu}}{\text{Phib} \times Fy} = \frac{65K' \times 12\text{in}/\text{ft}}{(.9 \times 50\text{ksi})} = 17.33\text{in}^3 \]

Using RISA to check Deflection
CHOOSE: W12x40

\[ \text{Deltamax} = 1.286" < 1.33" = \text{Deltau CHECK} \]
\[ \text{PhibMpx} = 214K' > 65K' = \text{Mu CHECK} \]
\[ \text{PhivVnx} = 105K > 9.1K = \text{Vu CHECK} \]
\[ \text{Zx} = 57\text{in}^3 > 17.33\text{in}^3 = \text{Zxreq CHECK} \]

USE W12 x 40 FOR 40' GIRDER W/ CANTILEVER
Size for unexpected lateral loads by adding 500# horizontally at center

\[ \text{AT} = 5' \times 26' = 130 \text{ SF} \]

\[ \text{DL Joist} = 26' (10 \text{ PLF}) = 260# \]

\[ \text{DL Girder} = 5' (40 \text{ PLF}) = 200# \]

\[ \text{DL} = 6 \text{ PSF} (130 \text{ SF}) + 260# + 200# = 1.24 \text{ k} \]

\[ \text{LL} = 15 \text{ PSF} (130 \text{ SF}) = 1.95 \text{ k} \]

\[ \text{Pu} = 1.2 \text{ D} + 1.6 \text{ L} = 1.2 (1.24) + 1.6 (1.95) = 4.0 \text{ k} = \text{Pu} \]

\[ k_{BLY} = 1.0 (16') = 16' \]

\[ P = 0.5k \]

\[ L = \frac{P l^3}{4E} = \frac{7.5\text{ PL}^2}{4E} \]

\[ I_{req} = \frac{7.5 \times 500 \times (6^2) (12^2)}{24 \times 10^6} = 5.32 \text{ in}^4 \]

Choose HSS 4 x 4 x 3/16

\[ I_x = 6.21 \text{ in}^4 > 5.32 \text{ in}^4 = I_{req} \checkmark \]

\[ \Phi_c Pu = 38 \text{ k} > 4.6 \text{ k} = \text{Pu} \checkmark \]

Choose 1' STD PIPE

\[ I_x = 6.82 \text{ in}^4 > 5.32 \text{ in}^4 = I_{req} \checkmark \]

\[ \Phi_c Pu = 40.8 \text{ k} > 4.6 \text{ k} = \text{Pu} \checkmark \]
Check Both Shapes w/ Eccentricity

<table>
<thead>
<tr>
<th>HSS 4 x 4 x 3/16</th>
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<tr>
<td>P = P_u = 4.6k</td>
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<tr>
<td>φ_e P_m = 38k</td>
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<tr>
<td>M_u = \frac{5''}{12} (P_u) = \frac{5''}{12} (4.6k) = 1.91 k''</td>
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<tr>
<td>M_p = φ_e F_y \cdot \frac{0.9 (3.671m^3)(50ksi)}{165.15k} = 13.76 k''</td>
</tr>
<tr>
<td>\frac{P}{2P_u} + \frac{M_p}{M_p}</td>
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<tr>
<td>4.6k</td>
</tr>
<tr>
<td>13.76k''</td>
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</table>

Pipe No. 4 Std

| P | \frac{P}{φ_e P_m} = \frac{4.6k}{408k} = 0.11 < 0.2 USE H1-2b |
| M_p = φ_e F_y \cdot \frac{0.91 (4.051m^3)(35ksi)}{127.6k} = 127.6k |
| \frac{P}{2P_u} + \frac{M_p}{M_p} = \frac{4.6}{2(408)} + \frac{1.91k''}{10.6k''} = 0.237 < 1 ✓ |

USE EITHER HSS 4 x 4 x 3/16
OR 4" STDPIPE! FOR 16' COLUMN
Size for unexpected lateral loads by adding 500# horizontally at center

\[ \text{AT} = 25' (12) = 300 \text{ SF} \]

Jrkt Load: \( (5' + 5' + 5') \times 10 \text{ PLF} = 125 \# \)

Girder Load: \( 15' \times 10 \text{ PLF} + 10' \times 14 \text{ PLF} = 740 \# \)

\[ \text{DL} = 6 \text{ PSF} \]

\[ \text{DL} = 6 \text{ PSF} (325 \text{ SF}) + 125 \# + 740 \# = 282 \text{ k} \]

\[ \text{LL} = 15 \text{ PSF} (325 \text{ SF}) = 4875 \text{ k} \]

\[ \text{Pu} = 1.2 \times D + 1.6 \times L = 1.2 \times (282) + 1.6 \times (4875) = 112 \text{ k} = \text{Pu} \]

\[ k_y \times y_3 = 1.0 (10') = 10' \]

\[ P = 0.5 \text{ k} \]

\[ I_{reg} = \frac{750 \times P l^2}{E} = \frac{7.5 (500) (10)^2 (12)^2}{2 \times 10^6} = 2.1 \text{ in}^4 \]

Choose HSS 4x4 x 7/8

\[ I_x = 4.4 \text{ in}^4 > 2.1 \text{ in}^4 \]

\[ \phi \times \text{Pu} = 52.2 \text{ k} > 11.2 \text{ k} = \text{Pu} \]

Choose 3' STD PIPE

\[ I_x = 2.85 \text{ in}^4 > 2.1 \text{ in}^4 = I_{reg} \]

\[ \phi \times \text{Pu} = 38.1 \text{ k} > 11.2 \text{ k} = \text{Pu} \]
Check Both Shapes For Eccentricity

HSS 4\times 4\times 1/8

\[ P = P_o = 11.2k \]
\[ \phi P_n = 5\times 2k \]
\[ \phi P_n = 5\times 2 = 10.2k = 10.2 \times 0.21 > 2 \]

USE H1-2a

\[ M_o = \frac{5}{4} (P_o) = \frac{5}{4} (11.2k) = 14.2k \]

\[ M_P = \phi Z F_y = 0.9 (2.56 in^3) (150 ksi) = 115k'' \]

\[ P = \frac{2 P_y}{Z} + \frac{M_P (\phi)}{M_P (\phi)} \leq 1 \]

\[ 11.2k + \frac{4.66k'' (\phi)}{5.5k'' (\phi)} = 1.53 \leq 1 \]

3' STD PIPE

\[ P = \frac{11.2k}{38.1k} = 0.294 \geq 2 \]

USE H1-2a

\[ M_P = \phi Z F_y = 0.9 (2.19 in^3) (35ksi) = 69k'' \]

\[ \frac{P}{P_y} + \frac{M_p (\phi)}{M_p (\phi)} = 11.2k \]

\[ 38.1k + \frac{4.66k'' (\phi)}{5.75k'' (\phi)} = 1 \leq 1 \]

USE EITHER HSS 4\times 4\times 1/8

OR 3' STD PIPE FOR 10 COLUMN
**Site Information**

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**Take Heart School**

1315 10th St room b-27, Sacramento, CA 95814, USA

Latitude, Longitude: 38.5765882, -121.4932368

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<td>D - Default (See Section 11.4.3)</td>
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<td>$S_{DS}$</td>
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<td>$S_{D1}$</td>
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<td>-See Section 11.4.8</td>
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Wind

B/C limited access to site information, assume 20 PSF Wind Load

**Estimating Base Shear Wind E/W Direction:**

\[ A = 819 \text{SF} = 351 \text{SF} + 468 \text{SF} > 702 \text{SF} \]
\[ V_e = 829 \text{SF} \times 20 \text{PSF} = 16.38 \text{K} \]

**Estimating Base Shear Wind N/S Direction:**

\[ A = 924 \text{SF} = 114 \text{SF} + 304 \text{SF} + 366 \text{SF} + 140 \text{SF} \]
\[ V_e = 924 \text{SF} \times 20 \text{PSF} = 18.48 \text{K} \]

**Estimating Seismic Base Shear**

\[ S_D = .51 \]
\[ R = 2 \]
\[ I = 1 \]
\[ W_{deck} = 4680 \text{sf} \times (2 \text{psf}) = 4 \text{K} \]
\[ W_{girders} = 40'\times 22 \text{PLF} + 20'\times 26 \text{PLF} + 140'\times 34 \text{PLF} + 70'\times 43 \text{PLF} = 9.17 \text{K} \]
\[ W_{joists} = 468'\times 26 \text{PLF} = 12.17 \text{K} \]
\[ W_{walls} = \left[ (13.66'\times 51.33 + 10.5'\times 80' + 12'\times 50') + 10.5'\times 80' + 12'\times 50' + 9'\times 20' \right] \times 78 \text{PSF} = 339 \text{K} \]
\[ \text{Weight} = 4 \text{K} + 9.17 \text{K} + 12.17 \text{K} + 339 \text{K} = 364.4 \text{K} \]
\[ V = 364.4 \text{K} \times (0.51)/(2/1) = 93 \text{K} \]
DESIGN BEARING WALL OUT OF PLANE

WIND LOADING:
Wwall = 20PSF

SEISMIC LOADING:
Wwall = .4*Sds*I*weightwall
Wwall = .4*.51*1*78 = 16PSF

DESIGN MOMENT:
Mu = WL^2/8 = 20PSF(13.66^2)/8 = .467Kft/ft

DESIGN AXIAL LOAD:
Pu = 13.66' / 2 * 1' * 78PSF = .532Kft

Area Trial = .001bh = .001*(12'')(7.625'') = .0915in^2/ft

Try No 4 @ 32' O.C.

PhiMp = Phi*(C)*(h/2-a/2)
Pu = (0.9-0.2*Sds)Pd
Pu = (0.9-0.2*.51)*(.532K/ft) = 424#/ft
C = AsFy + P
0.8*2*a*12 = 0.2/2.66in^2 * 60 - .424K
=> a = .213"
PhiMp = 0.9*0.8*2*.213*12*(7.63/2-.213/2)
PhiMp = 13.65K-in = 1.14Kft/ft > .467Kft/ft CHECK

USE No.4 @ 32" O.C.
DESIGN BEARING WALL OUT OF PLANE CONT.

CHECK CRACKING:
Mcr = Sxfr
fr = 163PSI - fully grouted joints - TMS 9.1.9.2
Mcr = bt^2/6*fr = (4*12*7.63^2/6) * ((163/1000)/12) = 6.31k-ft
Service Moment = W = .6 * 6.31Kft/ft = 3.79Kft/ft
Mcr = 3.79Kft/ft > .28Kft/ft = Service Moment CHECK

CHECK DEFLECTION:
Du = 5Muh^2/(48EmI)
Du = 5*.467Kft/ft*13.66^2/(48*900*1.5*245) = .000027"
Dallow = .007h  TMS Eq 9-32
Dallow = .007 *13.66*12 = 1.15"
Dallow = 1.15" > .000027" = Du CHECK
DESIGN BEARING WALL OUT OF PLANE @ DOOR

WIND LOADING:
Wwall = 20PSF

SEISMIC LOADING:
Wwall = .4*Sds*I*weightwall
Wwall = .4*.51*1*78 = 16PSF

DESIGN MOMENT:
At Door we will have extra load for 2 ft on either side of door b/c of surface area of header
AddedLoad = 20PSF*4'/2' = 40PSF

\[ M_u = 0.611 \text{ Kft} \]

DESIGN AXIAL LOAD:
Pu = \([(13.66'' / 2 * 1'') + 4''*3.66''/2] * 78\text{PSF} = 1.1\text{K/ft} \]

Area Trial = .001bh = .001*(12'')*(7.625'')
= .0915in^2/ft

Try No 4 @ 18'' O.C.

\[ \Phi M_p = \Phi (C)*(h/2-a/2) \]
\[ Pu = (0.9-0.2*Sds)Pd \]
\[ Pu = (0.9-0.2*.51)*(1.1K/ft) = 878#/ft \]
\[ C = AsFy + P \]
\[ 0.8^2*a^12 = .15in^2 * 60 - .878K \]
\[ => a = .423'' \]
\[ \Phi M_p = 0.9*0.8^2*.423*12*(7.63/2-.423/2) \]
\[ \Phi M_p = 26.3K-in = 2.19Kft/ft > .611Kft/ft \]

CHECK CRACKING:
Mcr = Sxfr
fr = 163PSI - fully grouted joints - TMS 9.1.9.2
Mcr = 245 / (7.625/2) * ((163/1000)/12) = .436k-ft
Service Moment = W = .6* .611Kft/ft = 3.66Kft/ft
Mcr = .436Kft/ft > .3.66Kft/ft = Service Moment CHECK

CHECK DEFLECTION:
Du = 5Muh^2/(48EmI)
Du = 5*.611Kft/ft*13.66^2/(48*900*1.5*245) = .000036''
Dallow = .007h  TMS Eq 9-32
Dallow = .007 *13.66'' = 1.15''
Dallow = 1.15'' > .000036'' = Du CHECK

No. 4 @ 18 work, **USE #4 @16** to match spacing of cells
DESIGN BEARING WALL OUT OF PLANE @ DOOR

WIND LOADING:
Wwall = 20PSF

SEISMIC LOADING:
Wwall = .4*Sds*I*weightwall
Wwall = .4*.51*1*78 = 16PSF

DESIGN MOMENT:
At Door we will have extra load for 2 ft on either side of door b/c of surface area of header
AddedLoad = 20PSF*2.5'/2' = 25PSF

Mu = .763 Kft

DESIGN AXIAL LOAD:
Pu = [(13.66' / 2 * 1') + 2.5'*6.66'/2] * 78PSF = 1.2K/ft
Area Trial = .001bh = .001*(12")*(7.625")
= .0915in^2/ft

Try No 4 @ 18" O.C.

PhiMp = Phi*(C)*(h/2-a/2)
Pu = (0.9-0.2*Sds)Pd
Pu = (0.9-0.2*.51)*(1.2K/ft) = 958#/ft
C = AsFy + P
0.8*2*a*12 = .15in^2 * 60 - .958K
=> a = .419"
PhiMp = 0.9*0.8*2*.419*12*(7.63/2-.419/2)
PhiMp = 26.1K-in = 2.19Kft/ft > .611Kft/ft CHECK

CHECK CRACKING:
Mcr = Sxfr
fr = 163PSI - fully grouted joints - TMS 9.1.9.2
Mcr = 245 / (7.625/2) * ((163/1000)/12) = .436k-ft
Service Moment = W = .6 * .763Kft/ft = .458Kft/ft
Mcr = .436Kft/ft < .4.58Kft/ft = Service Moment
We must account for cracking

CHECK DEFLECTION:
Du = 5Muh^2/(48EmI)+5*(Mu-Mcr)^2/(48EmI)
Du = 5*.763Kft/ft*13.66^2/(48*900*1.5*245)
+ 5*(.763Kft/ft-.436Kft/ft)*13.66^2/(48*900*1.5*245)
= .000467"
Dallow = .007h  TMS Eq 9-32
Dallow = .007*13.66 = 1.15"
Dallow = 1.15" > .000467" = Du CHECK

# 4 @ 18" O.C. work, use #4 @16" O.C. to match cell spacing
DETERMINATION STORY FORCES

PROJECT NAME: Take Heart
PROJECT NAME: Senior Project
PROJECT LOCATION: Kenya

### Mapped Spectral Accelerations (%g)

<table>
<thead>
<tr>
<th>Site Class D</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ss</td>
<td>0.568</td>
</tr>
<tr>
<td>S1</td>
<td>0.253</td>
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</tbody>
</table>

### Site Coefficients (%g)

<table>
<thead>
<tr>
<th>Design Site Class</th>
<th>Fa</th>
<th>Fv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 11.4-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table 11.4-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D - Default</td>
<td>1.2</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### Adjusted Maximum Considered EQ (MCE) Spectral Response Acceleration Parameters (ASCE 7-16 / 11.4.4)

\[
SM_S = F_a^*S_s = 0.6816 \\
SM_1 = F_v^*S_1 = 0.3975
\]

### Design Spectral Acceleration Parameters (ASCE 7-16 / 11.4.5)

\[
SDS = 2/3*SM_S = 0.4544 \\
SD_1 = 2/3*SM_1 = 0.2530
\]

### Design Coefficients and Factors for Seismic Force-Resisting System (ASCE 7-16 / 12.2.2)

- Response Modification Coefficient, R: 5
- System Overstrength Factor, Q, D: 2.5
- Deflection Amplification Factor, C, d: 1.75
- System Limitations (ft): NP

### Importance Factor (ASCE 7-16 / 1.5.2)

- Nature of Occupancy per Table 1604.1.5:
  - Buildings and other structures except those listed in Risk Categories I, III and IV
- Occupancy Category: III
- Importance Factor, I: 1.0

### Seismic Design Category (ASCE 7-16 / 11.6)

- Design Category based on S1: N/A S1 < 0.75
- Design Category based on SDS: D T 11.6-1
- Design Category based on SD1: D T 11.6-2
- Design Seismic Design Category: D

### Period Determination (ASCE 7-16 / 12.8.2)

- Structure Type:
  - Ct = 0.02 T12.8-2
  - x = 0.75 T12.8-2
  - h_n = 11 ft ht. above the base
  - T = Ta = Ct'(hr)^x = 0.12080 sec EQN 12.8-7
  - TL = 12 FIG 22-14

### Seismic Response Coefficient

\[
\rho = \frac{1}{1.0} \quad SECT 12.3.4.2 \text{ SDC removal of one wall results in only 25% reduction in strength}
\]

- \( C_s = \frac{SDS}{R/I} = 0.091 \quad EQN 12.8-2 \)
- For \( T <= TL \): C_s, max = SD1/(T/R/I) = 0.419 EQN 12.9-3
- For \( T > TL \): C_s, max = SD1*TL/(T2*R/I) = N/A EQN 12.9-4
- \( C_s, min = 0.044*SDS*I, >= 0.01 \) 0.020 EQN 12.8-5
- For S1 <= 0.6g, C_s, min = 0.5*S1/(R/I) = 0.025 EQN 12.9-6
- \( V = \rho^*C_s^*W = 0.091^* W \) STRENGTH
DETERMINATION STORY FORCES CONT.

<table>
<thead>
<tr>
<th>Building Weight</th>
<th>Item</th>
<th>Weight (K) * See Calculation Packet for determination of values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Decking</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Girders</td>
<td>9.17</td>
</tr>
<tr>
<td></td>
<td>Joists</td>
<td>12.17</td>
</tr>
<tr>
<td></td>
<td>Walls</td>
<td>339</td>
</tr>
<tr>
<td>Σ</td>
<td></td>
<td><strong>364.34</strong></td>
</tr>
</tbody>
</table>

Story Forces and Diaphragm Forces

<table>
<thead>
<tr>
<th>N/S &amp; E/W</th>
<th>Cxx</th>
<th>Fx = Cxx * V</th>
<th>Fx</th>
<th>ΣFx</th>
<th>Ax (coeff.)</th>
<th>Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level</td>
<td>Wx (kips)</td>
<td>ΣWx (kips)</td>
<td>hx (ft)</td>
<td>Wx<em>hx</em>k</td>
<td>Wx<em>hx</em>k/2(2Wx<em>hx</em>k)</td>
<td>Coefficient * W</td>
</tr>
<tr>
<td>Roof</td>
<td>364.34</td>
<td>364.34</td>
<td>11</td>
<td>4007.74</td>
<td>1</td>
<td>0.091*W</td>
</tr>
<tr>
<td>Σ</td>
<td>364.34</td>
<td>4007.74</td>
<td>1</td>
<td>0.091*W</td>
<td>33.15494</td>
<td></td>
</tr>
</tbody>
</table>

1' STRIP E/W wt x Ax

<table>
<thead>
<tr>
<th>Weight (k)</th>
<th>Ax</th>
<th>Wt x Ax</th>
<th>Total / 1' strip (Kip/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>364.34</td>
<td>0.091</td>
<td>33.15494</td>
<td><strong>0.368388222</strong></td>
</tr>
</tbody>
</table>

1' STRIP N/S wt x Ax

<table>
<thead>
<tr>
<th>Weight (k)</th>
<th>Ax</th>
<th>Wt x Ax</th>
<th>Total / 1' strip (Kip/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>364.34</td>
<td>0.091</td>
<td>33.15494</td>
<td><strong>0.637595</strong></td>
</tr>
</tbody>
</table>
DISTRIBUTION OF STORY FORCES TO WALL LINES

SHEAR ON WALL 2:
20' * 0.37KLF / 52' = 142PLF

SHEAR ON WALL 4:
55' * 0.37KLF / 26' = 783PLF

SHEAR ON WALL 6:
25' * 0.37KLF / 39' = 237PLF

SHEAR ON WALL A:
13' * 0.64KLF / 30' = 277PLF

SHEAR ON WALL C:
26' * 0.64KLF / 50' = 333PLF

SHEAR ON WALL 6:
13' * 0.64KLF / 90' = 92PLF
R = 1/(E*t)((H/L)^3+3*(H/L))

R1 = 1/(E*t)*((7'/16')^3+3*(7'/16')) = .716
R2 = 1/(E*t)*((7'/7')^3+3*(7'/7')) = .25
R3 = 1/(E*t)*((7'/7')^3+3*(7'/7')) = .25
R4 = 1/(E*t)*((7'/4')^3+3*(7'/4')) = .094

R1+R2+R3+R4 = .77

We will check pier 4

V' = .094 / .77 * 142PLF * 52' = .9K
Check In Plane Pier 4

\[ a = \frac{0.8 f_y}{E} = \frac{3(60)(60)}{0.8(2.5)(1.625)} = 2.36'' \]

\[ M_n = A f_y (d - \frac{a}{2}) = 3(1.2)(60)(24 - 1.5) = 236'' \]

\[ = 1110 \text{ k-in} = 92.46 \text{ kft} \]

\[ \Rightarrow \phi M_n = 83.2 \text{ k} \]

\[ t = 3.5'' \]

\[ 3.5''(2.25k) = 7.875 \text{ k-ft} = M_u \]

\[ \phi M_n = 83.2 \text{ k} > 8 \text{ k} = M_u \]
Check Shear

\[ V_u = 1.25 \left( \frac{\phi M_u}{M_0} \right) V' = 1.25 \left( \frac{83.7k''}{8k'} \right) 2.25k \]
\[ V_u = 29.25k \]

\[ V_{u,\text{max}} = 4A_n \sqrt{Fm} \]
\[ = 4 \left( 7.63'' \cdot 48'' \right) - 3(2) \} \sqrt{2500} \]
\[ = 70.54k \]

\[ V_{u,\text{max}} = 70.54k > 29.25k = V_u \checkmark \]

\[ \phi V_{n,m} = 0.8(2.25)(A_n) \sqrt{Fm} \]
\[ = 0.8 \left( 2.25 \right) \left( 7.63'' \cdot 48'' \right) - 3(2) \} \sqrt{2500} \]
\[ = 32.9k \]

\[ \phi V_{n,m} = 32.9k > 29.25k = V_u \checkmark \]
s 1809.9.1 and 1809.9.2, and the provisions of Chapter 21.

**Exception:** Where a specific design is not provided, masonry-unit footings supporting walls of light-frame construction shall be permitted to be designed in accordance with Table 1809.7.

1809.9.1 **Dimensions.** Masonry-unit footings shall be laid in Type M or S mortar complying with Section 2103.2.1 and the depth shall be not less than twice the projection beyond the wall, pier or column. The width shall be not less than 8 inches (203 mm) wider than the wall supported thereon.

1809.9.2 **Offsets.** The maximum offset of each course in brick foundation walls stepped up from the footings shall be 1 1/2 inches (38 mm) where laid in single courses, and 3 inches (76 mm) where laid in double courses.

**Width = 7.625+8 = 15.625 → 1'-4''**

**Depth = 2*(15.625-(7.625/2)) = 23.625 → 2'**
DIAPHRAGM DESIGN

N/S Direction
VE = VF = 1/2*0.64*52FT/90FT = 185PLF
.7VE = 0.7*185PLF = 129PLF

E/W Direction
VE = VF = 1/2*0.37*90FT/52FT = 320PLF
.7VE = 0.7*320PLF = 224PLF

Shear in E/W will govern B/C larger load with shorter distribution length
Shear along gridline 2 = 11340#/52' = 218PLF
Shear along gridline 6 = 8820#/39' = 226PLF

Choose SDI Screws
673#/2'O.C. = 336.5PLF > 226PLF CHECK

USE SDI RECOGNIZED SCREWS EVERY 2' O.C.

Table 4: Allowable Shear Strength (lbs/connection) for Arc Spot Welds, Arc Seam Welds, Hilti Fasteners, Pneutek Fasteners and SDI Recognized Screws for Verco Deck Panel Support Connections

<table>
<thead>
<tr>
<th>Deck Gage</th>
<th>Profile</th>
<th>BMT (in.)</th>
<th>ARC SPOT WELD (lbs)</th>
<th>ARC SEAM WELD (lbs)</th>
<th>HILTI X-ENDK22 or X-HSN 24 (lbs)</th>
<th>HILTI X-EKP-19 (lbs)</th>
<th>PNEUTEK SDK61 (lbs)</th>
<th>PNEUTEK SDK63 (lbs)</th>
<th>PNEUTEK K64 (lbs)</th>
<th>PNEUTEK K66 (lbs)</th>
<th>SDI RECOGNIZED SCREWS (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>B &amp; N</td>
<td>0.0299</td>
<td>783</td>
<td>1231</td>
<td>603</td>
<td>650</td>
<td>618</td>
<td>691</td>
<td>694</td>
<td>736</td>
<td>561</td>
</tr>
<tr>
<td>20</td>
<td>B &amp; N</td>
<td>0.0359</td>
<td>1091</td>
<td>1491</td>
<td>720</td>
<td>775</td>
<td>733</td>
<td>791</td>
<td>886</td>
<td>903</td>
<td>673</td>
</tr>
<tr>
<td>18</td>
<td>B &amp; N</td>
<td>0.0478</td>
<td>1850</td>
<td>2017</td>
<td>947</td>
<td>1020</td>
<td>951</td>
<td>967</td>
<td>1204</td>
<td>1253</td>
<td>896</td>
</tr>
<tr>
<td>16</td>
<td>B &amp; N</td>
<td>0.0598</td>
<td>2309</td>
<td>2564</td>
<td>1169</td>
<td>1259</td>
<td>1158</td>
<td>1125</td>
<td>1474</td>
<td>1630</td>
<td>1121</td>
</tr>
</tbody>
</table>
\[ TA = 26 \times (15' + 20') = 920 \text{ SF} \]
\[ DL_{\text{load}} = 26'(1000 \text{ lb}) = 26000 \text{ lb} \]
\[ DL_{\text{Girder}} = 35'(4000 \text{ lb}) = 140000 \text{ lb} \]
\[ DL = 6 \text{ PSF}(920 \text{ SF}) + 26000 \text{ lb} + 140000 \text{ lb} = 718k \]
\[ LL = 16 \text{ PSF}(920 \text{ SF}) = 138k \]
\[ Pu = 1.2(7.18k) + 1.6(13.8k) = 30.696k \geq 31k \]

Try 4 ksi:
\[ \phi P_n = 0.9(1.8)[f'\text{m} (A_y - A_s) + f_y A_s] \]
\[ \phi P_n = 0.9(1.8)(2\text{k}(15.63^2 - 4(441^2))) + 60\text{k} \left( 4(441) \right) \]
\[ \phi P_n = 425\text{k} > 31k = Pu \checkmark \]

\[ c = A_s f_y \leq \frac{c}{G} 0.81'' \text{ in} \]

\[ \Sigma F_x = A_s f_y - A's f'c - 0.8(2''\text{ mil}) = 0 \]
\[ O = 0.88 \times (60) - 0.88 \left[ -0.025 \frac{L - 3.625}{29000} \right. \]
\[ -0.8(2'') \left[ 0.8 (15.63) - 4(441) \right] \]
\[ \Rightarrow \ C = 3.2'' \text{ in} \]
\[\Phi M_n = 0.9 \left[ 0.88(60)(12.3.2) \right] + 0.88 \left[ 0.025 \left\{ \frac{3.2 - 3.625}{3.2} \right\}^3 \frac{79000}{3.7} \right] \]

\[\Phi M_n = 418.176 - 2.7116 + 27.2087 \]

\[\Phi M_n = 442.67 \text{ k-in} = 36.89 \text{ k"} = \Phi M_n \]

\[P_b = f_y A_s + E_m \left[ \frac{d - c}{c} \right] \epsilon_s A_s; = 641.69 \text{ k"} \]

\[= 60(1.88) + 0.0025 \left\{ \frac{3.625 - 3.2}{3.2} \right\} 29000(1.88) = 641.69(15.63)(3.2) \]

\[= 52.8 + 8.47 = 64.02 \]

\[P_b = 19.69 \text{ k} \]

\[\Phi P_b = 17.72 \text{ k} \]

\[M_b = 1 \left[ 12 - \frac{15.63}{2} \right] + 2 \left[ \frac{15.63}{2} - \frac{9}{2} \right] + 3 \left[ \frac{15.63}{2} - c \right] \]

\[M_b = 52.8 \left[ 12 - \frac{15.63}{2} \right] + 8.47 \left[ \frac{15.63}{2} - \frac{9}{2} \right] \]

\[+ 64.02 \left[ \frac{15.63}{2} - 3.625 \right] \]

\[M_b = 220.968 + 52.64 + 268.24 \]

\[M_b = 541.85 \text{ k"} = 45.15 \text{ k"} \]

\[\Phi M_b = 40.64 \text{ k"} \]

\[\Phi M_n = 17.72 \text{ k} \]

\[\Phi M_n = 36.89 \text{ k"} \]
Take Heart School

Migori, Kenya
By: Quinn Porter
Advisor: Kevin Dong
The Team

Quinn Porter

Spencer Mishky

Janelle Tatari

ARCE

Cal Poly

Construction Management

Cal Poly

Architecture
Scope

- 3 acre sloped site, surrounded by agriculture and empty land
- Located near a small rural village
- Buildings:
  - School with 8 classrooms
  - Housing
  - Cafeteria
  - Program space
- Design Considerations:
  - Maximise View out to the west
  - Maximise use of shaded outdoor space
Assumptions

- Site Assumptions
- Loading
- Materials
Specifications

Roof/Gravity System
- Steel Decking
- Steel wide flange beams/girder
- Steel columns & Masonry pilasters

Lateral System
- Reinforced masonry shear walls
- Used standard CMU
Gravity Design

20 GA DEEP VERCOR DECK
Roof Design Considerations

W12 x 40

W12 x 40

W12 x 14
Gravity Design Continued

- HSS 4x4x1/8 or 3' STD PIPE
- 16'x16" CMU PILLASTER W/ (4) NO. 4 REBAR
- HSS 4x4x3/16 or 4' STD PIPE
Column Design Considerations

Concerned about available materials

Two Options for 10ft Column
- HSS 4x4x1/8
- 3’ STD. PIPE

Two Options for 16ft Column
- HSS 4x4x3/16
- 4’ STD. PIPE
Lateral Design
Lateral Design Cont.
Lessons Learned

● The importance of communication and relationships
● The client does not always know what they want
● The luxury of materials/construction techniques we have here in the US
Next Steps

- Send Plans to Architect and Engineer in Kenya
- Client has gone rogue and hired their own architect
- Plans may merge, but the outlook for this project to be built in any way that resembles our design is pretty low
Questions