PROJECT REPORT

FOR

Empowering Villages Center and Agricultural Training Facility

IN

Rubagabaga Village, Rwanda

FOR

Journeyman International

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California Polytechnic State University, San Luis Obispo

June 5th, 2019
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ABSTRACT

By partnering with non-profit organizations such as Journeyman International and Empowering Villages, undergraduate students can engage in senior projects that have far reaching humanitarian impacts. Journeyman International is well known for creating powerful teams of students who tackle design challenges in developing countries. This paper details the work of two architectural engineering students from California Polytechnic State University, San Luis Obispo on a design for the Empowering Villages Center (EVC) and Agricultural Training Facility (ATF) in Rubagabaga Village, Rwanda. The EVC and ATF project was proposed by Empowering Villages, an organization that aims to bring electricity and socioeconomic growth to rural communities in East Africa. The students collaborated on an interdisciplinary team for nine months to produce structural calculations and drawings for the project. In addition to the structural calculations and drawings, this report includes a project overview, challenges, the final impact, team dynamics, and personal reflections.
INTRODUCTION

JOURNEYMAN INTERNATIONAL

Journeyman International (JI) is a non-profit organization founded in 2009 with the mission statement to “Build What Matters Most”. By partnering undergraduate students from the Architecture, Architectural Engineering, and Construction Management disciplines at Cal Poly, JI creates interdisciplinary teams to design humanitarian projects around the world. Student volunteers serve as the project designers in order to make JI a low cost option for building in developing and underprivileged areas.

EMPOWERING VILLAGES

JI partners with other nonprofit organizations to provide quality and meaningful design work for a variety of sectors. For this project, JI partnered with Empowering Villages, a rural community development model that helps bring socio-economic sustainability to developing areas. Empowering Villages is funded by East African Power who construct hydropower plants in developing villages throughout East Africa. These hydropower plants bring electricity to villages that may otherwise not have access to power and allows them to develop their small villages effectively and efficiently. Empowering Villages reached out to JI to design the Empowering Villages Center (EVC) and Agricultural Training Facility (ATF) in Rubagabaga Village, Rwanda.

RWANDA: THE HISTORY

From the 1300s to late 1800s, the Hutu and Tutsi were harmonious under a centralized monarchy with Tutsi kings. However, leadership was passed around under colonial rule—the Germans in 1899 and the Belgians in 1919. These sudden leadership changes were followed by the hostile Rwandan leadership of President Gregoire Kayibanda and President Juvenal Habyarimana. Discrimination against Tutsi was institutionalized, thus beginning one of the most extensive genocides the world has seen. The Tutsi were targeted from 1959 onwards—leading to hundreds of thousands of deaths and nearly two million exiles.

In 1979, the Rwandese Alliance for National Unity (RANU) was created to support Rwanda refugees in exile and mobilize against aggressive political actions and genocide ideology. The RANU was renamed the Rwandese Patriotic Front (RPF) in 1987, followed by the launch of an armed liberation struggle in 1990. The dictatorship was removed in 1994, ending the genocide of over one million Tutsi.
PROJECT DESCRIPTION

PURPOSE

The Empowering Villages Center was proposed to provide space for assembly, social programs, skills trainings, and recreation. Most importantly, the EVC will serve as a gathering place for the people of Rubagabaga Village and the surrounding areas. The creation of a centralized space where local people can congregate allows villagers to take ownership of their community.

The Agricultural Training Facility was proposed to allow local farmers to adopt innovative strategies that can make their land more profitable. As seen in Figure 2, the project site is located near steep mountainside slopes that local farmers currently struggle to stabilize. The goal is to provide local farmers with the tools to maximize crop yields and income while also emphasizing environmental sustainability.

The overarching goal of this project was to promote a healthy community dynamic and a sense of place for the people in Rubagabaga Village. East African Power recently completed a hydropower plant adjacent to the project site, proving their ability to employ local people, through construction and development, helping bring financial stability to the villagers. The goal of the design team for the EVC and ATF was to create a building that could be constructed by villagers to continue monetary flow into Rubagabaga Village.
DESIGN TEAM

The project design team consisted of architecture student Mackenzie Dias, construction management student Jake Stom, and architectural engineering students Jenna Williams and Julia De Hart. While this project fulfilled the student’s senior thesis projects for Cal Poly, they each joined the project to help the people of Rubagabaga Village. The team worked together for nine months to generate a final design product.

DESIGN OVERVIEW

It was decided by the design team that the best way to incorporate the goals of both the EVC and ATF was to bring them together as one building with two wings. As shown in beige in Figure 3, the ATF would be set up as a classroom with adjacent administration offices and storage rooms. A crops testing area is located outside the ATF for farmers to practice the techniques they learn about during their training. The EVC, as seen in red below, serves as the second wing of the combined-use building. The open floor plan offers flexibility so the people of Rubagabaga Village can utilize the space as needed. Large sliding doors serve as entrances to the ATF from either side of the building while a sliding door between program spaces offers separation during class time. An auxiliary building at the back of the site serve as bathrooms. A steel canopy is also located in front of the structure to provide covered outdoor seating.

Figure 3: Floor Plan
The structural system of the building was chosen based on material availability and on-site constructability. The gravity system consists of a steel decking roof and milled eucalyptus trusses. The trusses over the EVC are monosloped while those over the ATF are in a butterfly configuration as illustrated in Figures 4 and 5, respectively. Both systems allow natural sunlight and fresh air to enter and circulate throughout the building. Steel rod-braces serve as the roof diaphragm and the main lateral force resisting system consists of confined masonry walls with concrete tie beams and columns. The entire structure sits on a concrete slab on grade with robust concrete foundation walls.
DELIVERABLES

The deliverables required of the architectural engineering students were structural calculations (Appendix A) and structural drawings (Appendix B) for the project.

CALCULATIONS

The gravity calculations for this project began with estimating member sizes to find a building weight. Load take-offs were produced separately for the EVC and ATF since the buildings had separate roof systems and different wall heights. Next, a corrugated, concealed fix decking was chosen from a Rwandan manufacturer, Safintra, to prevent water leakage and to define a water runoff direction. A purlin spacing was chosen based on the decking specifications. Truss demands were determined in RISA-3D modeling. The students did not have sufficient information on the design properties of Rwandan eucalyptus for the purlins and trusses. The design values for Douglas Fir Larch Grade 2 were used instead, as they were determined to be conservative for the eucalyptus member design. All timber members and truss connections were designed using the 2015 National Design Specification (NDS) by the American Wood Council (AWC). Due to the variability of eucalyptus in a wet region like Rwanda, temperature and moisture content factors were taken into consideration. The final truss member sizes were taken to be the same for both program areas for constructability ease. The slab on grade design was chosen from a typical U.S. standard design for 1-2 story buildings, a 5” thick slab with #3 bars at 18” on center each way.

The lateral calculations considered both wind and seismic forces to determine the governing load case. A wind speed for the region near Rubagabaga Village was difficult to find, so the design team proceeded with a conservative wind speed of 110 mph. This is the lowest wind pressure found on maps for the U.S., but still highly conservative for Rwanda. Seismic values were easier to find, and the final values used are from a conference paper, Seismic Design Considerations for East Africa [2]. In accordance with ASCE 7-16 procedures, it was determined that the seismic loads governed for the project site.

Lateral load calculations were completed to determine the diaphragm design. Rod braces were designed to be placed between the purlins around the perimeter of the EVC and the ATF to serve as the load resisting system for governing seismic forces at the roof. Rod braces were also added in elevation, perpendicular to the trusses at midspan in the EVC and ATF to provide out of plane bracing to the bottom chord of both sets of trusses.
Confined masonry walls were designed in accordance with the manual created by EERI and IAEE, Seismic Design Guide for Low-Rise Confined Masonry Buildings [3]. The walls were designed for a lateral wall density based on seismic hazard, number of stories, brick type, and soil type. The walls were also designed for a gravity wall density based on the gravity load, brick strength, and mortar strength. The walls consist of two wythes made from custom size clay bricks that can be made by local people. The concrete tie-columns and tie-beams were sized and reinforced by the prescriptive design recommended by the Seismic Design Guide.

The wall foundations were designed to resist forces obtained from a lateral seismic load distribution. A conservative allowable soil bearing pressure was obtained from the 2015 International Building Code (IBC) since students were unable to obtain a geotechnical report for the site. The footing sizes and flexural reinforcement were determined using the American Concrete Institute (ACI) 318-14. The governing allowable stress design load combination was used to determine a sufficient footing size and the governing strength design combination was used to determine the flexural reinforcement, both transverse and longitudinal.

The restroom was dimensionally set to be the same plan size as one of the storage rooms in the ATF in order to minimize design calculations and provide uniformity throughout the design to make construction easier. The restroom gravity system was designed to mimic the ATF design, as the trusses were of the same size and spacing. The lateral system was designed with the same procedure used for the EVC and ATF.

Finally, a steel canopy area was designed using hollow structural steel sections for the beam, girder, and column members. The Safintra corrugated steel decking previously described for the EVC and ATF is also used for the canopy roofing and spans between beams.

**DRAWINGS**

The structural drawings consist of a foundation plan, roof framing plan, wall elevations, truss elevations, and supplementary details. The structural details included in the construction documents outline roof connections, truss connections, wall connections, and foundations. General notes are provided to specify materials and construction practices for this project. The structural drawings were coordinated with architectural drawings provided by the architecture student and were completed in metric units for ease of use in Rwanda.
CHALLENGES

Throughout this project, the students were met with different roadblocks that arise from considering international design aspects and working within an interdisciplinary team.

MATERIALS

One challenge was the availability and quality of materials available in Rwanda. The students were in contact with Rwandan engineers and JI staff members to determine the best design values for unfamiliar materials in the U.S., like eucalyptus. Eucalyptus in Rwanda also varies across the country, so it was established that controlling the species of eucalyptus that would be used for the project was impossible. Extensive research was conducted to attempt to find the compressive and bending values for Rwandan eucalyptus before it was decided to assume a conservative value that could account for discrepancies in wood quality, moisture content, and temperature effects.

CONFINED MASONRY DESIGN

Students were required to self-educate themselves on the design of confined masonry for this project. It was the chosen construction technique because of its success in previous earthquakes, unlike masonry infill. Confined masonry engages the masonry with concrete tie beams and tie columns, as shown in Figure 6. Using the Seismic Design Guide from EERI, the students were able to follow prescriptive design practices used for similar low-rise, confined masonry buildings.

INTERDISCIPLINARY TEAMWORK

The third challenge experienced by the students was working with an interdisciplinary team. Coordinating ideas with students from different disciplines required each student to present and communicate their ideas effectively so that other team members could understand the design intention. At times, the architecture student would move forward with an idea without consulting the other disciplines, and this required compromise from all students to come to an agreement on the final design.
THE FINAL IMPACT

Perhaps the most exciting part of this project is that construction of the EVC and ATF will begin in the summer of 2019. The hydropower plant has been completed since team members visited the site in December 2018 and it won an award at the annual Infrastructure Industry Conference in Cape Town, South Africa. The most rewarding part of completing a Journeyman International project is reflecting on the international scale of the project and all the people that the design will benefit. There were numerous considerations for the global, cultural, social, environmental, economic, and constructability impact that this project would have in Rwanda and around the world.

GLOBAL CONSIDERATIONS

Designing a building for Rwanda, a country located half-way around the world from the design team, produces inherent far-reaching impacts. The team designed an agricultural training facility and community center for a village that otherwise would remain fairly underdeveloped and underprivileged. The local people will also have electricity from the hydropower plant located around the river bend from the team's project. The Rubagabaga Village community will have access to new technology and resources that will allow them to become more integrated with the larger Rwandan as well as global society.

CULTURAL CONSIDERATIONS

Rwanda underwent a loss of identity followed by the birth of a new identity in a very short time period. Julia had the opportunity to experience Rwandan culture firsthand, and see the residual effects of the Rwandan genocide. Building in a small, somewhat remote village meant that we could be dealing with a community that has not yet recovered. By incorporating traditional practices into the building design, like the Rwandan paintings on the brick walls, we are able to establish a known identity that the local people can connect with.

SOCIAL CONSIDERATIONS

The building of the EVC and ATF will greatly impact the lives of the people in Rubagabaga Village. Farmers have the opportunity to become educated in high yield crops and environmentally friendly farming techniques. The community center will provide local people with a place to gather and discuss community concerns as well as organize local events. The entangled cultural and social value that this project brings to the local people will foster an engaged, tight-knit community.
ENVIROMENTAL CONSIDERATIONS

Rubagabaga Village is located on the Rubagabaga River, 25 kilometers south of the city of Musanze. There are vehicle accessible roads that land on the opposite side of the river, facing the site. This posed the challenge for our site to be built with materials that could be transported across the river. All materials were restricted in length and weight to ensure they were manageable to be hauled across the river. The proximity to the river also required the team to direct any site runoff away from the river to avoid pollution. Another environmental concern that the team took into consideration was providing a roof water collection system for rainfall. Using a water cistern, rainfall will go pass through different natural filters to produce clean, potable water.

ECONOMIC CONSIDERATIONS

All designs of this building were created so that local people could contribute to the construction. The villagers are paid for their labor contributions, establishing an economic flow throughout the village and surrounding areas. Labor is extremely inexpensive in Rwanda. For example, a laborer will be paid $2.00 a day to break rocks into gravel. This is much more cost effective and much better for the local laborers and their families than it would be to bring a concrete truck in from a third party for pouring. Not only will the construction of this project provide money for villagers, but the agricultural training facility will teach farmers how to produce more abundant crops—leading to an even more prosperous outcome for Rubagabaga Village.

CONSTRUCTABILITY CONSIDERATIONS

Each piece of the design was carried out with the intention that the Rubagabaga community could contribute to its construction. All buildings will have bamboo woven mat ceilings and brick walls painted with traditional Rwandan designs, both of which can be fabricated by local people. Given proper instruction and tools, locals can mill eucalyptus trees from the area to form the trusses, make handmade clay bricks for the walls, and mix the concrete for the site.
TRAVEL EXPERIENCE

In December 2018, project team member Julia De Hart travelled to Rwanda with six other students also partnering with JI. We landed in the country’s capital, Kigali, and were met by Carly Althoff, a Cal Poly architecture alumni who now lives in Rwanda as a full-time JI staff member, as well as other JI and Empowering Villages staff. The main purpose of the trip was to visit each JI team’s site while taking in as much culture and history along the way.

First, the site at Rubagabaga Village was visited, located about 30km south of Musanze, the nearest city of notable size. We travelled through villages and banana plantations on dirt roads before finally crossing a river in our car to arrive at our destination. The hydropower plant commissioned by the country of Rwanda with East African Power, was under construction while we were there. It was eye-opening to see how something as large-scale as a hydropower plant is constructed in a developing country. They compensate the lack of heavy machinery with sheer manpower. Huge groups of people line up to carry rocks uphill, dig trenches with shovels, and break rocks on site with a hammer and chisel to make aggregate.

The best part of the entire experience was interacting with the people, especially the kids, whom our project will impact. When we hiked through villages and country sides, kids would gather and follow us for miles, helping us take the right path and use the right footholds after laughing at us when we took the wrong ones. The native Rwandans travelling with us would tell elder members of the communities why we were there and their faces would light up and come over to shake our hands. Barriers of language and culture have no substance when compared to laughter and humanity.
TEAM EVALUATIONS

TEAM DYNAMICS

Unlike the architecture student or the construction management student, who work independently on their own tasks, the architectural engineering students on the team had a unique opportunity to work together on their deliverables. The students gravitated towards the parts of the project that best fit their skill sets. Jenna had previously completed a research project for a class on confined masonry, so she was more comfortable taking on this task. Julia had held a drafting internship for the past two years, so she was more efficient in creating the drawings for the project. The students usually worked at the same time, setting up work days so that they could bring any questions or concerns to each other easily. The students had already created a solid team dynamic foundation last quarter working on the Cal Poly EERI Seismic Design Competition Team, so they were quick to understand how each other communicated and worked best.

PERSONAL REFLECTION - JULIA DE HART

I am so grateful to be a part of a Journeyman project and the greater Journeyman team. I heard JI founder, Daniel Wiens, speak at a SEAOC student chapter meeting as an underclassman and was immediately convinced that I wanted to partner with them for my senior project. This project forced me to find solutions for things that I would not normally be faced with when designing in the United States. My design labs at Cal Poly prepared me to design a project of this scale. I had experience in all of the materials, but I had to adapt to the construction means and methods that are typical for a developing country like Rwanda.

Understanding the global scale of the project helped put everything into perspective. The enormous amount of pride I have for the impact our design will have on the Rwandan people makes every ounce of work worth the effort. I was fortunate enough to travel to Rwanda and interact with the people first hand. Being able to embrace their culture, learn about their history, and eat their food are all life-changing experiences that have earned a special place in my heart forever. I plan to return so that I can witness my first completed project as a structural engineer.
PERSONAL REFLECTION - JENNA WILLIAMS

Completing this humanitarian project taught me numerous technical and life lessons. From working on an interdisciplinary team to realizing the impact that this project will have in Rwanda, I have learned the importance of recognizing and embracing the big picture.

The international aspect of this project required me to engage in self-education. Even though we had learned how to assemble a calculations and drawings packet from design lab, this project required more research into Rwanda. Challenges with material availability and confined masonry design were new topics that I had to invest time learning about. In addition to learning on my own, I had to evaluate when it was best to contact our on-ground contacts at JI and Empowering Villages when I had a bigger question. This project began my regular use of “engineering judgement” to inform my decisions.

Working on an interdisciplinary team allowed me to learn the needs of everyone on a project: architect, engineer, contractor, and most importantly, the client. When a challenge was present, it was always most beneficial to consider how the project served the client. Journeyman International provided me the opportunity to develop my interpersonal skills for the workplace and for life.

Oddly enough, I never felt as if this was a “requirement”, but instead it was something that I was truly passionate about. I began working on humanitarian projects with Cal Poly Structural Engineering Students for Humanity (SESH) in 2018, and since then I’ve caught the “humanitarian bug”. My ambition to help others and spread safe engineering practices around the world has been met through designing for Rubagabaga Village. Having the opportunity to work with Journeyman International and continue my growth as a member of the structural engineering industry who gives back was extremely rewarding. I plan to continue my involvement in humanitarian work after I complete my graduate degree in June 2020.
STRUCTURAL CALCULATIONS
FOR
Empowering Village Center and Agricultural Training Facility
IN
RUBAGABAGA VILLAGE, RWANDA

Prepared For:
Journeyman International

Prepared By:
Jenna Williams and Julia De Hart

Prepared At:
California Polytechnic State University, San Luis Obispo

Prepared On:
June 5th, 2019
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DESIGN CRITERIA

Design Codes:  
- IBC 2015
- ASCE 7-16
- ACI 318-14
- AISC 360-16
- NDS-15

Risk Category:  II

Seismic:

Seismic Coefficients:
- $S_{DS} = 0.608 \text{ g}$
- $S_{D1} = 0.152 \text{ g}$

Importance Factor:
- $I_e = 1.0$

Site Class:  D

Wind:

Wind Exposure:  Partially Enclosed
Wind Speed:  110 mph

Material

Concrete:  $f'c = 3000 \text{ psi (20.7 MPa)}$
Steel Reinforcement:  $f_y = 40 \text{ ksi (275 MPa)}$
Masonry:  $f'm = 3000 \text{ psi (20.7 MPa)}$
Timber:  Eucalyptus (Design Values taken from DF #2)

Geotechnical Report:  Not Available
Use IBC Chapter 18 Soil Pressure Values
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<td><strong>ATF LOAD TAKE OFF</strong></td>
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<td><strong>TOTAL AREA</strong></td>
<td>96 m²</td>
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DECKING DESIGN

Purlin Spacing: 1 m
Load: 2.44 kg/m²

Choose SAFLOK 700 concealed fix roofing
Aluminum-Zinc, 0.5mm gauge

Allowable Spacing: 1.4 m > 1m GOOD
Allowable Load: 153 kg/m² > 2.44 kg/m² GOOD

USE SAFLOK 700 ALUMINUM-ZINC 0.5mm GAUGE DECKING
### Calculations

**PURLIN DESIGN**

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<td>( L )</td>
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<td>78.74 in</td>
</tr>
</tbody>
</table>

\[
F'_{b} = F_{b}(C_{D}C_{M}C_{t}C_{L}C_{F}C_{fu}C_{f})
\]

- \( F_{b} = 525 \text{ psi} \)
- \( C_{D} = 1.0 \)
- \( C_{M} = 1.0 \)
- \( C_{t} = 1.0 \)
- \( C_{L} = 1.0 \)
- \( C_{F} = 1.5 \)
- \( C_{fu} = 1.0 \)
- \( C_{f} = 1.0 \)

\[
f'_{b} = 787.5 \text{ psi}
\]

- \( f_{b} = M/S \)
- \( M = 1485.4 \text{ lb-in} \)
- \( S_{req} = 1.89 \text{ in}^3 \)
- \( S = 30910 \text{ mm}^3 \)

**Use 50mm x 100mm purlins @ 1m o.c. (S = 83,333 mm^3)**

**Use 2x4 purlins @ 40" o.c.**
ATF TRUSS DESIGN (TRUSS A&B)

Max Chord Force = 2086 kg 4598.8 lb
Max Web Force = 490 kg 1080.3 lb
Max Diagonal Force = 1525 kg 3362.0 lb

NDS T4.3.1

\[ F_c' = \frac{F_b(C_o * C_m * C_l * C_f * C_{fu} * C_{i} * C_r)}{F_c} \]

\[ F_c = 775 \text{ psi} \]
\[ C_d = 1.0 \]
\[ C_m = 0.8 \]
\[ C_l = 1.0 \]
\[ C_f = 1.15 \]
\[ C_i = 1.0 \]

\[ F_c' = 713.0 \text{ psi} \]

NDS T4.3.1

\[ F_t' = \frac{F_b(C_o * C_m * C_l * C_f * C_{fu} * C_{i} * C_r)}{F_t} \]

\[ F_t = 325 \text{ psi} \]
\[ C_d = 1.0 \]
\[ C_m = 1.0 \]
\[ C_l = 1.0 \]
\[ C_f = 1.50 \]
\[ C_i = 1.0 \]

\[ F_t' = 487.5 \text{ psi} \]

CHORD

\[ f_c = \frac{P}{A} \]
\[ A_{req} = 6.45 \text{ in}^2 \]
\[ 3.22 \text{ in}^2 \text{ per chord} \]
\[ 2080.64 \text{ mm}^2 \text{ per chord} \]

\[ f_t = \frac{P}{A} \]
\[ A_{req} = 9.43 \text{ in}^2 \]
\[ 4.72 \text{ in}^2 \text{ per chord} \]
\[ 3043.07 \text{ mm}^2 \text{ per chord} \]

Use double 50mm x 100mm chord members (A= 5000mm²)
Use double 2x4 chord members (A= 5.25in²)
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>ATF TRUSS DESIGN (TRUSS A&amp;B)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>WEB</strong></td>
</tr>
<tr>
<td></td>
<td>( f_c = \frac{P}{A} )</td>
</tr>
<tr>
<td></td>
<td>( A_{req} = 1.52 \text{ in}^2 )</td>
</tr>
<tr>
<td></td>
<td>977.48 mm(^2)</td>
</tr>
<tr>
<td></td>
<td>( f_t = \frac{P}{A} )</td>
</tr>
<tr>
<td></td>
<td>( A_{req} = 2.22 \text{ in}^2 )</td>
</tr>
<tr>
<td></td>
<td>1429.63 mm(^2)</td>
</tr>
<tr>
<td></td>
<td>Use 50mm x 100mm vertical members (A=5000mm(^2))</td>
</tr>
<tr>
<td></td>
<td>Use double 2x4 vertical members (A= 5.25in(^2))</td>
</tr>
<tr>
<td></td>
<td><strong>DIAGONAL</strong></td>
</tr>
<tr>
<td></td>
<td>( f_c = \frac{P}{A} )</td>
</tr>
<tr>
<td></td>
<td>( A_{req} = 4.72 \text{ in}^2 )</td>
</tr>
<tr>
<td></td>
<td>3042.16 mm(^2)</td>
</tr>
<tr>
<td></td>
<td>( f_t = \frac{P}{A} )</td>
</tr>
<tr>
<td></td>
<td>( A_{req} = 6.90 \text{ in}^2 )</td>
</tr>
<tr>
<td></td>
<td>4449.35 mm(^2)</td>
</tr>
<tr>
<td></td>
<td>Use 50mm x 100mm diagonal members (A=5000mm(^2))</td>
</tr>
<tr>
<td></td>
<td>Use double 2x4 diagonal members (A= 5.25in(^2))</td>
</tr>
<tr>
<td></td>
<td>Use 50mm x 150mm diagonal members (A= 7500mm(^2)) for all Truss B and C members</td>
</tr>
<tr>
<td></td>
<td>(double 2x6 diagonal members equivalent)</td>
</tr>
</tbody>
</table>
### ATF TRUSS CONNECTIONS

#### WEB MEMBER TO CHORD

<table>
<thead>
<tr>
<th></th>
<th>Web of main member</th>
<th>Web of side member</th>
<th>Thickness of main member</th>
<th>Thickness of side member</th>
<th>G</th>
<th>Bolt diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>5.5 in</td>
<td>5.5 in</td>
<td>1.5 in</td>
<td>1.5 in</td>
<td></td>
<td>0.5 in</td>
</tr>
<tr>
<td></td>
<td>150 mm</td>
<td>150 mm</td>
<td>50 mm</td>
<td>50 mm</td>
<td>0.55</td>
<td>12.7 mm</td>
</tr>
</tbody>
</table>

#### DEMAND =

<table>
<thead>
<tr>
<th></th>
<th>Truss A</th>
<th>Truss B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1107 kg</td>
<td>462 kg</td>
</tr>
<tr>
<td></td>
<td>2440.5 lb</td>
<td>1018.5 lb</td>
</tr>
</tbody>
</table>

#### CAPACITY

\[
Z_{\text{f}}' = Z_{\text{f1}}(C_0 C_{\text{m}} C_t C_8 C_{\Delta})
\]

- \(Z_{\text{f1}} = 1150\text{ lb}\)
- \(C_0 = 1.25\)
- \(C_{\text{m}} = 1\)
- \(C_t = 1\)
- \(C_8 = 0.99\)
- \(C_{\Delta} = 1\)

\[
Z_{\text{f1}}' = 1423.1\text{ lb per bolt}
\]

<table>
<thead>
<tr>
<th></th>
<th># bolts(_{\text{req}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truss A</td>
<td>1.71</td>
</tr>
<tr>
<td>Truss B</td>
<td>0.72</td>
</tr>
</tbody>
</table>

### TRUSS A
Use 2-12.7mm Ø bolts (2-1/2" Ø bolts)

### TRUSS B
Use 1-12.7mm Ø bolt (1/2" Ø bolt)
## Calculations

### EVC TRUSS DESIGN (TRUSS C)

<table>
<thead>
<tr>
<th>Max Chord Force</th>
<th>3495 kg</th>
<th>7705.2 lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Web Force</td>
<td>1232 kg</td>
<td>2716.1 lb</td>
</tr>
<tr>
<td>Max Diagonal Force</td>
<td>1827 kg</td>
<td>4027.8 lb</td>
</tr>
</tbody>
</table>

### NDS T4.3.1

\[
F_c' = F_b(C_d\times C_m\times C_t\times C_f\times C_u\times C_l)\]

- \(F_c = \) 775 psi
- \(C_d = \) 1.0
- \(C_m = \) 0.8
- \(C_t = \) 1.0
- \(C_f = \) 1.15
- \(C_l = \) 1.0

\[
F_c' = 713.0 \text{ psi}
\]

### NDS T4.3.1

\[
F_t' = F_b(C_d\times C_m\times C_t\times C_f\times C_u\times C_l)\]

- \(F_t = \) 325 psi
- \(C_d = \) 1.0
- \(C_m = \) 1.0
- \(C_t = \) 1.0
- \(C_f = \) 1.50
- \(C_l = \) 1.0

\[
F_t' = 487.5 \text{ psi}
\]

### CHORD

\[
f_c = \frac{P}{A}
\]

- \(A_{req} = 10.81 \text{ in}^2\)
- \(5.40 \text{ in}^2 \text{ per chord}\)
- \(3486.02 \text{ mm}^2 \text{ per chord}\)

\[
f_t = \frac{P}{A}
\]

- \(A_{req} = 15.81 \text{ in}^2\)
- \(7.90 \text{ in}^2 \text{ per chord}\)
- \(5098.52 \text{ mm}^2 \text{ per chord}\)

Use double 50mm x 150mm chord members (A= 7500mm^2)

Use double 2x6 chord members (A= 8.25in^2)
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WEB</strong></td>
<td>EVC TRUSS DESIGN (TRUSS C)</td>
</tr>
<tr>
<td>( f_c = \frac{P}{A} )</td>
<td>( A_{req} = 3.81 \text{ in}^2 \quad 2457.67 \text{ mm}^2 )</td>
</tr>
<tr>
<td>( f_t = \frac{P}{A} )</td>
<td>( A_{req} = 5.57 \text{ in}^2 \quad 3594.49 \text{ mm}^2 )</td>
</tr>
</tbody>
</table>

Use 50mm x 100mm vertical members (A= 5000mm\(^2\))
Use double 2x4 vertical members (A= 5.25in\(^2\))

| **DIAGONAL** | |
| \( f_c = \frac{P}{A} \) | \( A_{req} = 5.65 \text{ in}^2 \quad 3644.61 \text{ mm}^2 \) |
| \( f_t = \frac{P}{A} \) | \( A_{req} = 8.26 \text{ in}^2 \quad 5330.47 \text{ mm}^2 \) |

Use 50mm x 150mm diagonal members (A= 7500mm\(^2\))
Use double 2x6 diagonal members (A= 8.25in\(^2\))

Use 50mm x 150mm members (A= 7500mm\(^2\))
for all Truss A members

(double 2x6 diagonal members equivalent)
### EVC TRUSS CONNECTIONS

#### WEB MEMBER TO CHORD

- **Width of main member**: 5.5 in, 150 mm
- **Width of side member**: 5.5 in, 150 mm
- **Thickness of main member**: 1.5 in, 50 mm
- **Thickness of side member**: 1.5 in, 50 mm
- **G**: 0.55, 0.55
- **Bolt diameter**: 0.5 in, 12.7 mm

#### DEMAND

- **1200 kg, 2645.5 lb**

#### CAPACITY

- **NDS TA 12F**

  \[
  Z_{II} = Z_{II}(C_d \times C_m \times C_t \times C_g \times C_d)
  \]

  \[
  Z_{II} = 1150 \text{ lb}
  \]

  - **C_d**: 1.25
  - **C_m**: 1
  - **C_t**: 1
  - **C_g**: 0.99
  - **C_d**: 1

  \[
  Z_{II}' = 1423.1 \text{ lb}
  \]

  \[
  \# \text{ bolts}_{req} = 1.86
  \]

#### SPACING

- **Minimum end distance**
  \[
  4D = 2 \text{ in}, 50.8 \text{ mm}
  \]

- **Minimum spacing of bolts in a row**
  \[
  4D = 2 \text{ in}, 50.8 \text{ mm}
  \]

- **Minimum edge distance**
  \[
  1.5D = 0.75 \text{ in}, 19.05 \text{ mm}
  \]

**Use 2-12.7mm \(\odot\) bolts (2-1/2" \(\odot\) bolts)**

Check Bolt Spacing on Chord Member

- **50.8 mm end clear**
- **50.8 mm spacing**
- **19.05 mm edge clear**

**120.65 mm min. chord member**

**150mm deep chord necessary for chord members**
## TRUSS DESIGN SUMMARY

<table>
<thead>
<tr>
<th>TRUSS</th>
<th>Metric</th>
<th>U.S. Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TRUSS A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chords</td>
<td>50x150mm</td>
<td>2x6</td>
</tr>
<tr>
<td>Web</td>
<td>50x100mm</td>
<td>2x4</td>
</tr>
<tr>
<td>Diagonals</td>
<td>50x100mm</td>
<td>2x4</td>
</tr>
<tr>
<td>Bolts</td>
<td>2-12.7mm ø bolts</td>
<td>2-1/2&quot; ø</td>
</tr>
<tr>
<td><strong>TRUSS B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chords</td>
<td>50x150mm</td>
<td>2x6</td>
</tr>
<tr>
<td>Web</td>
<td>50x100mm</td>
<td>2x4</td>
</tr>
<tr>
<td>Diagonals</td>
<td>50x100mm</td>
<td>2x4</td>
</tr>
<tr>
<td>Bolts</td>
<td>1-12.7mm ø bolts</td>
<td>1-1/2&quot; ø</td>
</tr>
<tr>
<td><strong>TRUSS C</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chords</td>
<td>50x150mm</td>
<td>2x6</td>
</tr>
<tr>
<td>Vertical</td>
<td>50x150mm</td>
<td>2x6</td>
</tr>
<tr>
<td>Diagonal</td>
<td>50x100mm</td>
<td>2x4</td>
</tr>
<tr>
<td>Bolts</td>
<td>2-12.7mm ø bolts</td>
<td>2-1/2&quot; ø</td>
</tr>
</tbody>
</table>
## Calculations

**SLAB ON GRADE DESIGN - EVC AND ATF**

Slab on grade to be constructed by

*typical slab on grade construction and minimum reinforcing:*

**Imperial Equivalent:**
5" thick slab with #3 @18" o/c each way

**SI Equivalent:**

USE 125mm THICK SLAB w/ 10mm REINFORCING BARS @ 0.4m EACH WAY
SEISMIC LOAD CALCULATIONS - EVC AND ATF

**SEISMIC INPUT VALUES**

- **S** = 0.76 g  
  *See Appendix*

- **S1** = 0.19 g  
  *Page 113*

- **R** = 1 (Ordinary Reinforced Masonry Shear Wall)

- **Ie** = 1.0 (Risk Category II Building)

- **Site Class**: E (Soft Clay)

11.4-1

- **SMS** = 0.912 g

11.4-2

- **SM1** = 0.228 g

  - **F_a** = 1.2
  - **F_v** = 1.2

11.4-3

- **Sds** = 2SdS/3 = 0.608 g

11.4-4

- **SD1** = 2SM1/3 = 0.152 g

**SEISMIC WEIGHT**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>psf</th>
<th>kg/m²</th>
<th>ECV trib</th>
<th>kg</th>
<th>ATF trib</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>3.0</td>
<td>14.6</td>
<td>96</td>
<td>1406</td>
<td>112</td>
<td>1640</td>
</tr>
<tr>
<td>Purlins</td>
<td>2.08</td>
<td>10.2</td>
<td>96</td>
<td>975</td>
<td>112</td>
<td>137</td>
</tr>
<tr>
<td>EVC Truss</td>
<td>12.0</td>
<td>58.4</td>
<td>96</td>
<td>5606</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATF Truss</td>
<td>11.2</td>
<td>54.6</td>
<td></td>
<td></td>
<td>112</td>
<td>6114</td>
</tr>
<tr>
<td>Walls (10&quot;)</td>
<td>125</td>
<td>610.3</td>
<td>72</td>
<td>43942</td>
<td>88</td>
<td>53707</td>
</tr>
</tbody>
</table>

\[ \text{W}_{EVC} = 51929 \text{ kg} \]
\[ \text{W}_{ATF} = 62598 \text{ kg} \]
\[ \text{W}_{total} = 114527 \text{ kg} \]

**BASE SHEAR**

\[ V = C_s W \]

- **Cs** = \( S_{ds} / (R/I_e) \) = 0.608
- **Cs min** = 0.044SdS/le = 0.027
- **Cs max** = \( S_{ds} / (T/R/I_e) \) = 1.852

\[ T = C_{thn} \times x = 0.082 \]

\[ V = 69632 \text{ kg} \]  
153.5 kips
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCE 7-16</td>
<td>WIND LOAD CALCULATIONS</td>
</tr>
<tr>
<td></td>
<td>WIND SPEED VALUES</td>
</tr>
<tr>
<td></td>
<td>$V = 110 \text{ mph} \quad 49.17 \text{ m/s}$</td>
</tr>
<tr>
<td>T26.6-1</td>
<td>$K_d = 0.85$</td>
</tr>
<tr>
<td>26.7</td>
<td>Exposure: B</td>
</tr>
<tr>
<td>F26.8-1</td>
<td>$K_{zt} = 1.0$</td>
</tr>
<tr>
<td>T26.9-1</td>
<td>$K_e = 1.0$</td>
</tr>
<tr>
<td>26.11</td>
<td>$G = 0.85$</td>
</tr>
<tr>
<td>26.12</td>
<td>Enclosure: Partially Enclosed</td>
</tr>
<tr>
<td>T26.13-1</td>
<td>$G_{cp} = -0.55$</td>
</tr>
<tr>
<td>T26.10-1</td>
<td>$K_z = 0.7$</td>
</tr>
<tr>
<td>26.10-1</td>
<td>$q_z = 0.613 (K_z K_{zt} K_d K_e V^2) = 18.43 \text{ psf}$</td>
</tr>
<tr>
<td>F27.3-1</td>
<td>$C_p = 0.8$</td>
</tr>
<tr>
<td>27.3-1</td>
<td>$p = q_z (G C_p - G_{cp}) = 22.67 \text{ psf}$</td>
</tr>
<tr>
<td></td>
<td>110.58 \text{ kg/m}^2</td>
</tr>
<tr>
<td></td>
<td>General Building Parameters:</td>
</tr>
<tr>
<td></td>
<td>height = 4.5 m (tallest wall)</td>
</tr>
<tr>
<td></td>
<td>length = 20 m (longest wall length)</td>
</tr>
<tr>
<td></td>
<td>DETERMINE GOVERNING CASE</td>
</tr>
<tr>
<td></td>
<td>WIND LOADING</td>
</tr>
<tr>
<td></td>
<td>$V_w = p h^3 l = 9962 \text{ kg}$</td>
</tr>
<tr>
<td></td>
<td>SEISMIC LOADING</td>
</tr>
<tr>
<td></td>
<td>$V_s = 69632 \text{ kg}$</td>
</tr>
<tr>
<td></td>
<td>SEISMIC LOADING GOVERNS</td>
</tr>
</tbody>
</table>
EVC DIAPHRAGM DESIGN

\[ W_{NS} = 1578.6 \, \text{kg/m} \]

\[ \begin{align*}
W_{NS} & = 1578.6 \, \text{kg/m} \\
V(\text{kg}) & = 8.28 \times 10^5 \\
M(\text{kg-m}) & = 1262 \times 8
\end{align*} \]
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCE 7-16</td>
<td>EVC DIAPHRAGM DESIGN</td>
</tr>
<tr>
<td><strong>DIAPHRAGM FORCES</strong></td>
<td></td>
</tr>
<tr>
<td>$W_{EVC} =$</td>
<td>51929 kg</td>
</tr>
<tr>
<td>$F_p = V_s =$</td>
<td>31573 kg</td>
</tr>
<tr>
<td>$F_{p_{min}} =$</td>
<td>$0.2 \cdot S_{ds} \cdot l_e \cdot W_{px} =$</td>
</tr>
<tr>
<td>$F_{p_{max}} =$</td>
<td>$0.4 \cdot S_{ds} \cdot l_e \cdot W_{px} =$</td>
</tr>
<tr>
<td>$F_{p_{EVC}} =$</td>
<td>12629 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N/S</th>
<th>E/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{line} =$</td>
<td>6314.5 kg</td>
</tr>
<tr>
<td>$# \text{ rods} =$</td>
<td>6</td>
</tr>
<tr>
<td>$F_{rod} =$</td>
<td>1052.4 kg/rod</td>
</tr>
<tr>
<td>component =</td>
<td>0.9</td>
</tr>
<tr>
<td>$F_{axial} =$</td>
<td>941.3 kg/rod</td>
</tr>
<tr>
<td>Fline =</td>
<td>6314.5 kg</td>
</tr>
<tr>
<td># rods =</td>
<td>6</td>
</tr>
<tr>
<td>Frod =</td>
<td>789.3 kg/rod</td>
</tr>
<tr>
<td>component =</td>
<td>0.4</td>
</tr>
<tr>
<td>Faxial =</td>
<td>353.0 kg/rod</td>
</tr>
</tbody>
</table>

**DIAGONAL ROD DESIGN**

<table>
<thead>
<tr>
<th>N/S</th>
<th>E/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_u =$</td>
<td>941.3 kg</td>
</tr>
<tr>
<td>$\phi P_n =$</td>
<td>$\phi F_y A_g =$</td>
</tr>
<tr>
<td>$\phi =$</td>
<td>0.9</td>
</tr>
<tr>
<td>$F_y =$</td>
<td>50 ksi</td>
</tr>
<tr>
<td>$A_g \text{ req} =$</td>
<td>0.046 in$^2$</td>
</tr>
<tr>
<td>$\phi P_n - P_u =$</td>
<td>0.00</td>
</tr>
<tr>
<td>diam req =</td>
<td>0.24 in = 6.15 mm</td>
</tr>
<tr>
<td><strong>6.35mm diameter rod adequate for EVC in N/S direction (.25&quot; $\phi$)</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E/W</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_u =$</td>
<td>353.0 kg</td>
</tr>
<tr>
<td>$\phi P_n =$</td>
<td>$\phi F_y A_g =$</td>
</tr>
<tr>
<td>$\phi =$</td>
<td>0.9</td>
</tr>
<tr>
<td>$F_y =$</td>
<td>50 ksi</td>
</tr>
<tr>
<td>$A_g \text{ req} =$</td>
<td>0.017 in$^2$</td>
</tr>
<tr>
<td>$\phi P_n - P_u =$</td>
<td>0.00</td>
</tr>
<tr>
<td>diam req =</td>
<td>0.15 in = 3.77 mm</td>
</tr>
<tr>
<td><strong>6.35mm diameter rod adequate for EVC in N/S direction (.25&quot; $\phi$)</strong></td>
<td></td>
</tr>
</tbody>
</table>
### ATF DIPHRAGM DESIGN

**DIAPHRAGM FORCES**

- \( W_{ATF} = 62598 \) kg
- \( F_p = V_s = 38060 \) kg
- \( F_{p_{min}} = 0.2 \cdot S_{os} \cdot I_e \cdot W_{px} = 7612 \) kg
- \( F_{p_{max}} = 0.4 \cdot S_{os} \cdot I_e \cdot W_{px} = 15224 \) kg
- \( F_{p_{ATF}} = 15224 \) kg \( = 33.6 \) kips

<table>
<thead>
<tr>
<th>N/S</th>
<th>line 1-4</th>
<th>line 4-5</th>
<th>E/W</th>
<th>line A-B</th>
<th>line B-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area =</td>
<td>96</td>
<td>16</td>
<td>Area =</td>
<td>48</td>
<td>64</td>
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<tr>
<td>Fline =</td>
<td>6524.5</td>
<td>1087.4</td>
<td>Fline =</td>
<td>3262.3</td>
<td>4349.7</td>
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<tr>
<td># rods =</td>
<td>8</td>
<td>4</td>
<td># rods =</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Frod =</td>
<td>815.6</td>
<td>271.9</td>
<td>Frod =</td>
<td>543.7</td>
<td>543.7</td>
</tr>
<tr>
<td>component =</td>
<td>0.4</td>
<td>0.4</td>
<td>component =</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Faxial =</td>
<td>364.7</td>
<td>121.6</td>
<td>Faxial =</td>
<td>486.3</td>
<td>486.3</td>
</tr>
</tbody>
</table>

**DIAGONAL ROD DESIGN**

**N/S**

- \( Pu = 364.7 \) kg \( = 0.80 \) k
- \( \phi_{PN} = \frac{\phi_{FY} \cdot A_g}{\phi} = 0.80 \)
- \( \phi = 0.9 \)
- \( Fy = 50 \text{ ksi} \)
- \( A_g \text{ req} = 0.018 \text{ in}^2 \)
- \( \phi_{PN} - Pu = 0.00 \)
- \( \text{diam req} = 0.15 \text{ in} = 3.83 \text{ mm} \)

6.35mm diameter rod adequate for ATF in N/S direction (.25" Ø)

**E/W**

- \( Pu = 486.3 \) kg \( = 1.07 \) k
- \( \phi_{PN} = \frac{\phi_{FY} \cdot A_g}{\phi} = 1.07 \)
- \( \phi = 0.9 \)
- \( Fy = 50 \text{ ksi} \)
- \( A_g \text{ req} = 0.024 \text{ in}^2 \)
- \( \phi_{PN} - Pu = 0.00 \)
- \( \text{diam req} = 0.17 \text{ in} = 4.42 \text{ mm} \)

6.35mm diameter rod adequate for ATF in N/S direction (.25" Ø)
### Calculations

**CONFINED MASONRY WALL DESIGN - EVC AND ATF**

**Performance Objective:** Life Safety

**Lateral Wall Density**

- Required Wall Density = 1.0% for following conditions:
  - Low Seismic Hazard
  - PGA = 0.06g ≤ 0.08g
  - n = 1
  - 1 story building
  - Solid Clay Bricks
  - handmade, Mortar Type III conservatively
  - Soil Type C
  - Soft clay soil

**N/S Direction**

Assume 2 wythes of 120mm brick

| Floor area | Ap = | 192.00 m²² |
| Wall area  | Aw = | 5.00 m²²  |
| Wall density | d = Aw / Ap = 2.60 % | > 1.0 % **GOOD** |

**E/W Direction**

Assume 2 wythes of 120mm brick

| Floor area | Ap = | 192.00 m²² |
| Wall area  | Aw = | 3.00 m²²  |
| Wall density | d = Aw / Ap = 1.56 % | > 1.0 % **GOOD** |

**Gravity Wall Density**

- Strength Reduction Factor \( Fr = 0.6 \)
- Gravity Load Factor \( Fc = 1.4 \)
- Safety Factor \( Fs = Fc / Fr = 2.33 \)

**Compressive Strength, \( \sigma_R \)**

- Eccentricity/Slenderness Factor \( Fe = 0.7 \) for interior walls
- Masonry Comp Strength \( f'm = 15 \) kg/cm²²

\[
\sigma_R = Fe (f'm + 4) = 13.3 \text{ kg/cm}^2
\]
### Calculations

**CONFINED MASONRY WALL DESIGN - EVC AND ATF**

**Wall Density Index, \( \Sigma d \geq Fc (n*w) / \sigma R \)**

| Weight \( w \) | 83.22 kg/m²² |
| Stories \( n \) | 1 |

For both directions:

- \( Fc (n*w) / \sigma R = 0.876 \% \)
- \( \Sigma d = \Sigma Aw/Ap = 4.17 \% \)

\( \Sigma d = \Sigma Aw/Ap > 0.876 \% \)** \( \text{GOOD} \)

For one direction:

- \( Fc (n*w) / \sigma R = 0.438 \% \)
- \( \Sigma d = \Sigma Aw/Ap = 1.56 \% \)

\( \Sigma d = \Sigma Aw/Ap > 0.438 \% \)** \( \text{GOOD} \)

**Wall Distance/Thicknes Ratio, \( B/t \leq \sigma R/(Fs*D*w) \)**

| Distance \( B \) | 4 m |
| Thickness \( t \) | 0.250 m |
| \( B/t \) | 16.0 |

\( \sigma R/(Fs*D*w) = 684.93 \) \( \text{GOOD} \)

**Conclusion**

Provided confined masonry walls are sufficient
CONFINED MASONRY WALL DESIGN - EVC AND ATF

TIE-COLUMN DESIGN

Spacing
Maximum spacing of tie-columns shall not exceed 6m
Smax = 5 m < 6m GOOD

Minimum Dimensions
Minimum depth x width of a tie-column 150mm x t
\[ t = 250 \text{ mm} \]

Tie-Columns shall be 250mm x 250mm > 150mm x 250mm GOOD

Reinforcing
Longitudinal
Minimum 4 deformed reinforcing bars of minimum 10-mm diameter

Reinforcing shall be (4) 13-mm diameter bars GOOD

Tie Sizing and Spacing
Minimum 6-mm diameter bars with 135° hooked ends

Tie spacing cannot exceed 200mm with minimum 20mm cover

Ties shall be 10-mm diameter transverse stirrups, spaced at 200m, with 50mm cover GOOD
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confined Masonry Design Guide</td>
<td><strong>CONFINED MASONRY WALL DESIGN - EVC AND ATF</strong></td>
</tr>
<tr>
<td><strong>Spacing</strong></td>
<td>Tie-beams shall be provided at the top of each wall, and above and below each window opening <strong>GOOD</strong></td>
</tr>
<tr>
<td>Minimum Dimensions</td>
<td>Minimum depth x width of a tie-beam 150mm x t  &lt;br&gt; t = 250 mm  &lt;br&gt; <strong>Tie-Beams shall be 250mm x 250mm &gt; 150mm x 250mm</strong> <strong>GOOD</strong></td>
</tr>
<tr>
<td><strong>Reinforcing</strong></td>
<td><strong>Longitudinal</strong>  &lt;br&gt; Minimum 4 deformed reinforcing bars of minimum 10-mm diameter  &lt;br&gt; To ensure the effectiveness of tie-beams in resisting earthquake loads longitudinal bars should have a 90° hooked anchorage at intersections  &lt;br&gt; <strong>Reinforcing shall be (4) 13-mm diameter bar, with 90° hooked anchorage at intersections</strong> <strong>GOOD</strong></td>
</tr>
<tr>
<td>Tie Sizing and Spacing</td>
<td>Minimum 6-mm diameter bars with 135° hooked ends  &lt;br&gt; Tie spacing cannot exceed 200mm with minimum 20mm cover  &lt;br&gt; <strong>Ties shall be 10-mm diameter transverse stirrups, spaced at 200m, with 50mm cover</strong> <strong>GOOD</strong></td>
</tr>
</tbody>
</table>
### Calculations

#### SEISMIC LOAD DISTRIBUTION - EVC AND ATF

<table>
<thead>
<tr>
<th>WALL</th>
<th>DIRECTION</th>
<th>L (m)</th>
<th>H/L</th>
<th>Rc</th>
<th>origin dist.</th>
<th>d(m)</th>
<th>Rd</th>
<th>Rd^2</th>
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<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>2</td>
<td>2.00</td>
<td>0.263</td>
<td>16</td>
<td>6.62</td>
<td>1.74</td>
<td>11.53</td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td>4</td>
<td>1.00</td>
<td>1.429</td>
<td>16</td>
<td>6.62</td>
<td>9.46</td>
<td>62.63</td>
</tr>
<tr>
<td>3</td>
<td>X</td>
<td>2</td>
<td>2.00</td>
<td>0.263</td>
<td>8</td>
<td>-1.38</td>
<td>-0.36</td>
<td>0.50</td>
</tr>
<tr>
<td>4</td>
<td>X</td>
<td>4</td>
<td>1.00</td>
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<td>-9.38</td>
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<tr>
<td>5</td>
<td>Y</td>
<td>4</td>
<td>1.00</td>
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<td>-11.23</td>
<td>-16.05</td>
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</tr>
<tr>
<td>6</td>
<td>Y</td>
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<td>1.00</td>
<td>1.429</td>
<td>12</td>
<td>0.77</td>
<td>1.10</td>
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<td>7</td>
<td>Y</td>
<td>4</td>
<td>1.00</td>
<td>1.429</td>
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<td>4.77</td>
<td>6.82</td>
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<td>Y</td>
<td>4</td>
<td>1.00</td>
<td>1.429</td>
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<td>8.77</td>
<td>12.53</td>
<td>109.91</td>
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<tr>
<td>9</td>
<td>Y</td>
<td>4</td>
<td>1.00</td>
<td>1.429</td>
<td>20</td>
<td>8.77</td>
<td>12.53</td>
<td>109.91</td>
</tr>
</tbody>
</table>

\[ \Sigma = 633.78 \]

\[
\begin{align*}
\text{Xcm} &= 11.23 \, \text{m} \\
\text{Ycm} &= 9.38 \, \text{m} \\
\text{Xcr} &= 13.60 \, \text{m} \\
\text{Ycr} &= 8.62 \, \text{m}
\end{align*}
\]

**EAST/WEST (X)**

\[
\begin{align*}
\text{ex} &= 0.05\times 16m = 0.80 \, \text{m} \\
e &= (\text{Xcm} - \text{Xcr}) + \text{ex} = -1.57 \, \text{m}
\end{align*}
\]

\[
\begin{align*}
\text{Vbase} &= 70988 \, \text{kg-m} \\
\text{Mtor} &= -111451 \, \text{kg-m}
\end{align*}
\]

\[
\begin{align*}
\text{V1} &= 5517 \, \text{kN} \\
\text{V2} &= 29977 \, \text{kN} \\
\text{V3} &= 5517 \, \text{kN} \\
\text{V4} &= 29977 \, \text{kN}
\end{align*}
\]

**Largest East/West Force:** 32334 kg

**NORTH/SOUTH (Y)**

\[
\begin{align*}
\text{ey} &= 0.05\times 20m = 1.00 \, \text{m} \\
e &= (\text{Ycm} - \text{Ycr}) + \text{ey} = 1.76 \, \text{m}
\end{align*}
\]

\[
\begin{align*}
\text{Vbase} &= 70988 \, \text{kg-m} \\
\text{Mtor} &= 124815 \, \text{kg-m}
\end{align*}
\]

\[
\begin{align*}
\text{V5} &= 14198 \, \text{kN} \\
\text{V6} &= 14198 \, \text{kN} \\
\text{V7} &= 14198 \, \text{kN} \\
\text{V8} &= 14198 \, \text{kN} \\
\text{V9} &= 14198 \, \text{kN}
\end{align*}
\]

**Largest North/South Force:** 16666 kg
WALL LINE A EAST/WEST FOUNDATION DESIGN

**Loads:**
- P_{DL} = 73996 kg
- P_{LL} = 6249 kg
- V_E = 33524 kg  *Based on Wall 1 and 2 results*
- Sds = 0.608

\[ \text{Mot} = 0.75 \times 0.70 \times V_E \times H_{wall} = 70401 \text{ kg-m} \]

**Allowable Soil Bearing Pressure:**
- f_{IBC} = 7324 kg/m^2
- f_{allow} = 1.33 \times f_{IBC} = 9740 kg/m^2

**Try Footing Size:**
- Length = 18 m
- Width = 2 m
- Depth = 1 m
- Wall length = 16 m

- P_{footing} = 86501 kg
- P_{dead} = 73996 kg
- \Sigma P = 160497 kg

**USE 18m LONG x 2m WIDE x 1m DEEP FTG.**
## Calculations

### WALL LINE A EAST/WEST FOUNDATION DESIGN

#### Allowable Stress Design Combinations

**Load Case 8: \((1.0 + 0.14Sds)D + 0.7E\)**

\[
\begin{align*}
\Sigma P_{LC8} &= 197626 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 1778632 \text{ kg} \\
x &= (M_R - Mot)/\Sigma P = 8.6 \text{ m} \\
l &= 3x = 25.9 \text{ m}
\end{align*}
\]

\[f_{bearing} = 2*\Sigma P / l^2 \geq 6189 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}\]

**Load Case 9: \((1.0 + 0.105Sds)D + 0.525E + 0.75L\)**

\[
\begin{align*}
\Sigma P_{LC9} &= 193031 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 1737277 \text{ kg} \\
x &= (M_R - Mot)/\Sigma P = 8.6 \text{ m} \\
l &= 3x = 25.9 \text{ m}
\end{align*}
\]

\[f_{bearing} = 2*\Sigma P / l^2 \geq 7451 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOVERN, GOOD}\]

**Load Case 10: \((1.0 - 0.14Sds)D + 0.7E\)**

\[
\begin{align*}
\Sigma P_{LC10} &= 170303 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 1532725 \text{ kg} \\
x &= (M_R - Mot)/\Sigma P = 8.6 \text{ m} \\
l &= 3x = 25.8 \text{ m}
\end{align*}
\]

\[f_{bearing} = 2*\Sigma P / l^2 \geq 6611 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}\]

#### Strength Design Combinations

**Load Case 6: \((1.2 + 0.2Sds)D + E + L\)**

\[\Sigma P_{LC6} = 96933 \text{ kg} \quad \text{GOVERN}\]

**Load Case 7: \((0.9-0.2Sds)D + E\)**

\[\Sigma P_{LC7} = 67190 \text{ kg}\]
### WALL LINE A EAST/WEST FOUNDATION DESIGN

#### Check Footing Shear

\[
 Vu,LC6 \leq 96933 \text{ kg} 
\]

| \( \Phi \) | 0.75 |
| \( \alpha \) | 2 |
| \( f'c \) | 3000 psi |
| \( Acv = D^*W = \) | 3100 in\(^2\) |

\[
\Phi Vc = \Phi \alpha (f'c^{0.5}) Acv = 254691 \text{ lbs} 
\]

\[
115526 \text{ kg} > 96933 \text{ kg} \quad \text{GOOD} 
\]

#### Check for Longitudinal Flexural Reinforcement (Bottom)

\[
x = 8.6 \text{ m} 
\]

\[
l = 3x = 25.9 \text{ m} 
\]

\[
f_{\text{bearing}} = 7451 \text{ kg/m}^2 
\]

\[
Pt_{\text{triangle}} = 193031 \text{ kg} 
\]

\[
x_{\text{arm}} = 0.36 \text{ m} 
\]

\[
Mu = P^*x = 70401 \text{ kg-m} 
\]

#### Try (6) #5 bars

- # of bars = 12
- bar diameter = 0.625 in
- bar area = 0.31 in\(^2\)
- cover = 3.00 in

\[
As = 3.72 \text{ in}^2 
\]

\[
Fy = 60 \text{ ksi} 
\]

\[
T = AsFy = 223.2 \text{ k} 
\]

\[
a = T / 0.85*f'c*b = 1.11 \text{ in} 
\]

\[
c = a / \beta = 1.31 \text{ in} 
\]

\[
d = 35.19 \text{ in} 
\]

\[
\epsilon_t = 0.003(d-c/c) = 0.0777 >>> 0.005 
\]

\[
\Phi = 0.9 
\]

**STRAIN PASSES**
### Calculations

#### WALL LINE A EAST/WEST FOUNDATION DESIGN

\[ \Phi M_n = \Phi A_{s} F_y (d-a/2) = \]

\[ 6957.2 \text{ k-in} \]

\[ 80154 \text{ kg-m} \]

\[ > 70401 \text{ kg-m} \quad \text{GOOD} \]

Imperial Equivalent:  \(6\) #5 BARS

**Si Equivalent:**

\[ \begin{array}{c}
\text{USE (6) 16mm BARS LONGITUDINAL (B)}
\end{array} \]

**Check for Transverse Flexural Reinforcement (Bottom)**

\[ w_u = 10985 \text{ kg/m}^2 \]

\[ l = W / t = 0.875 \text{ m} \]

\[ M_u = 4205 \text{ kg-m} \]

**Try #5 bars @ 12" o/c**

- # of bars = \(1\)
- bar diameter = \(0.625 \text{ in}\)
- bar area = \(0.31 \text{ in}^2\)
- cover = \(3.00 \text{ in}\)
- \(A_s = 0.31 \text{ in}^2\)
- \(F_y = 60 \text{ ksi}\)
- \(T = A_{s} F_y = 18.6 \text{ k}\)

\[ a = T / 0.85 f_c b = 0.61 \text{ in} \]

\[ c = a / \beta = 0.72 \text{ in} \]

\[ d = 35.44 \text{ in} \]

\[ \varepsilon_t = 0.003 (d-c/c) = 0.1457 \quad >>> 0.005 \quad \text{STRAIN PASSES} \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_{s} F_y (d-a/2) = 588.2 \text{ k-in} \]

\[ 6777 \text{ kg-m} \quad > 4205 \text{ kg-m} \quad \text{GOOD} \]

Imperial Equivalent:

**Si Equivalent:**

\[ \begin{array}{c}
\text{USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)}
\end{array} \]
WALL LINE A EAST/WEST FOUNDATION DESIGN

Check for Longitudinal Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 9 \text{ m} \]
\[ M_u = 14831 \text{ kg-m} \]

Based on fig. rotating around toe

Try (6) #5 bars

\[ \# \text{ of bars} = 6 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 1.86 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 111.6 \text{ k} \]

\[ a = T / 0.85 f'c b = 0.56 \text{ in} \]
\[ c = a / \beta = 0.65 \text{ in} \]
\[ d = 35.47 \text{ in} \]

\[ \varepsilon_t = 0.003 (d-c/c) = 0.1597 \gg 0.005 \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 3534.4 \text{ k-in} \]
\[ 40720 \text{ kg-m} \]

GOOD

Imperial Equivalent: (6) #5 BARS

SI Equivalent:

USE (6) 16mm BARS LONGITUDINAL (T)
WALL LINE A EAST/WEST FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 0.875 \text{ m} \]
\[ M_u = 280 \text{ kg-m} \]

Based on fig. rotating around toe

**Try #5 bars @ 12" o/c**

- # of bars = 1
- bar diameter = 0.625 in
- bar area = 0.31 in\(^2\)
- cover = 3.00 in

\[ A_s = 0.31 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_sF_y = 18.6 \text{ k} \]

\[ a = T / 0.85f'_c b = 0.61 \text{ in} \]
\[ c = a / \beta = 0.72 \text{ in} \]
\[ d = 35.44 \text{ in} \]

\[ \varepsilon t = 0.003(d-c/c) = 0.1457 \gg 0.005 \]  
**STRAIN PASSES**

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 588.2 \text{ k-in} \]
\[ 6777 \text{ kg-m} > 280 \text{ kg-m} \]  
**GOOD**

Imperial Equivalent:  #5 BARS @ 12" O/C

SI Equivalent:

**USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)**
WALL LINE B EAST/WEST FOUNDATION DESIGN

Loads:
\[ P_{DL} = 36998 \text{ kg} \]
\[ P_{LL} = 3125 \text{ kg} \]
\[ V_{E} = 0 \text{ kg} \quad \text{No EQ Loads to Line B} \]
\[ S_{ds} = 0.608 \]

\[ M_{ot} = 0.75 \cdot 0.70 \cdot V_{E} \cdot H_{wall} = 0 \text{ kg-m} \]

Allowable Soil Bearing Pressure:
\[ f_{IBC} = 7324 \text{ kg/m}^2 \]
\[ f_{allow} = 1.33 \cdot f_{IBC} = 9740 \text{ kg/m}^2 \]

Try Footing Size:
\[ \text{Length} = 10 \text{ m} \]
\[ \text{Width} = 2 \text{ m} \]
\[ \text{Depth} = 1 \text{ m} \]
\[ \text{Wall length} = 8 \text{ m} \]
\[ P_{footing} = 48056 \text{ kg} \]
\[ P_{dead} = 36998 \text{ kg} \]
\[ \Sigma P = 85054 \text{ kg} \]

USE 10m LONG x 2m WIDE x 1m DEEP FTG.
### Calculations

#### WALL LINE B EAST/WEST FOUNDATION DESIGN

#### Allowable Stress Design Combinations

**Load Case 8: \((1.0 + 0.14Sds)D + 0.7E\)**

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Sigma PL_{c8})</td>
<td>92294 kg</td>
</tr>
<tr>
<td>(M_R = \Sigma P * L/2)</td>
<td>461470.3 kg</td>
</tr>
<tr>
<td>(x = (M_R - M_{ot}) / \Sigma P)</td>
<td>5.0 m</td>
</tr>
<tr>
<td>(l = 3x)</td>
<td>15.0 m</td>
</tr>
</tbody>
</table>

\[f_{bearing} = 2*\Sigma P / l*w\] 5670 kg/m² < 9740 kg/m²  **GOOD**

**Load Case 9: \((1.0 + 0.105Sds)D + 0.525E + 0.75L\)**

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Sigma PL_{c9})</td>
<td>92828 kg</td>
</tr>
<tr>
<td>(M_R = \Sigma P * L/2)</td>
<td>464138 kg</td>
</tr>
<tr>
<td>(x = (M_R - M_{ot}) / \Sigma P)</td>
<td>5.0 m</td>
</tr>
<tr>
<td>(l = 3x)</td>
<td>15.0 m</td>
</tr>
</tbody>
</table>

\[f_{bearing} = 2*\Sigma P / l*w\] 6189 kg/m² < 9740 kg/m²  **GOVERN, GOOD**

**Load Case 10: \((1.0 - 0.14Sds)D + 0.7E\)**

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Sigma PL_{c10})</td>
<td>77814 kg</td>
</tr>
<tr>
<td>(M_R = \Sigma P * L/2)</td>
<td>389072.1 kg</td>
</tr>
<tr>
<td>(x = (M_R - M_{ot}) / \Sigma P)</td>
<td>5.0 m</td>
</tr>
<tr>
<td>(l = 3x)</td>
<td>15.0 m</td>
</tr>
</tbody>
</table>

\[f_{bearing} = 2*\Sigma P / l*w\] 5188 kg/m² < 9740 kg/m²  **GOOD**

#### Strength Design Combinations

**Load Case 6: \((1.2 + 0.2Sds)D + E + L\)**

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Sigma PL_{c6})</td>
<td>34880 kg</td>
</tr>
</tbody>
</table>

**GOVERN**

**Load Case 7: \((0.9-0.2Sds)D + E\)**

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Sigma PL_{c7})</td>
<td>18703 kg</td>
</tr>
</tbody>
</table>
### Calculations

**WALL LINE B EAST/WEST FOUNDATION DESIGN**

**Check Footing Shear**

\[
Vu,tc6 \leq \quad 34880 \text{ kg}
\]

\[
\Phi = \quad 0.75
\]

\[
\alpha = \quad 2
\]

\[
f'_c = \quad 3000 \text{ psi}
\]

\[
Acv = D^*W = \quad 3100 \text{ in}^2
\]

\[
\Phi Vc = \Phi \alpha(f'_c^{0.5})Acv = \quad 254691 \text{ lbs}
\]

\[
115526 \text{ kg} \quad > \quad 34880 \text{ kg} \quad \textbf{GOOD}
\]

**Check for Longitudinal Flexural Reinforcement (Bottom)**

\[
x = \quad 5.0 \text{ m}
\]

\[
im = 3x = \quad 15.0 \text{ m}
\]

\[
f_{bearing} = \quad 6189 \text{ kg/m}^2
\]

\[
P_{triangle} = \quad 92828 \text{ kg}
\]

\[
x_{arm} = \quad 0.00 \text{ m}
\]

\[
Mu = P^*x = \quad 0 \text{ kg-m}
\]

**Try (6) #5 bars**

- # of bars = 12
- bar diameter = 0.625 in
- bar area = 0.31 in$^2$
- cover = 3.00 in

\[
As = \quad 3.72 \text{ in}^2
\]

\[
Fy = \quad 60 \text{ ksi}
\]

\[
T = AsFy = \quad 223.2 \text{ k}
\]

\[
a = T / 0.85*f'_c*b = \quad 1.11 \text{ in}
\]

\[
c = a / \beta = \quad 1.31 \text{ in}
\]

\[
d = \quad 35.19 \text{ in}
\]

\[
\epsilon t = 0.003(d-c/c) = \quad 0.0777 \quad \ggg \quad 0.005
\]

\[
\Phi = \quad 0.9
\]

**STRAIN PASSES**
### WALL LINE B EAST/WEST FOUNDATION DESIGN

\[ \Phi M_n = \Phi A_s F_y (d - a/2) = 6957.2 \text{ k-in} \]
\[ 80154 \text{ kg-m} > 0 \text{ kg-m} \quad \text{GOOD} \]

**Imperial Equivalent:** (6) #5 BARS

**SI Equivalent:**

USE (6) 16mm BARS LONGITUDINAL (B)

**Check for Transverse Flexural Reinforcement (Bottom)**

\[ w_u = 10985 \text{ kg/m}^2 \]
\[ l = W / t = 0.875 \text{ m} \]
\[ M_u = 4205 \text{ kg-m} \]

Try #5 bars @ 12" o/c

\[ \text{# of bars} = 1 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 0.31 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 18.6 \text{ k} \]

\[ a = T / 0.85*f'c*b = 0.61 \text{ in} \]
\[ c = a / \beta = 0.72 \text{ in} \]
\[ d = 35.44 \text{ in} \]

\[ \epsilon_t = 0.003(d-c/c) = 0.1457 >> 0.005 \quad \text{STRAIN PASSES} \]
\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d - a/2) = 588.2 \text{ k-in} \]
\[ 6777 \text{ kg-m} > 4205 \text{ kg-m} \quad \text{GOOD} \]

**Imperial Equivalent:**

USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)
Check for Longitudinal Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ I = 5 \text{ m} \]
\[ M_u = 4578 \text{ kg-m} \]

Based on ftg. rotating around toe

Try (6) #5 bars

\[ \text{# of bars} = 6 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 1.86 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 111.6 \text{ k} \]

\[ a = T / 0.85 F_c b = 0.56 \text{ in} \]
\[ c = a / \beta = 0.65 \text{ in} \]
\[ d = 35.47 \text{ in} \]

\[ \varepsilon_t = 0.003 (d-c/c) = 0.1597 \gg 0.005 \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 3534.4 \text{ k-in} \]
\[ 40720 \text{ kg-m} > 14831 \text{ kg-m} \]

Imperial Equivalent: (6) #5 BARS

SI Equivalent:

USE (6) 16mm BARS LONGITUDINAL (T)
WALL LINE B EAST/WEST FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

wu = 732 kg/m^2
l = 0.875 m
Mu = 280 kg-m

Based on ftg. rotating around toe

Try #5 bars @ 12" o/c

# of bars = 1
bar diameter = 0.625 in
bar area = 0.31 in^2
cover = 3.00 in

As = 0.31 in^2
Fy = 60 ksi
T = AsFy = 18.6 k

a = T / 0.85*f*c*b = 0.61 in
c = a / β = 0.72 in
d = 35.44 in

εt = 0.003(d-c/c) = 0.1457 >>> 0.005
φ = 0.9

ΦMn = ΦAsFy(d-a/2) = 588.2 k-in
6777 kg-m > 280 kg-m

GOOD

Imperial Equivalent: #5 BARS @ 12" O/C

SI Equivalent:
USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)
**WALL LINE C EAST/WEST FOUNDATION DESIGN**

**Loads:**
- PDL = 55497 kg
- PLL = 4687 kg
- VE = 5581 kg  
  *Based on Wall 3 results*
- Sds = 0.608

\[
\text{Mot} = 0.75 \ast 0.70 \ast \text{Ve} \ast \text{Hwall} = 11720 \, \text{kg-m}
\]

**Allowable Soil Bearing Pressure:**
- \( f_{IBC} = \)
- \( f_{allow} = 1.33 \ast f_{IBC} = 7324 \, \text{kg/m}^2 \)
- \( 9740 \, \text{kg/m}^2 \)

**Try Footing Size:**
- Length = 14 m
- Width = 2 m
- Depth = 1 m
- Wall length = 12 m

\[
P_{footing} = 67278 \, \text{kg}
\]
- \( P_{dead} = 55497 \, \text{kg} \)
- \( \Sigma P = 122776 \, \text{kg} \)

**USE 14m LONG x 2m WIDE x 1m DEEP FTG.**
### Calculations

#### WALL LINE C EAST/WEST FOUNDATION DESIGN

**Allowable Stress Design Combinations**

**Load Case 8: \((1.0 + 0.14Sds)D + 0.7E\)**

\[
\begin{align*}
\Sigma P_{L8} &= 137133 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 959931.5 \text{ kg} \\
x &= (M_R - M_{OT})/\Sigma P = 6.9 \text{ m} \\
l &= 3x = 20.7 \text{ m} \\

f_{bearing} &= 2*\Sigma P / l^w = 5919 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\end{align*}
\]

**Load Case 9: \((1.0 + 0.105Sds)D + 0.525E + 0.75L\)**

\[
\begin{align*}
\Sigma P_{L9} &= 137059 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 959413 \text{ kg} \\
x &= (M_R - M_{OT})/\Sigma P = 6.9 \text{ m} \\
l &= 3x = 20.7 \text{ m} \\

f_{bearing} &= 2*\Sigma P / l^w = 6607 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOVERS, GOOD}
\end{align*}
\]

**Load Case 10: \((1.0 - 0.14Sds)D + 0.7E\)**

\[
\begin{align*}
\Sigma P_{L10} &= 116232 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 813622.1 \text{ kg} \\
x &= (M_R - M_{OT})/\Sigma P = 6.9 \text{ m} \\
l &= 3x = 20.7 \text{ m} \\

f_{bearing} &= 2*\Sigma P / l^w = 5616 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\end{align*}
\]

**Strength Design Combinations**

**Load Case 6: \((1.2 + 0.2Sds)D + E + L\)**

\[
\begin{align*}
\Sigma P_{L6} &= 54726 \text{ kg} \quad \text{GOVERS}
\end{align*}
\]

**Load Case 7: \((0.9-0.2Sds)D + E\)**

\[
\begin{align*}
\Sigma P_{L7} &= 31766 \text{ kg}
\end{align*}
\]
WALL LINE C EAST/WEST FOUNDATION DESIGN

Check Footing Shear

\[ V_u,LC6 \leq 54726 \text{ kg} \]

\[ \Phi = 0.75 \]

\[ \alpha = 2 \]

\[ f_c' = 3000 \text{ psi} \]

\[ A_{cv} = D^*W = 3100 \text{ in}^2 \]

\[ \Phi V_c = \Phi \alpha f_c'^{0.5} A_{cv} = 254691 \text{ lbs} \]

\[ 115526 \text{ kg} > 34880 \text{ kg} \quad \text{GOOD} \]

Check for Longitudinal Flexural Reinforcement (Bottom)

\[ x = 6.9 \text{ m} \]

\[ l = 3x = 20.7 \text{ m} \]

\[ f_{bearing} = 6607 \text{ kg/m}^2 \]

\[ P_{triangle} = 137059 \text{ kg} \]

\[ x_{arm} = 0.09 \text{ m} \]

\[ M_u = P^*x = 11720 \text{ kg-m} \]

Try (6) #5 bars

\[ \# \text{ of bars} = 12 \]

\[ \text{bar diameter} = 0.625 \text{ in} \]

\[ \text{bar area} = 0.31 \text{ in}^2 \]

\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 3.72 \text{ in}^2 \]

\[ F_y = 60 \text{ ksi} \]

\[ T = A_s F_y = 223.2 \text{ k} \]

\[ a = T / 0.85 f_c' b = 1.11 \text{ in} \]

\[ c = a / \beta = 1.31 \text{ in} \]

\[ d = 35.19 \text{ in} \]

\[ \varepsilon_t = 0.003(d-c/c) = 0.0777 >> 0.005 \]

\[ \Phi = 0.9 \quad \text{STRAIN PASSES} \]
ACI 318-14

WALL LINE C EAST/WEST FOUNDATION DESIGN

\[ \Phi M_n = \Phi A s_{Fy}(d-a/2) = \]
\[ 6957.2 \text{ k-in} \]
\[ 80154 \text{ kg-m} \]
\[ > 11720 \text{ kg-m} \quad \text{GOOD} \]

Imperial Equivalent: (6) #5 BARS

SI Equivalent: USE (6) 16mm BARS LONGITUDINAL (B)

Check for Transverse Flexural Reinforcement (Bottom)

\[ w_u = 10985 \text{ kg/m}^2 \]
\[ l = W / t = 0.875 \text{ m} \]
\[ M_u = 4205 \text{ kg-m} \]

Try #5 bars @ 12" o/c

\[ \text{# of bars} = 1 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]
\[ A_s = 0.31 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A s F_y = 18.6 \text{ k} \]
\[ a = T / 0.85 * f_c * b = 0.61 \text{ in} \]
\[ c = a / \beta = 0.72 \text{ in} \]
\[ d = 35.44 \text{ in} \]
\[ \epsilon_t = 0.003(d-c/c) = 0.1457 \quad >> > 0.005 \quad \text{STRAIN PASSES} \]
\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A s_{Fy}(d-a/2) = \]
\[ 588.2 \text{ k-in} \]
\[ 6777 \text{ kg-m} \]
\[ > 4205 \text{ kg-m} \quad \text{GOOD} \]

Imperial Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)
WALL LINE C EAST/WEST FOUNDATION DESIGN

Check for Longitudinal Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 7 \text{ m} \]
\[ M_u = 8972 \text{ kg-m} \]

*Based on ftg. rotating around toe*

\[ \text{Try (6) #5 bars} \]

\[ \text{# of bars} = 6 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]
\[ A_s = 1.86 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 111.6 \text{ k} \]

\[ a = T / 0.85 f_c^* b = 0.56 \text{ in} \]
\[ c = a / \beta = 0.65 \text{ in} \]
\[ d = 35.47 \text{ in} \]

\[ \varepsilon_t = 0.003(d-c/c) = 0.1597 \gg 0.005 \]
\[ \Phi = 0.9 \]
\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 3534.4 \text{ k-in} \]
\[ 40720 \text{ kg-m} > 14831 \text{ kg-m} \]

*STRAIN PASSES*

*GOOD*

Imperial Equivalent: (6) #5 BARS

SI Equivalent:

*USE (6) 16mm BARS LONGITUDINAL (T)*
WALL LINE C EAST/WEST FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 0.875 \text{ m} \]
\[ M_u = 280 \text{ kg-m} \]

Based on ftg. rotating around toe

Try #5 bars @ 12" o/c

\[
\begin{align*}
\# \text{ of bars} &= 1 \\
\text{bar diameter} &= 0.625 \text{ in} \\
\text{bar area} &= 0.31 \text{ in}^2 \\
\text{cover} &= 3.00 \text{ in} \\
A_s &= 0.31 \text{ in}^2 \\
F_y &= 60 \text{ ksi} \\
T &= A_s F_y = 18.6 \text{ k} \\
\alpha &= T / 0.85 f_c' b = 0.61 \text{ in} \\
\beta &= \alpha / \beta = 0.72 \text{ in} \\
d &= 35.44 \text{ in} \\
\epsilon_t &= 0.003(d-c/c) = 0.1457 \gg 0.005 \text{ STRAIN PASSES} \\
\Phi &= 0.9 \\
\Phi M_n &= \Phi A_s F_y (d-a/2) = 588.2 \text{ k-in} \\
&= 6777 \text{ kg-m} > 280 \text{ kg-m} \text{ GOOD} \\
\end{align*}
\]

Imperial Equivalent: #5 BARS @ 12" O/C

SI Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>WALL LINE E EAST/WEST FOUNDATION DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Loads:</strong></td>
</tr>
<tr>
<td></td>
<td>$P_{DL} = 9250 \text{ kg}$</td>
</tr>
<tr>
<td></td>
<td>$P_{LL} = 781 \text{ kg}$</td>
</tr>
<tr>
<td></td>
<td>$V_{E} = 32334 \text{ kg}$ <em>(Based on Wall 4 results)</em></td>
</tr>
<tr>
<td></td>
<td>$S_{ds} = 0.608$</td>
</tr>
<tr>
<td>ASCE 7-16</td>
<td>$M_{ot} = 0.75 \times 0.70 \times V_{E} \times H_{wall} = 67901 \text{ kg-m}$</td>
</tr>
<tr>
<td>12.13.4</td>
<td></td>
</tr>
<tr>
<td>IBC</td>
<td><strong>Allowable Soil Bearing Pressure:</strong></td>
</tr>
<tr>
<td>TA 1806.2</td>
<td>$f_{IBC} = 7324 \text{ kg/m}^2$</td>
</tr>
<tr>
<td></td>
<td>$f_{allow} = 1.33 \times f_{IBC} = 9740 \text{ kg/m}^2$</td>
</tr>
<tr>
<td></td>
<td><strong>Try Footing Size:</strong></td>
</tr>
<tr>
<td></td>
<td>Length = 10 m</td>
</tr>
<tr>
<td></td>
<td>Width = 2 m</td>
</tr>
<tr>
<td></td>
<td>Depth = 1 m</td>
</tr>
<tr>
<td></td>
<td>Wall length = 8 m</td>
</tr>
<tr>
<td></td>
<td>$P_{footing} = 48056 \text{ kg}$</td>
</tr>
<tr>
<td></td>
<td>$P_{dead} = 9250 \text{ kg}$</td>
</tr>
<tr>
<td></td>
<td>$\Sigma P = 57306 \text{ kg}$</td>
</tr>
<tr>
<td></td>
<td><strong>USE 10m LONG x 2m WIDE x 1m DEEP FTG.</strong></td>
</tr>
</tbody>
</table>
# WALL LINE E EAST/WEST FOUNDATION DESIGN

## Allowable Stress Design Combinations

### Load Case 8: \((1.0 + 0.145sd)sD + 0.7E\)

\[
\begin{align*}
\Sigma P_{LC8} &= 84817 \text{ kg} \\
\frac{Mr}{\Sigma P * L/2} &= 424086.2 \text{ kg} \\
x &= \frac{(Mr - Mot)/\Sigma P}{3x} = 4.2 \text{ m} \\
l &= 12.6 \text{ m} \\
\frac{f_{bearing} = 2*\Sigma P}{lw} &= 4549 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\end{align*}
\]

### Load Case 9: \((1.0 + 0.105sd)sD + 0.525E + 0.75L\)

\[
\begin{align*}
\Sigma P_{LC9} &= 78525 \text{ kg} \\
\frac{Mr}{\Sigma P * L/2} &= 392626 \text{ kg} \\
x &= \frac{(Mr - Mot)/\Sigma P}{3x} = 4.1 \text{ m} \\
l &= 12.4 \text{ m} \\
\frac{f_{bearing} = 2*\Sigma P}{lw} &= 6330 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOVERN, GOOD}
\end{align*}
\]

### Load Case 10: \((1.0 - 0.145sd)sD + 0.7E\)

\[
\begin{align*}
\Sigma P_{LC10} &= 75062 \text{ kg} \\
\frac{Mr}{\Sigma P * L/2} &= 375307.7 \text{ kg} \\
x &= \frac{(Mr - Mot)/\Sigma P}{3x} = 4.1 \text{ m} \\
l &= 12.3 \text{ m} \\
\frac{f_{bearing} = 2*\Sigma P}{lw} &= 6109 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\end{align*}
\]

## Strength Design Combinations

### Load Case 6: \((1.2 + 0.2sd)sD + E + L\)

\[
\Sigma P_{LC6} = 64871 \text{ kg} \quad \text{GOVERN}
\]

### Load Case 7: \((0.9-0.2sd)sD + E\)

\[
\Sigma P_{LC7} = 51037 \text{ kg}
\]
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>WALL LINE E EAST/WEST FOUNDATION DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Check Footing Shear</strong></td>
</tr>
<tr>
<td>$V_{u,LC6} \leq$</td>
<td>64871 kg</td>
</tr>
<tr>
<td>$\Phi$ =</td>
<td>0.75</td>
</tr>
<tr>
<td>$\alpha$ =</td>
<td>2</td>
</tr>
<tr>
<td>$f'c =$</td>
<td>3000 psi</td>
</tr>
<tr>
<td>$Acv = D*W =$</td>
<td>3100 in$^2$</td>
</tr>
<tr>
<td>$\Phi Vc = \Phi \alpha (f'c^{0.5})Acv =$</td>
<td>254691 lbs</td>
</tr>
<tr>
<td></td>
<td>115526 kg</td>
</tr>
<tr>
<td></td>
<td><strong>Check for Longitudinal Flexural Reinforcement (Bottom)</strong></td>
</tr>
<tr>
<td>$x =$</td>
<td>4.1 m</td>
</tr>
<tr>
<td>$l = 3x =$</td>
<td>12.4 m</td>
</tr>
<tr>
<td>$f_{bearing} =$</td>
<td>6330 kg/m$^2$</td>
</tr>
<tr>
<td>$P_{triangle} =$</td>
<td>78525 kg</td>
</tr>
<tr>
<td>$x_{arm} =$</td>
<td>0.86 m</td>
</tr>
<tr>
<td>$M_u = P*x =$</td>
<td>67901 kg-m</td>
</tr>
<tr>
<td></td>
<td><strong>Try (6) #5 bars</strong></td>
</tr>
<tr>
<td># of bars =</td>
<td>12</td>
</tr>
<tr>
<td>bar diameter =</td>
<td>0.625 in</td>
</tr>
<tr>
<td>bar area =</td>
<td>0.31 in$^2$</td>
</tr>
<tr>
<td>cover =</td>
<td>3.00 in</td>
</tr>
<tr>
<td>$A_s =$</td>
<td>3.72 in$^2$</td>
</tr>
<tr>
<td>$F_y =$</td>
<td>60 ksi</td>
</tr>
<tr>
<td>$T =$</td>
<td>223.2 k</td>
</tr>
<tr>
<td>$a =$</td>
<td>1.11 in</td>
</tr>
<tr>
<td>$c =$</td>
<td>1.31 in</td>
</tr>
<tr>
<td>$d =$</td>
<td>35.19 in</td>
</tr>
<tr>
<td>$\epsilon_t = 0.003(d-c/c) =$</td>
<td>0.0777 &gt;&gt;&gt; 0.005</td>
</tr>
<tr>
<td>$\Phi =$</td>
<td>0.9</td>
</tr>
</tbody>
</table>
### WALL LINE E EAST/WEST FOUNDATION DESIGN

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 6957.2 \text{ k-in} \]
\[ 80154 \text{ kg-m} \quad > 67901 \text{ kg-m} \quad \text{GOOD} \]

Imperial Equivalent: \((6) \#5\) BARS

Si Equivalent:

**USE (6) 16mm BARS LONGITUDINAL (B)**

**Check for Transverse Flexural Reinforcement (Bottom)**

\[
egin{align*}
\text{wu} &= 10985 \text{ kg/m}^2 \\
I &= W / t = 0.875 \text{ m} \\
M_u &= 4205 \text{ kg-m} \\
\end{align*}
\]

*Based on max soil pressure at end of ftg.*

*Try #5 bars @ 12" o/c*

\[
egin{align*}
\# \text{ of bars} &= 1 \\
\text{bar diameter} &= 0.625 \text{ in} \\
\text{bar area} &= 0.31 \text{ in}^2 \\
\text{cover} &= 3.00 \text{ in} \\
\text{As} &= 0.31 \text{ in}^2 \\
F_y &= 60 \text{ ksi} \\
T &= A_s F_y = 18.6 \text{ k} \\
\text{a} &= T / 0.85 * f'_c * b = 0.61 \text{ in} \\
\text{c} &= a / \beta = 0.72 \text{ in} \\
\text{d} &= 35.44 \text{ in} \\
\varepsilon_t &= 0.003 (d-c/c) = 0.1457 >>> 0.005 \quad \text{STRAIN PASSES} \\
\Phi &= 0.9 \\
\Phi M_n = \Phi A_s F_y (d-a/2) &= 588.2 \text{ k-in} \\
&= 6777 \text{ kg-m} \quad > 4205 \text{ kg-m} \quad \text{GOOD} \\
\end{align*}
\]

Imperial Equivalent:

Si Equivalent:

**USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)**
WALL LINE E EAST/WEST FOUNDATION DESIGN

Check for Longitudinal Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 5 \text{ m} \]
\[ M_u = 4578 \text{ kg-m} \]

Based on ftg. rotating around toe

Try (6) #5 bars

\[ \# \text{ of bars} = 6 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 1.86 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 111.6 \text{ k} \]

\[ a = T / 0.85 f'_c b = 0.56 \text{ in} \]
\[ c = a / \beta = 0.65 \text{ in} \]
\[ d = 35.47 \text{ in} \]

\[ \epsilon_t = 0.003 (d-c/c) = 0.1597 >> > 0.005 \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 3534.4 \text{ k-in} \]
\[ 40720 \text{ kg-m} > 4578 \text{ kg-m} \]

GOOD

Imperial Equivalent: (6) #5 BARS

SI Equivalent:

USE (6) 16mm BARS LONGITUDINAL (T)
WALL LINE E EAST/WEST FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 0.875 \text{ m} \]
\[ M_u = 280 \text{ kg-m} \]

Based on ftg. rotating around toe

Try #5 bars @ 12" o/c

\[ \# \text{ of bars} = 1 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 0.31 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 18.6 \text{ k} \]

\[ a = T / 0.85 \times f'_c B = 0.61 \text{ in} \]
\[ c = a / \beta = 0.72 \text{ in} \]
\[ d = 35.44 \text{ in} \]

\[ \varepsilon_t = 0.003 (d - c)/c = 0.1457 \gg 0.005 \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d - a)/2 = 588.2 \text{ k-in} \]
\[ 6777 \text{ kg-m} > 280 \text{ kg-m} \]

GOOD

Imperial Equivalent: #5 BARS @ 12" O/C

SI Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>WALL LINE 1 NORTH/SOUTH FOUNDATION DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Loads:</strong></td>
</tr>
<tr>
<td></td>
<td>$P_{DL} =$ 9250 kg</td>
</tr>
<tr>
<td></td>
<td>$P_{LL} =$ 781 kg</td>
</tr>
<tr>
<td></td>
<td>$V_e =$ 11037 kg</td>
</tr>
<tr>
<td></td>
<td>$S_{ds} =$ 0.608</td>
</tr>
<tr>
<td>ASCE 7-16 12.13.4</td>
<td>$M_{ot} = 0.75<em>0.70</em>V_{e}*H_{wall} =$ 23178 kg-m</td>
</tr>
<tr>
<td>IBC TA 1806.2</td>
<td><strong>Allowable Soil Bearing Pressure:</strong></td>
</tr>
<tr>
<td></td>
<td>$f_{IBC} =$ 7324 kg/m^2</td>
</tr>
<tr>
<td></td>
<td>$f_{allow} = 1.33*F_{IBC} =$ 9740 kg/m^2</td>
</tr>
<tr>
<td></td>
<td><strong>Try Footing Size:</strong></td>
</tr>
<tr>
<td></td>
<td>Length = 10 m</td>
</tr>
<tr>
<td></td>
<td>Width = 2 m</td>
</tr>
<tr>
<td></td>
<td>Depth = 1 m</td>
</tr>
<tr>
<td></td>
<td>Wall length = 8 m</td>
</tr>
<tr>
<td></td>
<td>$P_{footing} =$ 48056 kg</td>
</tr>
<tr>
<td></td>
<td>$P_{dead} =$ 9250 kg</td>
</tr>
<tr>
<td></td>
<td>$\Sigma P =$ 57306 kg</td>
</tr>
</tbody>
</table>

**USE 10m LONG x 2m WIDE x 1m DEEP FTG.**
### Wall Line 1 North/South Foundation Design

#### Allowable Stress Design Combinations

**Load Case 8: (1.0 + 0.145ds)D + 0.7E**

\[
\begin{align*}
\Sigma P_{LC8} &= 69909 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 349547.2 \text{ kg} \\
x &= (M_R - M_{OT}) / \Sigma P = 4.7 \text{ m} \\
l &= 3x = 14.0 \text{ m} \\
\end{align*}
\]

\[
f_{bearing} = 2*\Sigma P / l^2w = 4092 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \text{ GOOD}
\]

**Load Case 9: (1.0 + 0.1055ds)D + 0.525E + 0.75L**

\[
\begin{align*}
\Sigma P_{LC9} &= 67344 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 336722 \text{ kg} \\
x &= (M_R - M_{OT}) / \Sigma P = 4.7 \text{ m} \\
l &= 3x = 14.0 \text{ m} \\
\end{align*}
\]

\[
f_{bearing} = 2*\Sigma P / l^2w = 4822 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \text{ GOVERNS, GOOD}
\]

**Load Case 10: (1.0 - 0.145ds)D + 0.7E**

\[
\begin{align*}
\Sigma P_{LC10} &= 60154 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 300768.7 \text{ kg} \\
x &= (M_R - M_{OT}) / \Sigma P = 4.6 \text{ m} \\
l &= 3x = 13.8 \text{ m} \\
\end{align*}
\]

\[
f_{bearing} = 2*\Sigma P / l^2w = 4345 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \text{ GOOD}
\]

#### Strength Design Combinations

**Load Case 6: (1.2 + 0.25ds)D + E + L**

\[
\Sigma P_{LC6} = 43574 \text{ kg} \text{ GOVERNS}
\]

**Load Case 7: (0.9 - 0.25ds)D + E**

\[
\Sigma P_{LC7} = 29741 \text{ kg}
\]
WALL LINE 1 NORTH/SOUTH FOUNDATION DESIGN

Check Footing Shear

\[ V_{u,lc6} \leq \quad 43574 \text{ kg} \]

\[ \Phi = \quad 0.75 \]
\[ \alpha = \quad 2 \]
\[ f'c = \quad 3000 \text{ psi} \]
\[ Acv = D*W = \quad 3100 \text{ in}^2 \]

\[ \Phi Vc = \Phi \alpha (f'c^{0.5}) Acv = \quad 254691 \text{ lbs} \]
\[ \quad 115526 \text{ kg} \quad > 43574 \text{ kg} \quad \text{GOOD} \]

Check for Longitudinal Flexural Reinforcement (Bottom)

\[ x = \quad 4.7 \text{ m} \]
\[ l = 3x = \quad 14.0 \text{ m} \]
\[ f_{\text{bearing}} = \quad 4822 \text{ kg/m}^2 \]

\[ P_{\text{triangle}} = \quad 67344 \text{ kg} \]
\[ x_{\text{arm}} = \quad 0.34 \text{ m} \]
\[ M_u = P*x = \quad 23178 \text{ kg-m} \]

Try (6) #5 bars

\[ \# \text{ of bars} = \quad 12 \]
\[ \text{bar diameter} = \quad 0.625 \text{ in} \]
\[ \text{bar area} = \quad 0.31 \text{ in}^2 \]
\[ \text{cover} = \quad 3.00 \text{ in} \]

\[ A_s = \quad 3.72 \text{ in}^2 \]
\[ F_y = \quad 60 \text{ ksi} \]
\[ T = A_s F_y = \quad 223.2 \text{ k} \]

\[ a = T / 0.85*f'c*b = \quad 1.11 \text{ in} \]
\[ c = a / \beta = \quad 1.31 \text{ in} \]
\[ d = \quad 35.19 \text{ in} \]

\[ \varepsilon_t = 0.003(d-c/c) = \quad 0.0777 >>> 0.005 \quad \text{STRAIN PASSES} \]
\[ \Phi = \quad 0.9 \]
### Wall Line 1 North/South Foundation Design

ΦMn = ΦAsFy(d-a/2) = 6957.2 k-in
80154 kg-m > 23178 kg-m **GOOD**

Imperial Equivalent: (6) #5 BARS

**SI Equivalent:**
**USE (6) 16mm BARS LONGITUDINAL (8)**

Check for Transverse Flexural Reinforcement (Bottom)

\[ w_u = 10985 \text{ kg/m}^2 \]
\[ l = W / t = 0.875 \text{ m} \]
\[ M_u = 4205 \text{ kg-m} \]

Try #5 bars @ 12" o/c

<table>
<thead>
<tr>
<th># of bars</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>bar diameter</td>
<td>0.625 in</td>
</tr>
<tr>
<td>bar area</td>
<td>0.31 in(^2)</td>
</tr>
<tr>
<td>cover</td>
<td>3.00 in</td>
</tr>
<tr>
<td>As</td>
<td>0.31 in(^2)</td>
</tr>
<tr>
<td>Fy</td>
<td>60 ksi</td>
</tr>
<tr>
<td>T = AsFy</td>
<td>18.6 k</td>
</tr>
<tr>
<td>a = T / 0.85<em>fc</em>b</td>
<td>0.61 in</td>
</tr>
<tr>
<td>c = a / β</td>
<td>0.72 in</td>
</tr>
<tr>
<td>d</td>
<td>35.44 in</td>
</tr>
<tr>
<td>(\epsilon_t = 0.003(d-c/c))</td>
<td>0.1457 &gt;&gt;&gt; 0.005 <strong>STRAIN PASSES</strong></td>
</tr>
<tr>
<td>Φ</td>
<td>0.9</td>
</tr>
</tbody>
</table>

ΦMn = ΦAsFy(d-a/2) = 588.2 k-in
6777 kg-m > 4205 kg-m **GOOD**

Imperial Equivalent:

**SI Equivalent:**
**USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)**
### WALL LINE 1 NORTH/SOUTH FOUNDATION DESIGN

**Check for Longitudinal Flexural Reinforcement (Top)**

\[
\begin{align*}
w_u &= 732 \text{ kg/m}^2 \\
l &= 5 \text{ m} \\
M_u &= 4578 \text{ kg-m} \\
\text{Based on ftg. rotating around toe}
\end{align*}
\]

**Try (6) #5 bars**

<table>
<thead>
<tr>
<th>Component</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td># of bars</td>
<td>6</td>
</tr>
<tr>
<td>bar diameter</td>
<td>0.625 in</td>
</tr>
<tr>
<td>bar area</td>
<td>0.31 in(^2)</td>
</tr>
<tr>
<td>cover</td>
<td>3.00 in</td>
</tr>
<tr>
<td>As</td>
<td>1.86 in(^2)</td>
</tr>
<tr>
<td>F_y</td>
<td>60 ksi</td>
</tr>
<tr>
<td>T = AsF_y</td>
<td>1116 k</td>
</tr>
<tr>
<td>a = T / 0.85<em>f_c</em>b</td>
<td>0.56 in</td>
</tr>
<tr>
<td>c = a / \beta</td>
<td>0.65 in</td>
</tr>
<tr>
<td>d</td>
<td>35.47 in</td>
</tr>
<tr>
<td>\varepsilon_t = 0.003(d-c/c)</td>
<td>0.1597 [&gt;&gt;] 0.005</td>
</tr>
<tr>
<td>\Phi</td>
<td>0.9</td>
</tr>
<tr>
<td>\Phi M_n = \Phi AsF_y(d-a/2)</td>
<td>3534.4 k-in 40720 kg-m &gt; 4578 kg-m</td>
</tr>
</tbody>
</table>

**Imperial Equivalent:** (6) #5 BARS

**SI Equivalent:**

**USE (6) 16mm BARS LONGITUDINAL (T)**
WALL LINE 1 NORTH/SOUTH FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[
\begin{align*}
w_u &= 732 \text{ kg/m}^2 \\
l &= 0.875 \text{ m} \\
Mu &= 280 \text{ kg-m} \\
\end{align*}
\]
Based on fig. rotating around toe

Try #5 bars @ 12" o/c

\[
\begin{align*}
\# \text{ of bars} &= 1 \\
\text{bar diameter} &= 0.625 \text{ in} \\
\text{bar area} &= 0.31 \text{ in}^2 \\
\text{cover} &= 3.00 \text{ in} \\
As &= 0.31 \text{ in}^2 \\
F_y &= 60 \text{ ksi} \\
T &= AsF_y = 18.6 \text{ k} \\
\alpha &= T / 0.85 \cdot f_c \cdot b = 0.61 \text{ in} \\
c &= \alpha / \beta = 0.72 \text{ in} \\
d &= 35.44 \text{ in} \\
\varepsilon_t &= 0.003 \cdot (d - c / c) = 0.1457 \gg 0.005 \\
\Phi &= 0.9 \\
\Phi Mn &= \Phi AsF_y(d-a/2) = 588.2 \text{ k-in} \\
&= 6777 \text{ kg-m} > 280 \text{ kg-m} \\
\text{Imperial Equivalent:} & \ #5 \text{ BARS @ 12" O/C} \\
\text{SI Equivalent:} & \ \text{USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)}
\end{align*}
\]
### WALL LINE 4 NORTH/SOUTH FOUNDATION DESIGN

**Loads:**
- P<sub_DL</sub> = 36998 kg
- P<sub_LL</sub> = 3125 kg
- V<sub_E</sub> = 14414 kg  \(\text{Based on Wall 6 results}\)
- Sds = 0.608

\[
\text{Mot} = 0.75 \times 0.70 \times V_E \times H_{wall} = 30270 \text{ kg-m}
\]

**Allowable Soil Bearing Pressure:**
- f<subIBC</sub> = 7324 kg/m<sup>2</sup>
- f<sub>allow</sub> = 1.33 \times f<subIBC</sub> = 9740 kg/m<sup>2</sup>

**Try Footing Size:**
- Length = 10 m
- Width = 2 m
- Depth = 1 m
- Wall length = 8 m
- P<sub>footing</sub> = 48056 kg
- P<sub>dead</sub> = 36998 kg
- ΣP = 85054 kg

**USE 10m LONG x 2m WIDE x 1m DEEP FTG.**
### Calculations

**WALL LINE 4 NORTH/SOUTH FOUNDATION DESIGN**

#### Allowable Stress Design Combinations

**Load Case 8: \((1.0 + 0.14Sds)D + 0.7E\)**

\[
\Sigma P_{LC8} = 102384 \text{ kg}
\]

\[
M_r = \Sigma P \times L/2 = 511920.3 \text{ kg}
\]

\[
x = (M_r - M_{ot}) \div \Sigma P = 4.7 \text{ m}
\]

\[
l = 3x = 14.1 \text{ m}
\]

\[
\text{f}_{bearing} = 2 \times \Sigma P \div l^*w = 6027 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\]

**Load Case 9: \((1.0 + 0.105Sds)D + 0.525E + 0.75L\)**

\[
\Sigma P_{LC9} = 100395 \text{ kg}
\]

\[
M_r = \Sigma P \times L/2 = 501976 \text{ kg}
\]

\[
x = (M_r - M_{ot}) \div \Sigma P = 4.7 \text{ m}
\]

\[
l = 3x = 14.1 \text{ m}
\]

\[
\text{f}_{bearing} = 2 \times \Sigma P \div l^*w = 7123 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOVERN, GOOD}
\]

**Load Case 10: \((1.0 - 0.14Sds)D + 0.7E\)**

\[
\Sigma P_{LC10} = 87904 \text{ kg}
\]

\[
M_r = \Sigma P \times L/2 = 439522.1 \text{ kg}
\]

\[
x = (M_r - M_{ot}) \div \Sigma P = 4.7 \text{ m}
\]

\[
l = 3x = 14.0 \text{ m}
\]

\[
\text{f}_{bearing} = 2 \times \Sigma P \div l^*w = 6294 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\]

#### Strength Design Combinations

**Load Case 6: \((1.2 + 0.2Sds)D + E + L\)**

\[
\Sigma P_{LC6} = 49294 \text{ kg} \quad \text{GOVERNS}
\]

**Load Case 7: \((0.9-0.2Sds)D + E\)**

\[
\Sigma P_{LC7} = 33118 \text{ kg}
\]
ACI 318-14

WALL LINE 4 NORTH/SOUTH FOUNDATION DESIGN

Check Footing Shear

\[ Vu,lc6 \leq 49294 \text{ kg} \]

\[ \Phi = 0.75 \]

\[ \alpha = 2 \]

\[ f'c = 3000 \text{ psi} \]

\[ Acv = D*W = 3100 \text{ in}^2 \]

\[ \Phi Vc = \Phi \alpha (f'c^{.5}) Acv = 254691 \text{ lbs} \]

\[ 115526 \text{ kg} > 49294 \text{ kg} \quad \text{GOOD} \]

Check for Longitudinal Flexural Reinforcement (Bottom)

\[ x = 4.7 \text{ m} \]

\[ l = 3x = 14.1 \text{ m} \]

\[ f_{\text{bearing}} = 7123 \text{ kg/m}^2 \]

\[ P_{\text{triangle}} = 100395 \text{ kg} \]

\[ x_{\text{arm}} = 0.30 \text{ m} \]

\[ Mu = P*x = 30270 \text{ kg-m} \]

Try (6) #5 bars

\[ \# \text{ of bars} = 12 \]

\[ \text{bar diameter} = 0.625 \text{ in} \]

\[ \text{bar area} = 0.31 \text{ in}^2 \]

\[ \text{cover} = 3.00 \text{ in} \]

\[ As = 3.72 \text{ in}^2 \]

\[ Fy = 60 \text{ ksi} \]

\[ T = AsFy = 223.2 \text{ k} \]

\[ a = \frac{T}{0.85*f'c*b} = 1.11 \text{ in} \]

\[ c = a / \beta = 1.31 \text{ in} \]

\[ d = 35.19 \text{ in} \]

\[ \varepsilon t = 0.003(d-c/c) = 0.0777 >>> 0.005 \quad \text{STRAIN PASSES} \]

\[ \Phi = 0.9 \]
### WALL LINE 4 NORTH/SOUTH FOUNDATION DESIGN

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 6957.2 \text{ k-in} \]

\[ 80154 \text{ kg-m} \quad > 30270 \text{ kg-m} \quad \text{GOOD} \]

**Imperial Equivalent:** (6) #5 BARS

**SI Equivalent:**

**USE (6) 16mm BARS LONGITUDINAL (B)**

#### Check for Transverse Flexural Reinforcement (Bottom)

\[ w_u = 10985 \text{ kg/m}^2 \]

\[ l = W/t = 0.875 \text{ m} \]

\[ M_u = 4205 \text{ kg-m} \]

Try #5 bars @ 12" o/c

\[ A_s = 0.31 \text{ in}^2 \]

\[ F_y = 60 \text{ ksi} \]

\[ T = A_s F_y = 18.6 \text{ k} \]

\[ a = T/0.85f_c b = 0.61 \text{ in} \]

\[ c = a/\beta = 0.72 \text{ in} \]

\[ d = 35.44 \text{ in} \]

\[ \epsilon_t = 0.003(d-c/c) = 0.1457 >> 0.005 \quad \text{STRAIN PASSES} \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 588.2 \text{ k-in} \]

\[ 6777 \text{ kg-m} \quad > 4205 \text{ kg-m} \quad \text{GOOD} \]

**Imperial Equivalent:**

**USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)**
### Calculations

**WALL LINE 4 NORTH/SOUTH FOUNDATION DESIGN**

**Check for Longitudinal Flexural Reinforcement (Top)**

\[
w_u = 732 \text{ kg/m}^2 \\
l = 5 \text{ m} \\
Mu = 4578 \text{ kg-m} \\
\text{Based on ftg. rotating around toe}
\]

**Try (6) #5 bars**

<table>
<thead>
<tr>
<th># of bars</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>bar diameter</td>
<td>0.625 in</td>
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<tr>
<td>bar area</td>
<td>0.31 in^2</td>
</tr>
<tr>
<td>cover</td>
<td>3.00 in</td>
</tr>
<tr>
<td>As</td>
<td>1.86 in^2</td>
</tr>
<tr>
<td>Fy</td>
<td>60 ksi</td>
</tr>
<tr>
<td>T = AsFy</td>
<td>111.6 k</td>
</tr>
<tr>
<td>a = T / 0.85<em>f</em>c*b</td>
<td>0.56 in</td>
</tr>
<tr>
<td>c = a / \beta</td>
<td>0.65 in</td>
</tr>
<tr>
<td>d</td>
<td>35.47 in</td>
</tr>
<tr>
<td>(\epsilon_t = 0.003(d-c/c))</td>
<td>0.1597 &gt;&gt;&gt; 0.005</td>
</tr>
<tr>
<td>(\Phi)</td>
<td>0.9</td>
</tr>
<tr>
<td>(\Phi M_n = \Phi As_Fy(d-a/2))</td>
<td>3534.4 k-in</td>
</tr>
<tr>
<td></td>
<td>40720 kg-m</td>
</tr>
<tr>
<td></td>
<td>&gt; 4578 kg-m</td>
</tr>
</tbody>
</table>

**Strain Passes**

**Good**

**Imperial Equivalent:** (6) #5 BARS

**SI Equivalent:**

USE (6) 16mm BARS LONGITUDINAL (T)
WALL LINE 4 NORTH/SOUTH FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 0.875 \text{ m} \]
\[ M_u = 280 \text{ kg-m} \]

Based on fig. rotating around toe

Try #5 bars @ 12" o/c

\[ \# \text{ of bars} = 1 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 0.31 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 18.6 \text{ k} \]

\[ a = T / 0.85 f'_c b = 0.61 \text{ in} \]
\[ c = a / \beta = 0.72 \text{ in} \]
\[ d = 35.44 \text{ in} \]

\[ \varepsilon_t = 0.003 (d - c) / c = 0.1457 \gg 0.005 \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 588.2 \text{ k-in} \]
\[ 6777 \text{ kg-m} > 280 \text{ kg-m} \]

STRAIN PASSES

GOOD

Imperial Equivalent: #5 BARS @ 12" O/C

SI Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)
WALL LINE 6 NORTH/SOUTH FOUNDATION DESIGN

**Loads:**
- $P_{DL} = 36998 \text{ kg}$
- $P_{LL} = 3125 \text{ kg}$
- $V_E = 15540 \text{ kg}$  \textit{Based on Wall 7 results}
- $Sds = 0.608$

ASCE 7-16
12.13.4

$M_{ot} = 0.75*0.70*V_E*H_{wall} = 32634 \text{ kg-m}$

**Allowable Soil Bearing Pressure:**
- $f_{IBC} = 7324 \text{ kg/m}^2$
- $f_{allow} = 1.33*F_{IBC} = 9740 \text{ kg/m}^2$

**Try Footing Size:**
- Length = 6 m
- Width = 2 m
- Depth = 1 m
- Wall length = 4 m
- $P_{footing} = 28834 \text{ kg}$
- $P_{dead} = 36998 \text{ kg}$
- $\Sigma P = 65832 \text{ kg}$

\textbf{USE 6m LONG x 2m WIDE x 1m DEEP FTG.}
## WALL LINE 6 NORTH/SOUTH FOUNDATION DESIGN

### Allowable Stress Design Combinations

**Load Case 8: \( (1.0 + 0.14Sds)D + 0.7E \)**

\[
\begin{align*}
\Sigma P_{LC8} &= 82313 \text{ kg} \\
M_R &= \Sigma P \times \frac{L}{2} = 246940.3 \text{ kg} \\
X &= \frac{(M_R - M_{MT})}{\Sigma P} = 2.6 \text{ m} \\
L &= 3X = 7.8 \text{ m} \\
\end{align*}
\]

\( f_{bearing} = 2 \times \Sigma P / L^2 \times w \) \( \leq 9740 \text{ kg/m}^2 \) **GOOD**

**Load Case 9: \( (1.0 + 0.105Sds)D + 0.525E + 0.75L \)**

\[
\begin{align*}
\Sigma P_{LC9} &= 80537 \text{ kg} \\
M_R &= \Sigma P \times \frac{L}{2} = 241610 \text{ kg} \\
X &= \frac{(M_R - M_{MT})}{\Sigma P} = 2.6 \text{ m} \\
L &= 3X = 7.8 \text{ m} \\
\end{align*}
\]

\( f_{bearing} = 2 \times \Sigma P / L^2 \times w \) \( \leq 9740 \text{ kg/m}^2 \) **GOVERNS, GOOD**

**Load Case 10: \( (1.0 - 0.14Sds)D + 0.7E \)**

\[
\begin{align*}
\Sigma P_{LC10} &= 71106 \text{ kg} \\
M_R &= \Sigma P \times \frac{L}{2} = 213318.7 \text{ kg} \\
X &= \frac{(M_R - M_{MT})}{\Sigma P} = 2.5 \text{ m} \\
L &= 3X = 7.6 \text{ m} \\
\end{align*}
\]

\( f_{bearing} = 2 \times \Sigma P / L^2 \times w \) \( \leq 9740 \text{ kg/m}^2 \) **GOOD**

### Strength Design Combinations

**Load Case 6: \( (1.2 + 0.2Sds)D + E + L \)**

\[
\Sigma P_{LC6} = 37718 \text{ kg} \] **GOVERNS**

**Load Case 7: \( (0.9-0.2Sds)D + E \)**

\[
\Sigma P_{LC7} = 26762 \text{ kg} \]
### WALL LINE 6 NORTH/SOUTH FOUNDATION DESIGN

#### Check Footing Shear

<table>
<thead>
<tr>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{u,LC6} \leq$</td>
<td>37718 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Phi$</td>
<td>0.75</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>2</td>
</tr>
<tr>
<td>$f'_c$</td>
<td>3000 psi</td>
</tr>
<tr>
<td>$A_{cv} = D \times W =$</td>
<td>3100 in$^2$</td>
</tr>
</tbody>
</table>

$$\Phi V_c = \Phi \alpha (f'_c^{.5}) A_{cv} = \frac{254691 \text{ lbs}}{115526 \text{ kg}} > 37718 \text{ kg} \quad \text{GOOD}$$

#### Check for Longitudinal Flexural Reinforcement (Bottom)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x$</td>
<td>2.6 m</td>
</tr>
<tr>
<td>$l = 3x$</td>
<td>7.8 m</td>
</tr>
<tr>
<td>$f_{\text{bearing}}$</td>
<td>10346 kg/m$^2$</td>
</tr>
<tr>
<td>$P_{\text{triangle}}$</td>
<td>80537 kg</td>
</tr>
<tr>
<td>$x_{\text{arm}}$</td>
<td>0.41 m</td>
</tr>
<tr>
<td>$M_u = P \times x$</td>
<td>32634 kg-m</td>
</tr>
</tbody>
</table>

**Try (6) #5 bars**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of bars</td>
<td>12</td>
</tr>
<tr>
<td>bar diameter</td>
<td>0.625 in</td>
</tr>
<tr>
<td>bar area</td>
<td>0.31 in$^2$</td>
</tr>
<tr>
<td>cover</td>
<td>3.00 in</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_s$</td>
<td>3.72 in$^2$</td>
</tr>
<tr>
<td>$F_y$</td>
<td>60 ksi</td>
</tr>
<tr>
<td>$T = A_s F_y$</td>
<td>223.2 k</td>
</tr>
</tbody>
</table>

$$a = \frac{T}{0.85 f'_c b} = 1.11 \text{ in}$$

$$c = a / \beta = 1.31 \text{ in}$$

$$d = 35.19 \text{ in}$$

$$\epsilon_t = 0.003 (d-c)/c = 0.0777 >>> 0.005 \quad \text{STRAIN PASSES}$$

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Phi$</td>
<td>0.9</td>
</tr>
</tbody>
</table>
### Wall Line 6 North/South Foundation Design

**Calculations**

\[
\Phi M_n = \Phi A_s F_y (d-a/2) = 6957.2 \text{ k-in} \\
80154 \text{ kg-m} > 32634 \text{ kg-m} \quad \text{GOOD}
\]

Imperial Equivalent: (6) #5 BARS

SI Equivalent:

USE (6) 16mm BARS LONGITUDINAL (B)

**Check for Transverse Flexural Reinforcement (Bottom)**

\[
w_u = 10985 \text{ kg/m}^2 \\
l = \frac{W}{t} = 0.875 \text{ m} \\
M_u = 4205 \text{ kg-m}
\]

Try #5 bars @ 12" O/C

<table>
<thead>
<tr>
<th># of bars</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>bar diameter =</td>
<td>0.625 in</td>
</tr>
<tr>
<td>bar area =</td>
<td>0.31 in^2</td>
</tr>
<tr>
<td>cover =</td>
<td>3.00 in</td>
</tr>
</tbody>
</table>

As = 0.31 in^2
F_y = 60 ksi
T = AsF_y = 18.6 k

\[
a = \frac{T}{0.85f'c'b} = 0.61 \text{ in} \\
c = \frac{a}{\beta} = 0.72 \text{ in} \\
d = 35.44 \text{ in}
\]

\[
\varepsilon_t = 0.003(d-c/c) = 0.1457 >> 0.005 \quad \text{STRAIN PASSES}
\]

\[
\Phi = 0.9
\]

\[
\Phi M_n = \Phi A_s F_y (d-a/2) = 588.2 \text{ k-in} \\
6777 \text{ kg-m} > 4205 \text{ kg-m} \quad \text{GOOD}
\]

Imperial Equivalent: #5 BARS @ 12" O/C

SI Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)
WALL LINE 6 NORTH/SOUTH FOUNDATION DESIGN

Check for Longitudinal Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 3 \text{ m} \]
\[ M_u = 1648 \text{ kg-m} \]

**Based on ftg. rotating around toe**

**Try (6) #5 bars**

- # of bars = 6
- bar diameter = 0.625 in
- bar area = 0.31 in\(^2\)
- cover = 3.00 in

\[ A_s = 1.86 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 111.6 \text{ k} \]

\[ a = T / 0.85 * f_c * b = 0.56 \text{ in} \]
\[ c = a / \beta = 0.65 \text{ in} \]
\[ d = 35.47 \text{ in} \]

\[ \varepsilon_t = 0.003 (d - c / c) = 0.1597 \text{ >>> 0.005} \]

**STRAIN PASSES**

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d - a / 2) = 3534.4 \text{ k-in} \]
\[ 40720 \text{ kg-m} > 1648 \text{ kg-m} \]

**GOOD**

Imperial Equivalent: (6) #5 BARS

SI Equivalent:

**USE (6) 16mm BARS LONGITUDINAL (T)**
WALL LINE 6 NORTH/SOUTH FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[
w_u = 732 \text{ kg/m}^2
\]
\[
l = 0.875 \text{ m}
\]
\[
M_u = 280 \text{ kg-m}
\]  
Based on ftg. rotating around toe

Try #5 bars @ 12" o/c

\[
\text{# of bars} = 1
\]
\[
\text{bar diameter} = 0.625 \text{ in}
\]
\[
\text{bar area} = 0.31 \text{ in}^2
\]
\[
\text{cover} = 3.00 \text{ in}
\]

\[
A_s = 0.31 \text{ in}^2
\]
\[
F_y = 60 \text{ ksi}
\]
\[
T = A_sF_y = 18.6 \text{ k}
\]

\[
a = T / 0.85f'c*b = 0.61 \text{ in}
\]
\[
c = a / \beta = 0.72 \text{ in}
\]
\[
d = 35.44 \text{ in}
\]

\[
\varepsilon_t = 0.003(d-c/c) = 0.1457 \gg 0.005
\]

\[
\Phi = 0.9
\]

\[
\Phi M_n = \Phi A_s F_y(d-a/2) = 588.2 \text{ k-in}
\]
\[
6777 \text{ kg-m} \gg 280 \text{ kg-m}
\]

Imperial Equivalent:  #5 BARS @ 12" O/C

SI Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)
### WALL LINE 7 NORTH/SOUTH FOUNDATION DESIGN

**Loads:**
- PD_L = 55497 kg
- PL_L = 4687 kg
- VE = 33331 kg  
  *Based on Wall 8 and Wall 9 results*
- Sds = 0.608

\[
\text{Mot} = 0.75 \times 0.70 \times \text{Ve} \times H_{\text{wall}} = 69996 \text{ kg-m}
\]

**Allowable Soil Bearing Pressure:**
- f_{IBC} = 7324 kg/m^2
- fallow = 1.33 \times f_{IBC} = 9740 kg/m^2

**Try Footing Size:**
- Length = 14 m
- Width = 2 m
- Depth = 1 m
- Wall length = 12 m

- P_{footing} = 67278 kg
- P_{dead} = 55497 kg
- ΣP = 122776 kg

**USE 14m LONG x 2m WIDE x 1m DEEP FTG.**
### Calculations

#### WALL LINE 7 NORTH/SOUTH FOUNDATION DESIGN

**Allowable Stress Design Combinations**

**Load Case 8: \((1.0 + 0.145sds)D + 0.7E\)**

\[
\begin{align*}
\Sigma P_{LC8} &= 156558 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 1095909 \text{ kg} \\
x &= (M_R - M_{OT}) / \Sigma P = 6.6 \text{ m} \\
l &= 3x = 19.7 \text{ m} \\
\end{align*}
\]

\[
\text{f}_{\text{bearing}} = 2 \Sigma P / l^*w = 6245 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\]

**Load Case 9: \((1.0 + 0.105sds)D + 0.525E + 0.75L\)**

\[
\begin{align*}
\Sigma P_{LC9} &= 151628 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 1061396 \text{ kg} \\
x &= (M_R - M_{OT}) / \Sigma P = 6.5 \text{ m} \\
l &= 3x = 19.6 \text{ m} \\
\end{align*}
\]

\[
\text{f}_{\text{bearing}} = 2 \Sigma P / l^*w = 7730 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOVERNS, GOOD}
\]

**Load Case 10: \((1.0 - 0.14sds)D + 0.7E\)**

\[
\begin{align*}
\Sigma P_{LC10} &= 135657 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 949599.4 \text{ kg} \\
x &= (M_R - M_{OT}) / \Sigma P = 6.5 \text{ m} \\
l &= 3x = 19.5 \text{ m} \\
\end{align*}
\]

\[
\text{f}_{\text{bearing}} = 2 \Sigma P / l^*w = 6974 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}
\]

**Strength Design Combinations**

**Load Case 6: \((1.2 + 0.2sds)D + E + L\)**

\[
\Sigma P_{LC6} = 82476 \text{ kg} \quad \text{GOVERN}
\]

**Load Case 7: \((0.9 - 0.2sds)D + E\)**

\[
\Sigma P_{LC7} = 59516 \text{ kg}
\]
ACI 318-14

WALL LINE 7 NORTH/SOUTH FOUNDATION DESIGN

Check Footing Shear

\[ V_{u_{LC6}} \leq 82476 \text{ kg} \]

\[ \Phi = 0.75 \]
\[ \alpha = 2 \]
\[ f'c = 3000 \text{ psi} \]
\[ Acv = D*W = 3100 \text{ in}^2 \]

\[ \Phi Vc = \Phi \alpha (f'c^{0.5}) Acv = 254691 \text{ lbs} \]
\[ 115526 \text{ kg} > 82476 \text{ kg} \]

GOOD

Check for Longitudinal Flexural Reinforcement (Bottom)

\[ x = 6.5 \text{ m} \]
\[ l = 3x = 19.6 \text{ m} \]
\[ f_{bearing} = 7730 \text{ kg/m}^2 \]

\[ P_{triangle} = 151628 \text{ kg} \]
\[ x_{arm} = 0.46 \text{ m} \]
\[ M_u = P*x_{triangle} = 69996 \text{ kg-m} \]

Try (6) #5 bars

\[ \text{# of bars} = 12 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 3.72 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 223.2 \text{ k} \]

\[ a = T / 0.85f'c*b = 1.11 \text{ in} \]
\[ c = a / \beta = 1.31 \text{ in} \]
\[ d = 35.19 \text{ in} \]

\[ \epsilon_t = 0.003(d-c/c) = 0.0777 >>> 0.005 \]

\[ \Phi = 0.9 \]

STRAIN PASSES
### Calculations

**WALL LINE 7 NORTH/SOUTH FOUNDATION DESIGN**

\[
\Phi M_n = \Phi A_s F_y (d - a/2) = 6957.2 \text{ k-in}
\]

\[
80154 \text{ kg-m} > 69996 \text{ kg-m} \quad \text{GOOD}
\]

Imperial Equivalent: (6) #5 BARS

**SI Equivalent:**

USE (6) 16mm BARS LONGITUDINAL (B)

**Check for Transverse Flexural Reinforcement (Bottom)**

\[ w_u = 10985 \text{ kg/m}^2 \]

\[ l = W / t = 0.875 \text{ m} \]

\[ M_u = 4205 \text{ kg-m} \]

Try #5 bars @ 12" o/c

- # of bars = 1
- bar diameter = 0.625 in
- bar area = 0.31 in\(^2\)
- cover = 3.00 in

\[ A_s = 0.31 \text{ in}^2\]

\[ F_y = 60 \text{ ksi} \]

\[ T = A_s F_y = 18.6 \text{ k} \]

\[ a = T / 0.85 f'c b = 0.61 \text{ in} \]

\[ c = a / \beta = 0.72 \text{ in} \]

\[ d = 35.44 \text{ in} \]

\[ \epsilon_t = 0.003 (d - c / c) = 0.1457 \gg 0.005 \quad \text{STRAIN PASSES} \]

\[ \Phi = 0.9 \]

\[
\Phi M_n = \Phi A_s F_y (d - a/2) = 588.2 \text{ k-in}
\]

\[
6777 \text{ kg-m} > 4205 \text{ kg-m} \quad \text{GOOD}
\]

Imperial Equivalent: #5 BARS @ 12" O/C

**SI Equivalent:**

USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)
WALL LINE 7 NORTH/SOUTH FOUNDATION DESIGN

Check for Longitudinal Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 7 \text{ m} \]
\[ M_u = 8972 \text{ kg-m} \]

\[ \text{Based on ftg. rotating around toe} \]

Try (6) #5 bars

<table>
<thead>
<tr>
<th># of bars</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>bar diameter</td>
<td>0.625 in</td>
</tr>
<tr>
<td>bar area</td>
<td>0.31 in(^2)</td>
</tr>
<tr>
<td>cover</td>
<td>3.00 in</td>
</tr>
<tr>
<td>As</td>
<td>1.86 in(^2)</td>
</tr>
<tr>
<td>F_y</td>
<td>60 ksi</td>
</tr>
<tr>
<td>T = AsF_y</td>
<td>111.6 k</td>
</tr>
</tbody>
</table>

\[ a = \frac{T}{0.85*F_y*b} = 0.56 \text{ in} \]
\[ c = \frac{a}{\beta} = 0.65 \text{ in} \]
\[ d = 35.47 \text{ in} \]

\[ \epsilon_t = 0.003(d-c/c) = 0.1597 >> 0.005 \quad \text{STRAIN PASSES} \]
\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 3534.4 \text{ k-in} \]
\[ 40720 \text{ kg-m} > 8972 \text{ kg-m} \quad \text{GOOD} \]

Imperial Equivalent: (6) #5 BARS

SI Equivalent:

USE (6) 16mm BARS LONGITUDINAL (T)
WALL LINE 7 NORTH/SOUTH FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 0.875 \text{ m} \]
\[ M_u = 280 \text{ kg-m} \]

*Based on ftg. rotating around toe*

Try #5 bars @ 12" o/c

\[ \# \text{ of bars} = 1 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ A_s = 0.31 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = A_s F_y = 18.6 \text{ k} \]

\[ a = T / 0.85 f'_c b = 0.61 \text{ in} \]
\[ c = a / \beta = 0.72 \text{ in} \]
\[ d = 35.44 \text{ in} \]

\[ \epsilon_t = 0.003(d-c/c) = 0.1457 \gg 0.005 \]

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A_s F_y (d-a/2) = 588.2 \text{ k-in} \]
\[ 6777 \text{ kg-m} > 280 \text{ kg-m} \]

*STRAIN PASSES*

*GOOD*

Imperial Equivalent: #5 BARS @ 12" O/C

SI Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESTROOM LOAD TAKE OFF</strong></td>
<td>WEIGHT (PSF)</td>
</tr>
<tr>
<td>DEAD LOAD</td>
<td></td>
</tr>
<tr>
<td>METAL DECKING</td>
<td>0.50</td>
</tr>
<tr>
<td>BAMBOO WEAVE CEILING</td>
<td>0.50</td>
</tr>
<tr>
<td>MISC.</td>
<td>2.00</td>
</tr>
<tr>
<td>TOTAL TO PURLINS:</td>
<td>3.00</td>
</tr>
<tr>
<td>PURLINS</td>
<td>2.08</td>
</tr>
<tr>
<td>TOTAL TO TRUSSES:</td>
<td>5.08</td>
</tr>
<tr>
<td>WOOD TRUSSES</td>
<td>11.18</td>
</tr>
<tr>
<td>TOTAL TO COLUMNS AND WALLS:</td>
<td>16.26</td>
</tr>
<tr>
<td>CONCRETE COLUMNS</td>
<td>3.85</td>
</tr>
<tr>
<td>MASONRY WALLS</td>
<td>246.16</td>
</tr>
<tr>
<td>TOTAL TO FOUNDATION:</td>
<td>266.26</td>
</tr>
<tr>
<td><strong>LIVE LOAD</strong></td>
<td></td>
</tr>
<tr>
<td>ROOF</td>
<td>20.00</td>
</tr>
<tr>
<td><strong>TOTAL AREA</strong></td>
<td>96 m²</td>
</tr>
<tr>
<td>References</td>
<td>Calculations</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td><strong>RESTROOM DECKING DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td>DECKING TO MATCH DECKING IN EVC AND ATF</td>
</tr>
<tr>
<td></td>
<td>Loads to decking in Restroom are equal to the loads to decking in ATF</td>
</tr>
<tr>
<td></td>
<td><strong>USE EVC AND ATF DECKING DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td><strong>RESTROOM PURLIN DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td>PURLINS TO MATCH PURLINS IN EVC AND ATF</td>
</tr>
<tr>
<td></td>
<td>Loads to purlins in Restroom are equal to the loads to purlins in ATF</td>
</tr>
<tr>
<td></td>
<td><strong>USE EVC AND ATF PURLIN DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td><strong>RESTROOM TRUSS DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td>TRUSS TO MATCH TRUSS B FROM ATF</td>
</tr>
<tr>
<td></td>
<td>Loads to truss in Restroom are equal to the loads to truss in ATF</td>
</tr>
<tr>
<td></td>
<td><strong>USE ATF TRUSS B DESIGN</strong></td>
</tr>
<tr>
<td>References</td>
<td>Calculations</td>
</tr>
<tr>
<td>------------</td>
<td>--------------</td>
</tr>
<tr>
<td></td>
<td><strong>SLAB ON GRADE DESIGN - RESTROOM</strong></td>
</tr>
<tr>
<td></td>
<td>Slab on grade to be constructed by</td>
</tr>
<tr>
<td></td>
<td>typical slab on grade construction and minimum reinforcing:</td>
</tr>
<tr>
<td></td>
<td>Imperial Equivalent:</td>
</tr>
<tr>
<td></td>
<td>5&quot; thick slab with #3 @18&quot; o/c each way</td>
</tr>
<tr>
<td></td>
<td>SI Equivalent:</td>
</tr>
<tr>
<td></td>
<td><strong>USE 125mm THICK SLAB w/ 10mm REINFORCING BARS @ 0.4m EACH WAY</strong></td>
</tr>
</tbody>
</table>
Journeyman International
Rubagabella Village EVC and ATF

<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCE 7-16</td>
<td>SEISMIC LOAD CALCULATIONS - RESTROOMS</td>
</tr>
</tbody>
</table>

**SEISMIC INPUT VALUES**

- $S_0 = 0.608 \text{ g}$
- $R = 1$

**SEISMIC WEIGHT - RESTROOMS**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>psf</th>
<th>kg/m²</th>
<th>rib Area (m)</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>3.0</td>
<td>14.6</td>
<td>16</td>
<td>234.4</td>
</tr>
<tr>
<td>Purlins</td>
<td>2.1</td>
<td>10.2</td>
<td>16</td>
<td>162.5</td>
</tr>
<tr>
<td>Truss B</td>
<td>11.2</td>
<td>54.6</td>
<td>4</td>
<td>873.4</td>
</tr>
<tr>
<td>Walls (10&quot;)</td>
<td>125</td>
<td>610.3</td>
<td>16</td>
<td>19529.7</td>
</tr>
</tbody>
</table>

**TOTAL**

- $W = 20800 \text{ kg}$
- $45.86 \text{ kips}$

**BASE SHEAR**

$$V = C_s W$$

$$C_s = 0.608$$

$$V = 12646 \text{ kg}$$

$$27.88 \text{ kips}$$
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RESTROOM DIAPHRAGM DESIGN</td>
</tr>
<tr>
<td></td>
<td>DIAPHRAGM TO MATCH DIAPHRAGM IN EVC AND ATF</td>
</tr>
<tr>
<td></td>
<td>Lateral loads to EVC and ATF are larger than lateral loads to the Restroom</td>
</tr>
<tr>
<td></td>
<td><strong>USE EVC AND ATF DIAPHRAGM DESIGN</strong> conservative</td>
</tr>
</tbody>
</table>
**Calculations**

**CONFINED MASONRY WALL DESIGN - RESTROOM**

**Performance Objective:**  Life Safety

**Lateral Wall Density**

- Required Wall Density = 1.0% for following conditions:
  - Low Seismic Hazard
  - PGA = 0.06g ≤ 0.08g
  - n = 1
  - 1 story building
  - Solid Clay Bricks: handmade, Mortar Type III conservatively
  - Soil Type C: Soft clay soil

**N/S Direction**

- Assume 2 wythes of 120mm brick
- Floor area: \( A_p = 16.00 \, m^2 \)
- Wall area: \( A_w = 2.00 \, m^2 \)
- Wall density: \( d = \frac{A_w}{A_p} = 12.50 \% \) > 1.0%  **GOOD**

**E/W Direction**

- Assume 2 wythes of 120mm brick
- Floor area: \( A_p = 16.00 \, m^2 \)
- Wall area: \( A_w = 1.00 \, m^2 \)
- Wall density: \( d = \frac{A_w}{A_p} = 6.25 \% \) > 1.0%  **GOOD**

**Gravity Wall Density**

- Strength Reduction Factor: \( F_r = 0.6 \)
- Gravity Load Factor: \( F_c = 1.4 \)
- Safety Factor: \( F_s = \frac{F_c}{F_r} = 2.33 \)

**Compressive Strength, \( \sigma_R \)**

- Eccentricity/Slenderness Factor: \( F_e = 0.7 \) for interior walls
- Masonry Comp Strength: \( f'm = 15 \, kg/cm^2 \)
  \[ \sigma_R = F_e (f'm + 4) = 13.3 \, kg/cm^2 \]
<table>
<thead>
<tr>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONFINED MASONRY WALL DESIGN - RESTROOM</strong></td>
</tr>
</tbody>
</table>

Wall Density Index, $\Sigma d \geq F_c (n^w) / \sigma R$

| Weight | $w = 83.22 \text{ kg/m}^2$ |
| Stories | $n = 1$ |

For both directions:

- $F_c (n^w) / \sigma R = 0.876 \%$
- $\Sigma d = \Sigma Aw/Ap = 18.75 \% > 0.876 \%$ **GOOD**

For one direction:

- $F_c (n^w) / \sigma R = 0.438 \%$
- $\Sigma d = \Sigma Aw/Ap = 6.25 \% > 0.438 \%$ **GOOD**

Wall Distance/Thickness Ratio, $B/t \leq \sigma R/(F_s*D*w)$

| Distance | $B = 4 \text{ m}$ |
| Thickness | $t = 0.250 \text{ m}$ |
| $B/t = 16.0$ |

- $D = 1.0$
- $\sigma R/(F_s*D*w) = 684.93 > 16.7$ **GOOD**

**Conclusion**

Provided confined masonry walls are sufficient
### Calculations

**CONFINED MASONRY WALL DESIGN - RESTROOM**

#### TIE-COLUMN DESIGN

**Spacing**

Maximum spacing of tie-columns shall not exceed 6m

\[ S_{\text{max}} = 4 \text{ m} < 6\text{m} \quad \text{GOOD} \]

**Minimum Dimensions**

Minimum depth x width of a tie-column 150mm x t

\[ t = 250 \text{ mm} \]

**Tie-Columns shall be 250mm x 250mm > 150mm x 250mm** \text{GOOD}

**Reinforcing**

**Longitudinal**

Minimum 4 deformed reinforcing bars of minimum 10-mm diameter

**Reinforcing shall be (4) 13-mm diameter bars** \text{GOOD}

**Tie Sizing and Spacing**

Minimum 6-mm diameter bars with 135° hooked ends

Tie spacing cannot exceed 200mm with minimum 20mm cover

**Ties shall be 10-mm diameter transverse stirrups, spaced at 200m, with 50mm cover** \text{GOOD}
CONFINED MASONRY WALL DESIGN - RESTROOM

TIE-BEAM DESIGN

Spacing
Tie-beams shall be provided at the top of each wall, and above and below each window opening

Minimum Dimensions
Minimum depth x width of a tie-beam 150mm x t
\[ t = \text{250 mm} \]

Tie-Beams shall be 250mm x 250mm > 150mm x 250mm GOOD

Reinforcing

Longitudinal
Minimum 4 deformed reinforcing bars of minimum 10-mm diameter

To ensure the effectiveness of tie-beams in resisting earthquake loads, longitudinal bars should have a 90° hooked anchorage at intersections

Reinforcing shall be (4) 13-mm diameter bar, with 90° hooked anchorage at intersections GOOD

Tie Sizing and Spacing
Minimum 6-mm diameter bars with 135° hooked ends

Tie spacing cannot exceed 200mm with minimum 20mm cover

Ties shall be 10-mm diameter transverse stirrups, Spaced at 200m, with 50mm cover GOOD
### Calculations

**SEISMIC LOAD DISTRIBUTION - RESTROOM**

<table>
<thead>
<tr>
<th>WALL</th>
<th>DIRECTION</th>
<th>L (m)</th>
<th>H/L</th>
<th>Rc</th>
<th>origin dist.</th>
<th>d(m)</th>
<th>Rd</th>
<th>Rd^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td>2</td>
<td>2.00</td>
<td>0.263</td>
<td>0</td>
<td>-9.38</td>
<td>-2.47</td>
<td>23.14</td>
</tr>
<tr>
<td>2</td>
<td>X</td>
<td>4</td>
<td>1.00</td>
<td>1.429</td>
<td>4</td>
<td>-5.38</td>
<td>-7.69</td>
<td>41.36</td>
</tr>
<tr>
<td>3</td>
<td>Y</td>
<td>4</td>
<td>1.00</td>
<td>1.429</td>
<td>0</td>
<td>-9.38</td>
<td>-13.40</td>
<td>125.73</td>
</tr>
<tr>
<td>4</td>
<td>Y</td>
<td>4</td>
<td>1.00</td>
<td>1.429</td>
<td>4</td>
<td>-5.38</td>
<td>-7.69</td>
<td>41.36</td>
</tr>
</tbody>
</table>

$$\sum 231.59$$

**Xcm = 2 m**

**Ycm = 2 m**

**Xcr = 2.00 m**

**Ycr = 3.38 m**

**EAST/WEST (X)**

$$ex = 0.05 \times 16m = 0.20 \text{ m}$$

$$e = (Xcm - Xcr) + ex = 0.20 \text{ m}$$

<table>
<thead>
<tr>
<th>Vbase</th>
<th>DIRECT</th>
<th>TORSION</th>
<th>WALL</th>
<th>FORCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>12646 kg</td>
<td>983</td>
<td>-27</td>
<td>956 kg</td>
<td></td>
</tr>
<tr>
<td>2529 kg-m</td>
<td>29977</td>
<td>-84</td>
<td>29893 kg</td>
<td></td>
</tr>
</tbody>
</table>

Largest East/West Force: 29893 kg

**NORTH/SOUTH (Y)**

$$ey = 0.05 \times 20m = 0.20 \text{ m}$$

$$e = (Ycm - Ycr) + ey = -1.18 \text{ m}$$

<table>
<thead>
<tr>
<th>Vbase</th>
<th>DIRECT</th>
<th>TORSION</th>
<th>WALL</th>
<th>FORCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>12646 kg-m</td>
<td>5340</td>
<td>862</td>
<td>6203 kg</td>
<td></td>
</tr>
<tr>
<td>-14900 kg-m</td>
<td>29977</td>
<td>495</td>
<td>30472 kg</td>
<td></td>
</tr>
</tbody>
</table>

Largest North/South Force: 30472 kg
## Restroom Wall Foundation Design

### Loads:
- PDL = 9250 kg
- PLL = 781 kg
- \( V_\text{E} = 30472 \text{ kg} \)
- Sds = 0.608

Based on Largest Wall Force, Wall 4

\[ \text{Mot} = 0.75 \times 0.70 \times V_\text{E} \times H_{\text{wall}} = 63990 \text{ kg}\cdot\text{m} \]

### Allowable Soil Bearing Pressure:
- \( f_{\text{IBC}} = 7324 \text{ kg/m}^2 \)
- \( f_{\text{allow}} = 1.33 \times f_{\text{IBC}} = 9740 \text{ kg/m}^2 \)

### Try Footing Size:
- Length = 6 m
- Width = 1 m
- Depth = 1 m
- Wall length = 4 m

\[ P_{\text{footing}} = 14417 \text{ kg} \]
\[ P_{\text{dead}} = 9250 \text{ kg} \]
\[ \Sigma P = 23666 \text{ kg} \]

**USE 6m LONG x 2m WIDE x 1m DEEP FTG.**
### Calculations

#### RESTROOM WALLS FOUNDATION DESIGN

**Allowable Stress Design Combinations**

**Load Case 8:** \((1.0 + 0.14Sds)D + 0.7E\)

\[
\begin{align*}
\Sigma P_{c8} &= 47011 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 141032.7 \text{ kg} \\
x &= (M_R - M_{ot}) / \Sigma P = 1.6 \text{ m} \\
l &= 3x = 4.9 \text{ m}
\end{align*}
\]

\[f_{bearing} = 2*\Sigma P / l^*w = 9627 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}\]

**Load Case 9:** \((1.0 + 0.105Sds)D + 0.525E + 0.75L\)

\[
\begin{align*}
\Sigma P_{c9} &= 41761 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 125282 \text{ kg} \\
x &= (M_R - M_{ot}) / \Sigma P = 1.5 \text{ m} \\
l &= 3x = 4.4 \text{ m}
\end{align*}
\]

\[f_{bearing} = 2*\Sigma P / l^*w = 18969 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOVERN, GOOD}\]

**Load Case 10:** \((1.0 - 0.14Sds)D + 0.7E\)

\[
\begin{align*}
\Sigma P_{c10} &= 42982 \text{ kg} \\
M_R &= \Sigma P \times L/2 = 128945.9 \text{ kg} \\
x &= (M_R - M_{ot}) / \Sigma P = 1.5 \text{ m} \\
l &= 3x = 4.5 \text{ m}
\end{align*}
\]

\[f_{bearing} = 2*\Sigma P / l^*w = 18961 \text{ kg/m}^2 < 9740 \text{ kg/m}^2 \quad \text{GOOD}\]

#### Strength Design Combinations

**Load Case 6:** \((1.2 + 0.2Sds)D + E + L\)

\[\Sigma P_{c6} = 40779 \text{ kg} \quad \text{GOVERN}\]

**Load Case 7:** \((0.9-0.2Sds)D + E\)

\[\Sigma P_{c7} = 36083 \text{ kg}\]
### Calculations

#### RESTROOM WALLS FOUNDATION DESIGN

**Check Footing Shear**

\[ V_{u, LCS} \leq \quad 40779 \text{ kg} \]

\[
\begin{align*}
\Phi &= 0.75 \\
\alpha &= 2 \\
f'c &= 3000 \text{ psi} \\
Acv &= D^*W = 1550 \text{ in}^2
\end{align*}
\]

\[
\Phi Vc = \Phi \alpha (f'c^{.5}) Acv = 127345 \text{ lbs} \\
57763 \text{ kg} > 40779 \text{ kg} \quad \text{GOOD}
\]

**Check for Longitudinal Flexural Reinforcement (Bottom)**

\[
\begin{align*}
x &= 1.5 \text{ m} \\
l &= 3x &= 4.4 \text{ m} \\
f_{\text{bearing}} &= 18969 \text{ kg/m}^2
\end{align*}
\]

\[
\begin{align*}
P_{\text{triangle}} &= 41761 \text{ kg} \\
x_{\text{arm}} &= 1.53 \text{ m} \\
Mu &= P^*x &= 63990 \text{ kg-m}
\end{align*}
\]

**Try (6) #5 bars**

\[
\begin{align*}
\# \text{ of bars} &= 12 \\
\text{bar diameter} &= 0.625 \text{ in} \\
\text{bar area} &= 0.31 \text{ in}^2 \\
\text{cover} &= 3.00 \text{ in} \\
As &= 3.72 \text{ in}^2 \\
Fy &= 60 \text{ ksi} \\
T &= AsFy = 223.2 \text{ k}
\end{align*}
\]

\[
\begin{align*}
a &= T / 0.85*f'c*b &= 2.22 \text{ in} \\
c &= a / \beta &= 2.62 \text{ in} \\
d &= 34.63 \text{ in}
\end{align*}
\]

\[
\begin{align*}
\epsilon_t &= 0.003(d-c/c) &= 0.0367 \gg 0.005 \\
\Phi &= 0.9 \quad \text{STRAIN PASSES}
\end{align*}
\]
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACI 318-14</td>
<td><strong>RESTROOM WALLS FOUNDATION DESIGN</strong></td>
</tr>
<tr>
<td></td>
<td>$\Phi M_n = \Phi A s F_y (d-a/2) = 6733.9 \text{ k-in}$</td>
</tr>
<tr>
<td></td>
<td>77581 kg-m $&gt;$ 63990 kg-m <strong>GOOD</strong></td>
</tr>
<tr>
<td></td>
<td>Imperial Equivalent: (4) #5 BARS</td>
</tr>
<tr>
<td></td>
<td>SI Equivalent: <strong>USE (4) 16mm BARS LONGITUDINAL (8)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Check for Transverse Flexural Reinforcement (Bottom)</strong></td>
</tr>
<tr>
<td></td>
<td>$w_u = 10985 \text{ kg/m}^2$</td>
</tr>
<tr>
<td></td>
<td>$l = W/t = 0.375 \text{ m}$</td>
</tr>
<tr>
<td></td>
<td>$M_u = 772 \text{ kg-m}$</td>
</tr>
<tr>
<td></td>
<td>Try #5 bars @ 12&quot; o/c</td>
</tr>
<tr>
<td></td>
<td># of bars = 1</td>
</tr>
<tr>
<td></td>
<td>bar diameter = 0.625 in</td>
</tr>
<tr>
<td></td>
<td>bar area = 0.31 in$^2$</td>
</tr>
<tr>
<td></td>
<td>cover = 3.00 in</td>
</tr>
<tr>
<td></td>
<td>$A_s = 0.31 \text{ in}^2$</td>
</tr>
<tr>
<td></td>
<td>$F_y = 60 \text{ ksi}$</td>
</tr>
<tr>
<td></td>
<td>$T = A_s F_y = 18.6 \text{ k}$</td>
</tr>
<tr>
<td></td>
<td>$a = T / 0.85 f' c b = 0.61 \text{ in}$</td>
</tr>
<tr>
<td></td>
<td>$c = a / \beta = 0.72 \text{ in}$</td>
</tr>
<tr>
<td></td>
<td>$d = 35.44 \text{ in}$</td>
</tr>
<tr>
<td></td>
<td>$\varepsilon t = 0.003 (d-c/c) = 0.1457 &gt;&gt; 0.005 \text{ STRAIN PASSES}$</td>
</tr>
<tr>
<td></td>
<td>$\Phi = 0.9$</td>
</tr>
<tr>
<td></td>
<td>$\Phi M_n = \Phi A s F_y (d-a/2) = 588.2 \text{ k-in}$</td>
</tr>
<tr>
<td></td>
<td>6777 kg-m $&gt;$ 772 kg-m <strong>GOOD</strong></td>
</tr>
<tr>
<td></td>
<td>Imperial Equivalent: #5 BARS @ 12&quot; O/C</td>
</tr>
<tr>
<td></td>
<td>SI Equivalent: <strong>USE 16mm BARS @ 0.3m O/C TRANSVERSE (B)</strong></td>
</tr>
</tbody>
</table>
RESTROOM WALLS FOUNDATION DESIGN

Check for Longitudinal Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 3 \text{ m} \]
\[ M_u = 3296 \text{ kg-m} \]

*Based on ftg. rotating around toe*

**Try (6) #5 bars**

<table>
<thead>
<tr>
<th>Term</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td># of bars</td>
<td>6</td>
</tr>
<tr>
<td>bar diameter</td>
<td>0.625 in</td>
</tr>
<tr>
<td>bar area</td>
<td>0.31 in(^2)</td>
</tr>
<tr>
<td>cover</td>
<td>3.00 in</td>
</tr>
<tr>
<td>As</td>
<td>1.86 in(^2)</td>
</tr>
<tr>
<td>Fy</td>
<td>60 ksi</td>
</tr>
<tr>
<td>T</td>
<td>111.6 k</td>
</tr>
</tbody>
</table>

\[ a = \frac{T}{0.85f'c'b} = 1.11 \text{ in} \]
\[ c = \frac{a}{\beta} = 1.31 \text{ in} \]
\[ d = 35.19 \text{ in} \]

\[ \varepsilon_t = 0.003(d-c/c) = 0.0777 \gg 0.005 \]

**Strain Passes**

\[ \Phi = 0.9 \]

\[ \Phi M_n = \Phi A F_y (d-a/2) = 3478.6 \text{ k-in} \]
\[ 40077 \text{ kg-m} \gg 3296 \text{ kg-m} \]

**Good**

Imperial Equivalent: (4) #5 BARS

SI Equivalent:

**USE (4) 16mm BARS LONGITUDINAL (T)**
RESTROOM WALLS FOUNDATION DESIGN

Check for Transverse Flexural Reinforcement (Top)

\[ w_u = 732 \text{ kg/m}^2 \]
\[ l = 0.375 \text{ m} \]
\[ Mu = 51 \text{ kg-m} \]

*Based on ftg. rotating around toe*

Try #5 bars @ 12" o/c

\[ \text{# of bars} = 1 \]
\[ \text{bar diameter} = 0.625 \text{ in} \]
\[ \text{bar area} = 0.31 \text{ in}^2 \]
\[ \text{cover} = 3.00 \text{ in} \]

\[ As = 0.31 \text{ in}^2 \]
\[ F_y = 60 \text{ ksi} \]
\[ T = AsF_y = 18.6 \text{ k} \]

\[ a = T / 0.85f'c'b = 0.61 \text{ in} \]
\[ c = a / \beta = 0.72 \text{ in} \]
\[ d = 35.44 \text{ in} \]

\[ \epsilon_t = 0.003(d-c/c) = 0.1457 >>> 0.005 \]

*STRAIN PASSES*

\[ \Phi = 0.9 \]

\[ \Phi Mn = \Phi AsF_y(d-a/2) = 588.2 \text{ k-in} \]
\[ = 6777 \text{ kg-m} > 51 \text{ kg-m} \]

*GOOD*

Imperial Equivalent:  #5 BARS @ 12" O/C

SI Equivalent:

USE 16mm BARS @ 0.3m O/C TRANSVERSE (T)
TRUSS TO WALL CONNECTION

Design for out-of-plane wall loads

\[ F_p = 0.8 \times S_{ds} \times I_e \times W_p \]

\( S_{ds} = \) 0.608 g
\( I_e = \) 1
\( W_p = \) \( W_{pc} \times t_{wall} \times S_{truss} \times h_{wall} \)

Wall thickness, \( t_{wall} = \) 250 mm
Truss spacing, \( S_{truss} = \) 2 m
Wall height, \( h_{wall} = \) 4 m

\( W_p = \) 2403 kg

\( F_p = \) 1169 kg

Bolt Design

Try (2) 1/2" diameter A307 bolts

\[ V = \Phi \times \rho_m = 8.29 \text{ k} \]
\( \rho_m = 16.58 \text{ k} \)
\( 7521 \text{ kg} > 1169 \text{ kg} \) GOOD

USE EQUIVALENT OF (2) 1/2" DIAMETER A307 BOLTS
<table>
<thead>
<tr>
<th>References</th>
<th>Calculations</th>
<th>WEIGHT (PSF)</th>
<th>WEIGHT (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEAD LOAD</strong></td>
<td><strong>STEEL CANOPY LOAD TAKE OFF</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>METAL DECKING</td>
<td></td>
<td>0.50</td>
<td>2.44</td>
</tr>
<tr>
<td>MISC.</td>
<td></td>
<td>1.00</td>
<td>4.88</td>
</tr>
<tr>
<td></td>
<td>TOTAL TO HSS BEAMS:</td>
<td>1.50</td>
<td>7.32</td>
</tr>
<tr>
<td>HSS BEAMS</td>
<td></td>
<td>1.65</td>
<td>8.05</td>
</tr>
<tr>
<td></td>
<td>TOTAL TO HSS GIRDER:</td>
<td>3.15</td>
<td>15.37</td>
</tr>
<tr>
<td>HSS GIRDER</td>
<td></td>
<td>3.52</td>
<td>17.21</td>
</tr>
<tr>
<td></td>
<td>TOTAL TO COLUMNS:</td>
<td>6.67</td>
<td>32.58</td>
</tr>
<tr>
<td>HSS COLUMNS</td>
<td></td>
<td>0.98</td>
<td>4.77</td>
</tr>
<tr>
<td></td>
<td>TOTAL TO FOUNDATION:</td>
<td>7.65</td>
<td>37.35</td>
</tr>
<tr>
<td><strong>LIVE LOAD</strong></td>
<td>**WEIGHT (PSF) **</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROOF</td>
<td></td>
<td>20.00</td>
<td>97.65</td>
</tr>
<tr>
<td><strong>TOTAL AREA</strong></td>
<td></td>
<td>16 m²</td>
<td></td>
</tr>
</tbody>
</table>
STEEL CANOPY FOUNDATION KEY PLAN
N.T.S.

STEEL CANOPY FRAMING KEY PLAN
N.T.S.
### STEEL CANOPY FRAMING - HSS BEAM DESIGN

<table>
<thead>
<tr>
<th></th>
<th>psf</th>
<th>trib (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead</td>
<td>1.50</td>
<td>3.28</td>
</tr>
<tr>
<td>Live</td>
<td>20.00</td>
<td>3.28</td>
</tr>
</tbody>
</table>

\[ L = 5 \text{ m} \]

\[ D = 4.9 \text{ lb/ft} \]
\[ L = 65.6 \text{ lb/ft} \]

Load Combinations

\[ 1.4D = 6.9 \text{ lb/ft} \]
\[ 1.2D + 1.6L = 110.9 \text{ lb/ft} \] *governs*

#### AISC 360 Bending

\[ M_u = 3.7 \text{ k-ft} \]

\[ \phi M_n = \phi F_y Z_x \]
\[ \phi = 0.9 \]

\[ F_y = 50 \text{ ksi} \]
\[ Z_{req} = 0.082891 \text{ in}^3 \]

\[ \phi M_n - M_u = 0 \]

**HSS 2x2x1/8" adequate (Zx = .584 in^3)**

#### Shear Check

\[ V_u = 0.91 \text{ kips} \]

\[ \phi V_n = 0.6 F_y A_w C_v \]

\[ k_v = 5.34 \]
\[ E = 29000 \text{ ksi} \]
\[ C_v = 1.0 \text{ since } h/tw < 1.1 V(k_v E/F_y) = 1503.5 \]
\[ h/tw = 16 V(k_v E/F_y) = \]
\[ h = 2.0 \text{ in} \]
\[ t_w = 0.125 \text{ in} \]

\[ A_w = 0.5 \text{ in}^2 \]

\[ \phi V_n = 15 \text{ kips} \]

\[ \phi V_n > V_u \text{ OKAY} \]

#### Deflection Check

\[ \Delta = \frac{5 w l^4}{384 E I} \]
\[ l = 0.486 \text{ in}^4 \]

\[ \Delta = 0.01 \text{ in} \]

\[ \Delta_{allow} = \frac{L}{180} = 0.09 \text{ in} \]

\[ \Delta_{allow} > \Delta \text{ OKAY} \]

**use HSS 2x2x1/8" beams for steel canopy**
STEEL CANOPY FRAMING - HSS GIRDER DESIGN

\[ L = 5 \text{ m} \]

<table>
<thead>
<tr>
<th>psf</th>
<th>trib (ft)</th>
<th>D = 25.8 lb/ft</th>
<th>L = 164.0 lb/ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead</td>
<td>3.15</td>
<td>8.20</td>
<td></td>
</tr>
<tr>
<td>Live</td>
<td>20.00</td>
<td>8.20</td>
<td></td>
</tr>
</tbody>
</table>

Load Combinations

\[ 1.4D = 36.2 \text{ lb/ft} \]
\[ 1.2D + 1.6L = 293.5 \text{ lb/ft} \]

\( \text{governs} \)

AISC 360

Bending

\( Mu = 9.9 \text{ k-ft} \)
\( \phi Mn = \phi FyZx \)
\( \phi = 0.9 \)
\( Fy = 50 \text{ ksi} \)
\( Zx_{req} = 0.21936 \text{ in}^3 \)
\( \phi Mn - Mu = 0 \)

HSS2x2x1/8" adequate (Zx = .584 in^3)

Shear Check

\( Vu = 2.41 \text{ kips} \)
\( \phi Vn = 0.6FyAwCv2 \)
\( kv = 5.34 \)
\( E = 29000 \text{ ksi} \)
\( Cv2 = 1.0 \text{ since } h/tw < 1.1(V(kvE/Fy)) \)
\( h/tw = 16 V(kvE/Fy) = 61.2 \)
\( h = 2.0 \text{ in} \)
\( tw = 0.125 \text{ in} \)
\( Aw = 0.5 \text{ in}^2 \)
\( \phi Vn = 15 \text{ kips} \)

\( \phi Vn > Vu \text{ OKAY} \)

Deflection Check

\( \Delta = 5wl^4/384EI \)
\( l = 0.486 \text{ in}^4 \)
\( \Delta = 0.02 \text{ in} \)

\( \text{IBC T1604.3} \)
\( \Delta_{allow} = L/180 = 0.09 \text{ in} \)

\( \Delta_{allow} > \Delta \text{ OKAY} \)

use HSS 2x2x1/8" girders for steel canopy
### STEEL CANOPY FRAMING - HSS COLUMN DESIGN

<table>
<thead>
<tr>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>L = 3 m</td>
</tr>
<tr>
<td>Dead</td>
</tr>
<tr>
<td>Live</td>
</tr>
</tbody>
</table>

#### Load Combinations

1.4D = 383.1 lb  
1.2D + 1.6L = 1640.7 lb \(\text{governs}\)

#### AISC 360

- **Compression**
  - \(P_u = 1.6\) kips
  - \(\phi P_n = \phi F_{cr Ag}\)
  - \(\phi = 0.9\)
  - check HSS2x2x1/8"
  - \(I_u = 9.84\) ft

#### E3-1

- \(\phi P_n = 7.63\) kips

\(\phi P_n > P_u\) OKAY

*use HSS2x2x1/8" columns for steel canopy*
STEEL CANOPY PAD FOOTING DESIGN

<table>
<thead>
<tr>
<th>psf</th>
<th>trib (ft^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead</td>
<td>7.65</td>
</tr>
<tr>
<td>Live</td>
<td>20.00</td>
</tr>
</tbody>
</table>

Load Combinations

\[
1.4D = 439.2 \text{ lb}
\]

\[
1.2D + 1.6L = 1688.8 \text{ lb} \quad \text{governs}
\]

\[
Pu = 1688.8 \text{ lb}
\]

\[
f_{\text{bearing}} = 1500 \text{ psf}
\]

\[
A_{\text{req}} = 0.89 \text{ ft}^2
\]

\[
b_{\text{req}} = 0.94 \text{ ft}
\]

\[
0.29 \text{ m}
\]

use 0.3x0.3x0.5m footing
PRODUCT DESCRIPTION & FEATURES

Concealed-fixing, also referred to as secret fix, is designed for very low pitched roofs. Because clips under the sheet hold it down, the sheet is not punctured with fasteners, and remains completely watertight even at a very low slope. The securing clips are pre-fixed into the purlins and the sheet is mechanically snapped onto the clip. As a concealed fix sheet can also expand and contract over the clips as the temperature changes, this system is ideal for long spans on industrial, commercial and retail buildings.

SAFLOK 700 is a concealed fix sheet profile with an effective cover width of 700mm. It is an angular interlocking standing seam trapezoidal rib profile, and is usually roll formed on mobile mills on the building site.

CLIPPING SYSTEM

The SAFLOK 700 clip incorporates a dual action component to positively hold down the male-female joint on every third rib, and an anchor to clasp the two inner ribs. Every rib is therefore secured, making it fully interlocking. It is essential that the male rib is directly engaged to the underside of the clip.

Clips for Aluminium Material:
- An Aluminium clip is a necessity when using Aluminium Material.
- When using Aluminium material on galvanized steel purlins it is recommended to make use of an isolation tape to prevent the bridging of the two dissimilar materials. The recommended tape is a "Dense LDG 300" or similar. Should the two metals have direct contact it will ultimately result in the manifestation of galvanic corrosion. The service life of the Aluminium will be compromised.

MATERIAL OPTIONS

<table>
<thead>
<tr>
<th>Aluminium - Zinc</th>
<th>Gauge [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ150 G550 Unpainted</td>
<td>0.50</td>
</tr>
<tr>
<td>AZ150 G550 Painted</td>
<td>0.50</td>
</tr>
<tr>
<td>Aluminium</td>
<td>Gauge [mm]</td>
</tr>
<tr>
<td>Aluminum Mill Finish</td>
<td>0.70</td>
</tr>
<tr>
<td>Aluminium G4 Coloritech</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Other gauges are available on special request.

SAMPLE SPECIFICATION

Safintra 0.50mm thick SAFLOK 700 Colorplus® AZ150 interlocking roof sheeting fixed to steel internal purlins at 2000mm, and ridge/eaves purlins at 1700mm centres using SAFLOK 700 clips which must be screw fixed to steel purlins with class 3 wafer head self-tapping screws, all in accordance with manufacturer's recommendations.

The sheeting will be a double interlocking concealed fix "SAFLOK 700" profile as manufactured by Safintra Roofing, roll formed in continuous lengths from certified G550 steel or aluminium 3504 H14.

The profile shall be roll formed with 4 ribs and centres not exceeding 233mm and a cover width not exceeding 700mm. The male rib is to include spurs to ensure a double interlocking action with adjacent sheets. The minimum sheet depth will be 41mm. Two stiffening ribs are incorporated in each pan.

We do not recommend using Saflon on a roof pitch exceeding 5 degrees due to the possibility of oil canning.
PURLIN SPACINGS

Span tables are for SAFLOK 700 with light foot traffic only. Span tables are based on 1.5kPa downward pressure, 1.6kPa upward pressure and 0.75kPa for the side cladding, inward or outward. The span tables are maximum recommended spans based on buildings up to 10m high in Region B, Terrain Category 3. For further clarity on terrain categories, and wind speeds, please refer to the Safintra Design and Installation Manual (specifically pages 5, 6 and 10, 11).

<table>
<thead>
<tr>
<th>GAUGE</th>
<th>MATERIAL</th>
<th>0.5mm</th>
<th>0.55mm</th>
<th>0.8mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ALUMINIUM-ZINC</td>
<td>ALUMINIUM-ZINC</td>
<td>ALUMINIUM</td>
</tr>
<tr>
<td>ROOFS</td>
<td></td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
</tr>
<tr>
<td>Single Span</td>
<td>1,400</td>
<td>1,700</td>
<td>1,400</td>
<td></td>
</tr>
<tr>
<td>End Span</td>
<td>1,700</td>
<td>2,100</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>Internor/Double Span</td>
<td>2,000</td>
<td>2,300</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>Cantilever [Unstiffened]</td>
<td>150</td>
<td>260</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Cantilever [Stiffened]</td>
<td>350</td>
<td>400</td>
<td>380</td>
<td></td>
</tr>
<tr>
<td>SIDE CLADDING</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Span</td>
<td>2,100</td>
<td>2,300</td>
<td>1,600</td>
<td></td>
</tr>
<tr>
<td>End Span</td>
<td>2,400</td>
<td>2,600</td>
<td>2,200</td>
<td></td>
</tr>
<tr>
<td>Internor Span</td>
<td>2,600</td>
<td>2,700</td>
<td>2,400</td>
<td></td>
</tr>
<tr>
<td>Cantilever</td>
<td>300</td>
<td>400</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Approximate Mass/m²</td>
<td>5.2kg</td>
<td>6.2kg</td>
<td>2.9kg</td>
<td></td>
</tr>
</tbody>
</table>

Saflok 700 clips are calculated at 330g per clip - require approximately 1.5 clips per m².

WIND SPEED TABLE

<table>
<thead>
<tr>
<th>Wind Zone</th>
<th>Purlin spacing for sheeting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (32 m/s) 115km/h</td>
<td>As per the profile span tables</td>
</tr>
<tr>
<td>Medium (37 m/s) 133km/h</td>
<td>As per the profile span tables - 5%</td>
</tr>
<tr>
<td>High (44 m/s) 158km/h</td>
<td>As per the profile span tables - 25%, all roof perimeters secured</td>
</tr>
<tr>
<td>Severe (50 m/s) 179km/h</td>
<td>As per the profile span tables - 25%. Consult your local Safintra branch</td>
</tr>
</tbody>
</table>

LENGTHS & ROOF PITCH

SAFLOK 700 can be ordered in any practical length as per customer requirements. On site rolling is recommended for lengths in excess of 13 metres. The minimum roof pitch when using SAFLOK 700 is 2° on steel and 3° on wood.

DRAINAGE TABLE

<table>
<thead>
<tr>
<th>DRAINAGE TABLE</th>
<th>ROOF SLOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAINFALL INTENSITY MM/HOUR</td>
<td>2°</td>
</tr>
<tr>
<td>250</td>
<td>75</td>
</tr>
<tr>
<td>300</td>
<td>65</td>
</tr>
<tr>
<td>400</td>
<td>50</td>
</tr>
<tr>
<td>500</td>
<td>40</td>
</tr>
</tbody>
</table>

Maximum roof run for roof slopes and rainfall intensities shown.
### Joint Coordinates and Temperatures

<table>
<thead>
<tr>
<th>Label</th>
<th>X [m]</th>
<th>Y [m]</th>
<th>Temp [F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>0</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N2</td>
<td>1</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N3</td>
<td>2</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N4</td>
<td>3</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N5</td>
<td>4</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N6</td>
<td>5</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N7</td>
<td>6</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N8</td>
<td>7</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N9</td>
<td>8</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N10</td>
<td>9</td>
<td>-0.4</td>
<td>0</td>
</tr>
<tr>
<td>N11</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N12</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N13</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N14</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N15</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N16</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N17</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N18</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N19</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N20</td>
<td>9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N21</td>
<td>1.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N22</td>
<td>1.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N23</td>
<td>2.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N24</td>
<td>2.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N25</td>
<td>3.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N26</td>
<td>3.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N27</td>
<td>4.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N28</td>
<td>4.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N29</td>
<td>5.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N30</td>
<td>5.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N31</td>
<td>6.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N32</td>
<td>6.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N33</td>
<td>7.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N34</td>
<td>7.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N35</td>
<td>8.2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N36</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N37</td>
<td>8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>N38</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Member Distributed Loads (BLC 1 : Dead)

<table>
<thead>
<tr>
<th>Member Label</th>
<th>Direction</th>
<th>Start Magnitude[kg/m]</th>
<th>End Magnitude[kg/m]</th>
<th>Start Location[m, %]</th>
<th>End Location[m, %]</th>
</tr>
</thead>
<tbody>
<tr>
<td>M10</td>
<td>Y</td>
<td>-50</td>
<td>-50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M11</td>
<td>Y</td>
<td>-50</td>
<td>-50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M12</td>
<td>Y</td>
<td>-50</td>
<td>-50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M13</td>
<td>Y</td>
<td>-50</td>
<td>-50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>M14</td>
<td>Y</td>
<td>-50</td>
<td>-50</td>
<td>0</td>
<td>0</td>
</tr>
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### Member Distributed Loads (BLC 2 : Live)

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RISA-2D Version 17.0.1 [U:\SENIOR PROJECT\truss design\RISA\truss_sloped_analysis.r2d]
### Member Distributed Loads (BLC 2 : Live) (Continued)

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## Maximum Member Section Forces (Continued)

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RISA-2D Version 17.0.1 [U:\SENIOR PROJECT\truss design\RISA\truss sloped half analysis.r2d] Page 1
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<td>-748,531</td>
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<td>1</td>
<td>-633,685</td>
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### Maximum Member Section Forces (Continued)

<table>
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<tr>
<th>LC</th>
<th>Member Label</th>
<th>Axial[kg]</th>
<th>Loc[m]</th>
<th>Shear[kg]</th>
<th>Loc[m]</th>
<th>Moment[kg-m]</th>
<th>Loc[m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>73</td>
<td>1 M37</td>
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<td>.208</td>
<td>1058.758</td>
<td>.198</td>
<td>65,262</td>
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<td></td>
<td>min -83.854</td>
<td>.198</td>
<td>-178.557</td>
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<td>.802</td>
<td>1173.579</td>
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<td>206.196</td>
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<tr>
<td></td>
<td></td>
<td>min 852.387</td>
<td>.792</td>
<td>-271.094</td>
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<td>-26.156</td>
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</table>
Table 6 shows the spectral values at T=0 s (PGA), 0.2 s and 1 s for both RP=475 and 2475 yr., as well as the values provided by GSHAP. It is highlighted that the PGA values for RP=475 yr. derived in this study are generally larger than those provided by GHSAP with differences larger than three times in Mombasa, Dar Es Salaam, Dodoma and Lilongwe. It also shows the highest hazard is in Bujumbura and Djibouti, again substantially higher than the equivalent GSHAP values.

Table 6: PSHA results in terms of spectral acceleration at T=0 s (PGA), 0.2 s and 1 s for RP=475 and 2475 yr. The PGA values provided by GSHAP are also show for comparison.

<table>
<thead>
<tr>
<th>Country</th>
<th>City</th>
<th>PGA GSHAP</th>
<th>PGA</th>
<th>SA (T=0.2s)</th>
<th>SA (T=1s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethiopia</td>
<td>Addis Ababa</td>
<td>0.13</td>
<td>0.11</td>
<td>0.29</td>
<td>0.71</td>
</tr>
<tr>
<td>South Sudan</td>
<td>Juba</td>
<td>0.18</td>
<td>0.13</td>
<td>0.36</td>
<td>0.89</td>
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<tr>
<td>Uganda</td>
<td>Kampala</td>
<td>0.09</td>
<td>0.09</td>
<td>0.18</td>
<td>0.45</td>
</tr>
<tr>
<td>Rwanda</td>
<td>Kigali</td>
<td>0.15</td>
<td>0.06</td>
<td>0.31</td>
<td>0.76</td>
</tr>
<tr>
<td>Burundi</td>
<td>Bujumbura</td>
<td>0.27</td>
<td>0.13</td>
<td>0.48</td>
<td>1.24</td>
</tr>
<tr>
<td>Kenya</td>
<td>Nairobi</td>
<td>0.09</td>
<td>0.06</td>
<td>0.21</td>
<td>0.54</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Dar Es Salaam</td>
<td>0.09</td>
<td>0.03</td>
<td>0.20</td>
<td>0.50</td>
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<td>Tanzania</td>
<td>Arusha</td>
<td>0.12</td>
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<td>0.23</td>
<td>0.56</td>
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<tr>
<td>Malawi</td>
<td>Lilongwe</td>
<td>0.20</td>
<td>0.05</td>
<td>0.37</td>
<td>0.94</td>
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<tr>
<td>Malawi</td>
<td>Blantyre</td>
<td>0.12</td>
<td>0.09</td>
<td>0.25</td>
<td>0.62</td>
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<tr>
<td>Djibouti</td>
<td>Djibouti</td>
<td>0.26</td>
<td>0.17</td>
<td>0.47</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Figure 5: Uniform hazard spectra at Addis Ababa, Kigala, Kampala and Nairobi (blue curves) compared with the elastic acceleration spectra derived from EN 1998 based on the PGA for RP=475 yr. and country seismic code criteria.
APPENDIX C: PRESENTATION
OUTLINE

➢ Project Partners
➢ Project Description
➢ Structural Design
➢ Challenges
➢ Travel Experience
➢ Takeaways
PROJECT PARTNERS - Journeyman International

- Non-profit company founded in 2009
- Design and construction of international humanitarian projects
- “Build What Matters Most”
CAL POLY JI TEAM

Mackenzie Dias
Architecture

Jenna Williams
Architectural Engineering

Julia De Hart
Architectural Engineering

Jake Stom
Construction Management
PROJECT PARTNERS - East African Power

- EmPOWERing Villages through Renewable Energy Development

- The 5 E’s
  - Energy
  - Environment
  - Education
  - Entrepreneurship
  - Enjoyment
PROJECT PARTNERS - East African Power
PROJECT DESCRIPTION - LOCATION
PROJECT DESCRIPTION - LOCATION

Project Site

Rubagabaga River

Kaseke Village
PROJECT DESCRIPTION - EVC and ATF

● **Empowering Villages Center (EVC)**

  “To provide space for assembly, social programs, skills trainings, and recreation”

● **Agricultural Training Facility (ATF)**

  “To allow local farmers to adopt innovative strategies that can make their land more profitable - even to a commercial level”
PROJECT DESCRIPTION - EVC and ATF
PROJECT DESCRIPTION - THE DELIVERABLES

- Architectural Design and Drawings
- **Structural Calculations and Drawings**
- Construction Costs and Quantity Take-Offs
STRUCTURAL DESIGN – THE CODES
STRUCTURAL DESIGN - MATERIALS

- Steel Decking
- Milled Eucalyptus
- Handmade Clay Bricks
- Concrete
STRUCTURAL DESIGN - COMPONENTS

- Steel Decking
- Eucalyptus Purlins with Steel Rod Bracing
- Eucalyptus Trusses
- Confined Masonry Walls
- Concrete Slab/Foundations
STRUCTURAL DESIGN – TRUSSES

ATF Truss

EVC Truss

Truss Connection Detail
STRUCTURAL DESIGN – DIAPHRAGM BRACING

Roof Plan

Rod to Purlin Detail
STRUCTURAL DESIGN – CONFINED MASONRY

Masonry Infill

Confined Masonry

Floor Plan

Missing Bricks
Confined Masonry Walls Considered
STRUCTURAL DESIGN – FOUNDATIONS

TYPICAL MASONRY WALL, SEE 43 & 44/54.0

6-16mm Ø BARS TOP AND BOTTOM

16mm Ø TRANSVERSE BARS TOP & BOTTOM

BOND BEAM, SEE 21/4.0 FOR TYPICAL REINFORCEMENT

SLAB ON GRADE

1.0m

2.0m
CHALLENGES

Material Availability

Confined Masonry Design

Interdisciplinary Teamwork
TRAVEL EXPERIENCE
TAKEAWAYS
Acknowledgements

**Journeyman International:**
Daniel Weins and Carly Althoff

**East African Power:**
Daniel Klinck and Brad Sanders

**California Polytechnic State University:**
Dr. James Mwangi
QUESTIONS?
APPENDIX D: WORKS CITED


[6] ACI 318-14: Building Code Requirements for Structural Concrete, American Concrete Institute, 2014.
