Design of a Care Facility for Young Mothers in Uganda

Introduction

A catholic church in Masaka, Uganda envisions a facility to house unwed mothers to provide space for their prenatal care, child birth, and a place to develop skills to earn a living.

The facility is to consist of three buildings:

- a clinic to provide medical care.
- an education center to train the mothers to develop skills enabling them to earn a living.
- a convent to provide housing, counseling and to meet the spiritual needs of occupants.

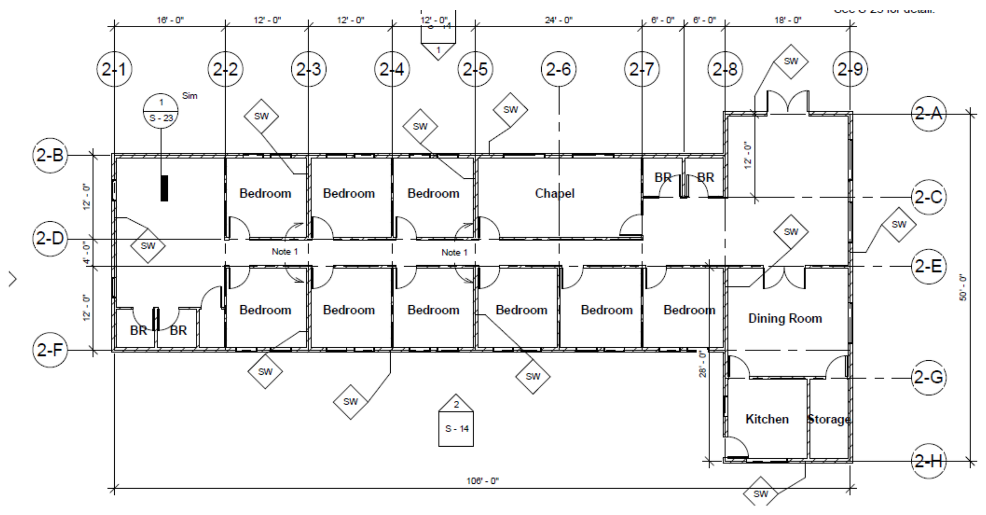
Scope of Work & Deliverables

- Project Proposal (submitted in Dec 15)
- Deliverables (submitted in May 16) consisted of
  - site and Architectural lay out of facility,
  - construction Material selection,
  - structural design of roof trusses, shear walls, and foundation recommendation, and
  - a 32-page plan set showing Engineering Drawings of the facility.

Design Constraints & Challenges

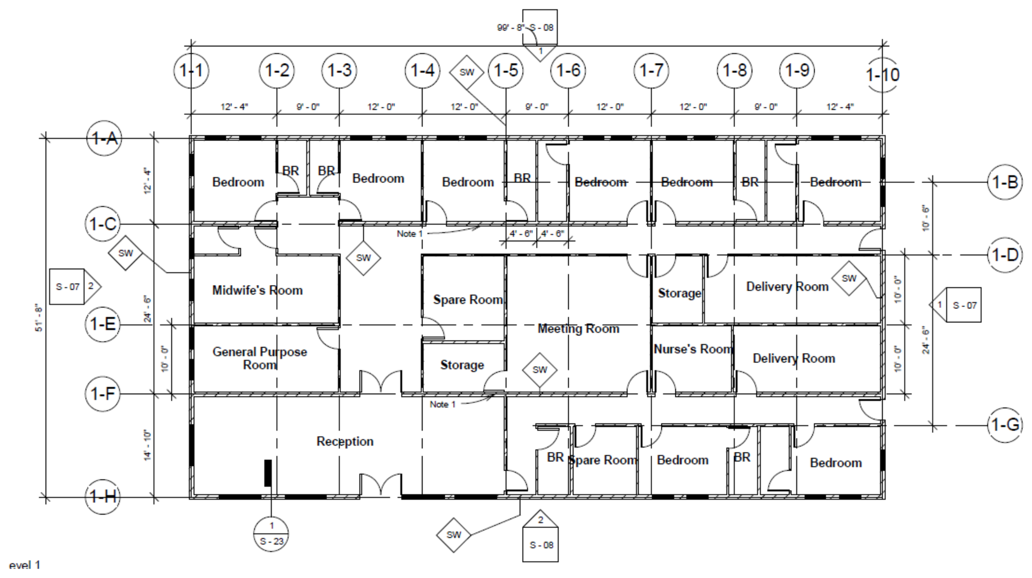
- Team researched local construction materials and practices and discovered that walls are made of clay fired bricks, Mahogany for roof trusses, and corrugated metal for roofing plus use of reinforced concrete to be limited due to cost.
- Due to frequent power outages, ventilation and daylighting was optimized during design.
- Due to lack of local design codes, International Building Code was used in design.

Engineering Design Work

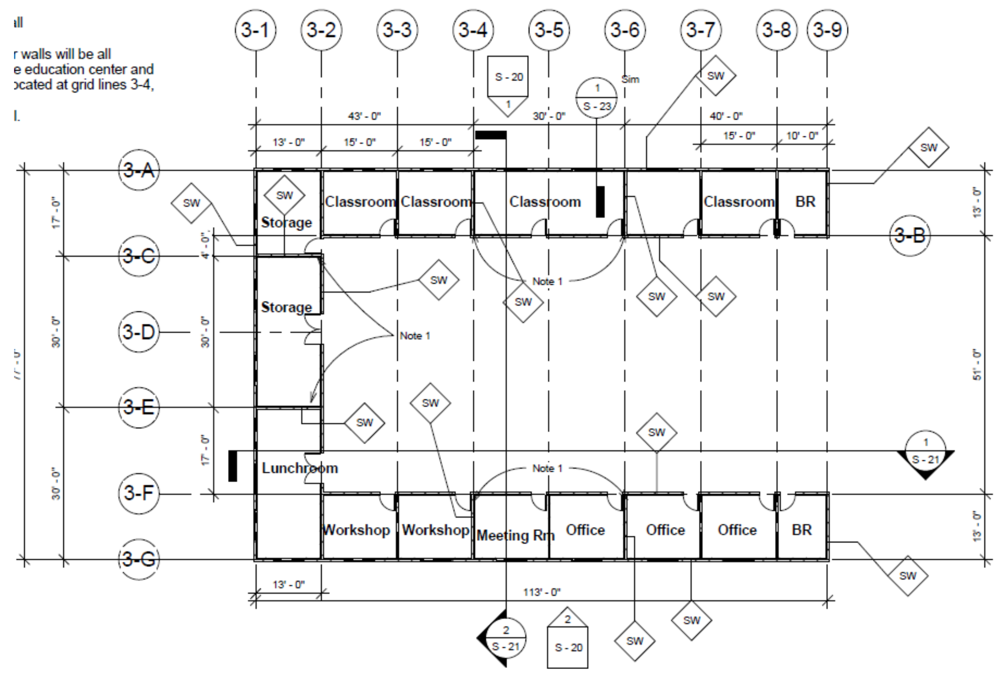


Convent Floor plan

Facility Site Layout

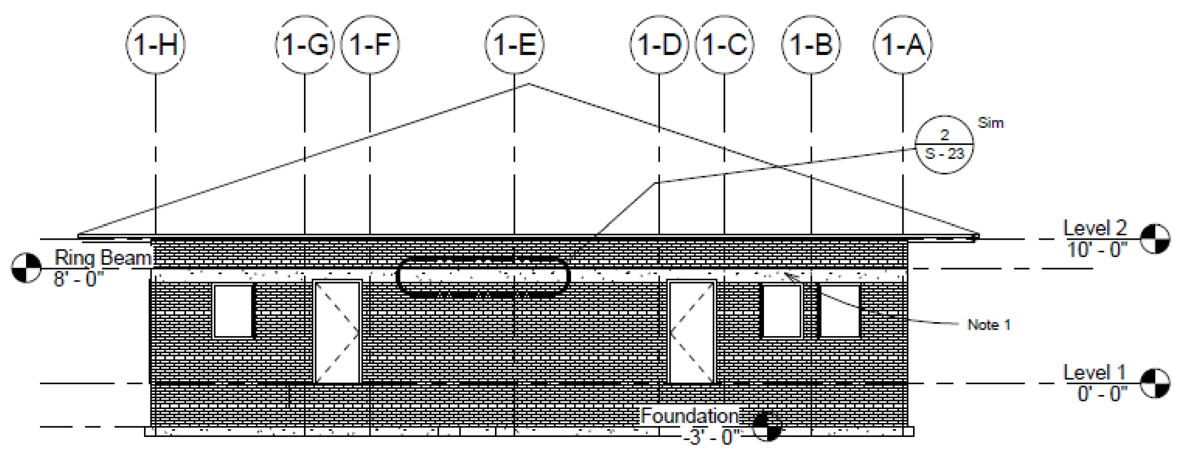


Clinic Floor plan

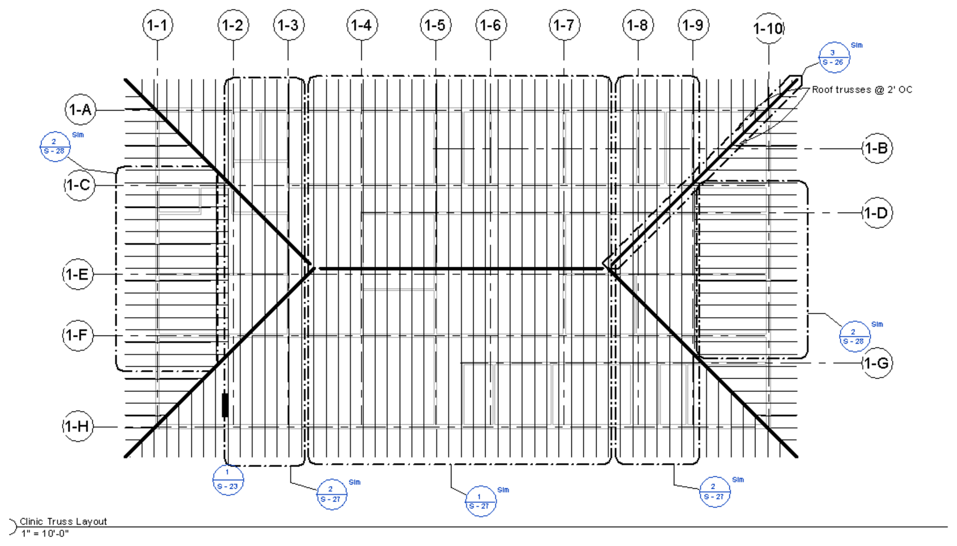


Education Center Floor plan

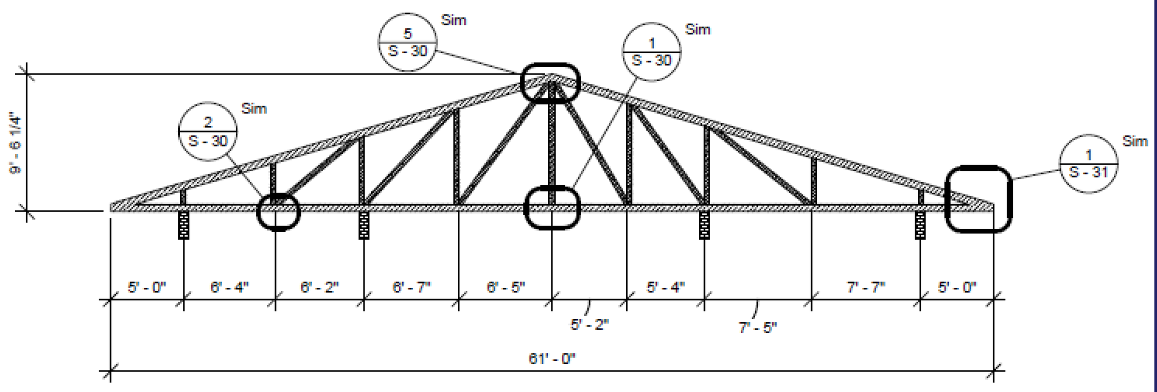
Examples of Engineering Drawings of Clinic



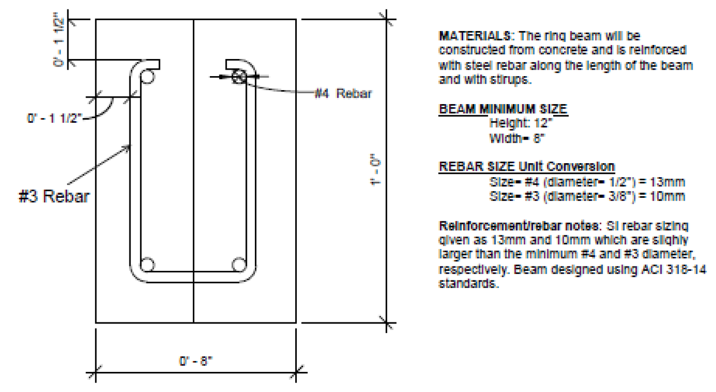
Clinic East Elevation



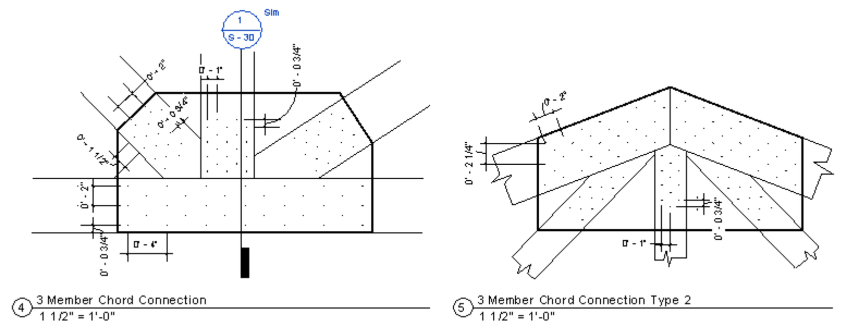
Clinic Roof Truss Plan View



Main Truss in Clinic



Cross section of Ring Beam



Roof Connection Design

A plan set consisting of 32 sheets of engineering design drawings were developed for the facility.

Faculty-Student-Licensed & Allied Professional Collaboration:

Three civil engineering students worked with two licensed faculty members and two engineers from a local company, one of whom is a Structural Engineer (SE) and Leadership in Energy and Environmental Design (LEED) professional and the other a Professional Engineer (PE). Both from Uganda, a nun served as the client and an architect served as a resource to the team.

Benefits to Public Health, Safety & Welfare:

In any culture, a mother's health, security, and welfare greatly impact a child's future well being. This project, when implemented, will provide a strong foundation to a marginalized group.

Knowledge & Skills Gained

- **Technical Expertise**
  - Developed working knowledge of international building code (IBC 2012), American Society of Civil Engineers Standard ASCE 7-10, American Concrete Institute ACI 318-08, 2012 National Specification for Wood Construction
  - Familiarity with Computer Software: AutoCAD 2015, Revit 2016, and SAP2000
- **Communication and Collaboration**
  - Developed public speaking and technical writing skills.
  - Interpersonal communication with a lay-client, professional engineers, and an architect.
- **Professional Skills**
  - Project Management skills: running meetings, preparing meeting agenda, following up on action items, scheduling, and professional responsibility.
  - Ability to be team players.
  - Exposure to societal, cultural, and global issues.
  - Appreciation for human-centered engineering, public safety and welfare.

Design of a Care Facility for Young Mothers in Uganda

Abstract

A nun from Uganda approached our department with a vision of developing a facility in her country to provide services to unwed pregnant women who are abandoned by their families. A team of three civil engineering seniors worked on this project as part of their year-long capstone experience. The students were supervised by two faculty advisors and two practicing civil engineers from a local structural engineering company, all professional engineers (PE). One of the practitioners was also structural engineer (SE) and a Leadership in Energy and Environmental (LEED) certified professional. An architect from Uganda served as a resource to the team to answer any questions on the local construction practices.

The facility consisted of three buildings: a clinic to provide pre- and post- natal care for the mother and baby, an education center to provide skills to the mothers to earn a living, and a convent to provide accommodation and to meet the spiritual needs. The nun provided hand drawn sketches showing the desired features in two of the buildings. The team improved these sketches with input from the PE, SE and LEED professionals and came up with a revised architectural layout for the facility. The team was responsible for the site and architectural layouts of the buildings, structural design of the roof, walls and the foundations. The team researched the construction materials and local construction practices in Uganda and methods to determine site specific forces (wind and seismic) acting on the structure. Through this project the team learned ways to modify or customize codes and construction practices to fit the needs of a developing country.

The students became aware of global and cultural differences and how their engineering work could positively impact unwed mothers who are a marginalized group in Uganda. This project when implemented could change a whole community as the health and wellbeing of a child is closely tied to that of the mother.

The project experience helped the team to improve their communication skills. During the year the team presented its work to the local structural engineering company, professional societies (local chapter of American Society of Civil Engineers and Structural Engineering Association), the departmental advisory board members and to their fellow students. The team prepared a written proposal for the nun in fall quarter describing the project scope and approach; in spring quarter it prepared a final report describing the final design, a 32-page engineering drawing set and a tri-fold project poster. The team also learned to interact with a non-civil engineering client, and an international architect.

The team applied their engineering knowledge and skills they acquired from course work and internships to a real life project. They developed various project management skills: time management, scheduling, and team work. Each student served as the project manager for a quarter and was responsible for setting up team meetings, preparing agendas, running the meeting, assigning tasks to team mates and following up on the completion of previously assigned tasks. The project gave the students a renewed sense of appreciation for global issues and human centered engineering.

Design of a Care Facility for Young Mothers in Uganda

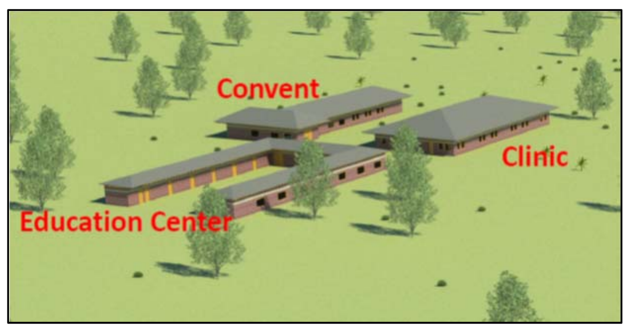
I. Project Description

Introduction

In Uganda young women who become pregnant out of wedlock are ostracized and abandoned by their family. A Catholic Church in Uganda is planning on developing a facility to support these mothers providing them with prenatal care, assistance during child birth, educating them on newborn care and developing skills to earn a livelihood after their babies are born. A nun from the church (hereafter referred to as the Client) approached our department to carry out the preliminary design for this facility as part of our senior design program. The Client was envisioning a facility consisting of three buildings: a clinic, a convent and an education center. The facility was to be built on a flat agricultural land just outside Masaka, Uganda.

Three civil engineering seniors and a licensed faculty member were assigned to this project. A Structural engineering company near our university provided two of their licensed engineers as consultants to the team. The Client introduced an architect from Uganda to the team to serve as a resource to learn about Ugandan construction practices. Figure 1a shows the site where the facility is to be built. The student team came up with a site layout for the three buildings as shown in Figure 1b.

a)



b)

Figure 1. a) Site for the Facility; b) Facility Layout Developed by the Team

Design Consideration, Constraints and Challenges

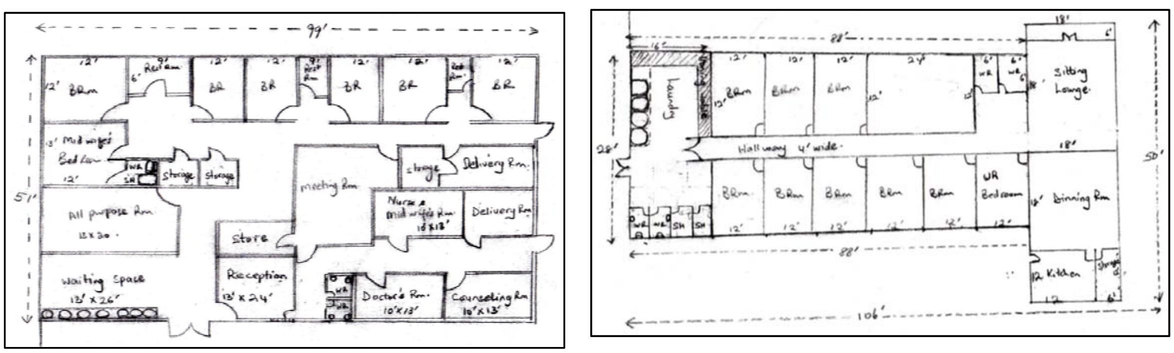
The Client requested the team to provide an architectural layout for the facility, select appropriate construction material and design of the structural members, namely the roof, walls and foundations, for the three buildings. The team came up with the site layout with a central court yard as presented in Figure 1b. Due to page limitation, detailed floor plans that the teams developed for the three buildings are presented in the poster.

The design team researched local construction practices and construction materials. From the research, the team decided to use corrugated metal sheets for the roof and Mahogany for the roof trusses. Walls were to be of clay fired bricks and mortar. Reinforced concrete was used in limited quantities to keep the cost low. Because the area experiences frequent power outages, the team incorporated passive systems such as increased ventilation and daylighting in the design.

Uganda has no local structural codes and standards. Therefore the team adopted the 2012 International Building Code and the 2010 American Society of Civil Engineers ASCE 7-10 for the design loads. The mechanical properties of Mahogany were not listed in these design codes as it is not used for structural members in the US. Through research the team found that Red Oak had properties closest to that of Mahogany and therefore used those values in the design.

In addition to the dead and live loads, the team had to consider wind and seismic loads in their design. Maximum gust speeds are required for wind load calculations. However, only sustained winds were available for Masaka. Through literature review the team learned how sustained winds could be converted to obtain gust speeds. For seismic loading the team used the earthquake loading data obtained for Kampala which is about 80 miles from Masaka.

Technical Details
The Client provided hand-drawn sketches of the floor plans showing the desired features for two of the buildings (Figure 2). Using the sketches as the starting point, the team developed an improved architectural layout for the buildings with input from the structural engineering company liaisons. For example, the team relocated the bathrooms to maximize ventilation, added a reception area in the clinic to improve patient safety, and rearranged the classroom in the education center in a horseshoe shape to create a central courtyard as shown in Figure 1b. All three buildings were designed as single story structures for the occupant safety.



a) b)

Figure 2. Hand Drawn Sketches Provided by Client, a) Clinic, b) Convent

Roof Truss Design
The team designed Mahogany roof trusses with 1V:3H slopes and a five foot overhang. Figure 3 shows the main roof truss configuration for the convent, one of 12 configurations the team designed for different parts of the facility. In each case, the team sized the truss members by computing the demand to capacity ratio (D/C) for different modes of failure: bending, shear, tension, and buckling. For satisfactory performance a member must have a D/C ratio of less than 1. As an example, Table 1 shows the D/C ratios for the truss presented in Figure 3.

After sizing the structural members, the team designed the connections between the members. Figure 4 shows one of the typical connections (at the junction of members 3 and 8 in Figure 3). Typically gang nail plates are used for such connections in the US. However, in this project to keep the cost low and to avoid prohibitive components the team designed a timber gusset plate.

The top and bottom chords (members 1, 2 and 3 shown in in Figure 3) were too long to be designed as a single member. Therefore the team designed splices near points of least moments within each member. The splices consisted of two 1½ in thick, 4x6 timber pieces attached to both sides of the chords with wooden nails for load transfer. Figure 5 shows a cross sectional view of an example splice.

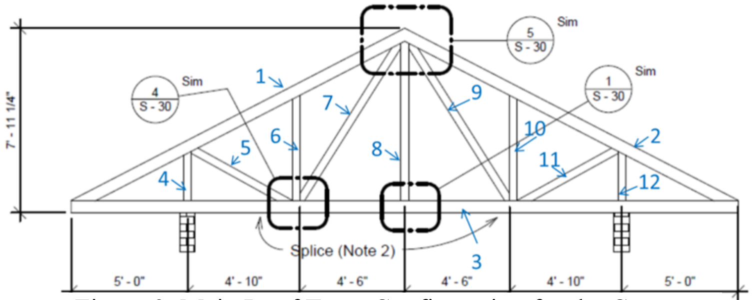


Figure 3. Main Roof Truss Configuration for the Convent

Table 1. Demand (D) vs. Capacity (C) for Convent Main Roof Truss Members

Member	Size	Length (ft)	Compression/Buckling			Tension			Shear			Bending		
			D (psi)	C (psi)	DCR*	D (psi)	C (psi)	DCR	D (psi)	C (psi)	DCR	D (psi)	C (psi)	DCR
1, 2	4x6	20.7	171	376	0.45	0	594	0.00	51	356	0.14	151	797	0.14
3	4x6	38.7	58	394	0.15	16	594	0.03	76	356	0.21	190	797	0.21
4, 12	4x4	1.9	137	512	0.27	0	594	0.00	0	356	0.00	0	801	0.00
5, 11	4x4	7.4	0	384	0.00	25	594	0.04	1	356	0.00	0	799	0.00
6, 10	4x4	4.7	26	475	0.05	7	594	0.01	0	356	0.00	0	800	0.00
7, 9	4x4	10.3	5	260	0.02	35	594	0.06	1	356	0.00	0	798	0.00
8	4x4	7.4	0	288	0.00	153	594	0.26	0	356	0.00	0	599	0.00

* Demand to Capacity ratio

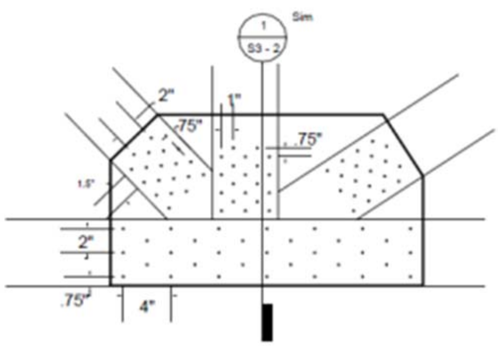


Figure 4. Profile View of a Sample Structural Connection

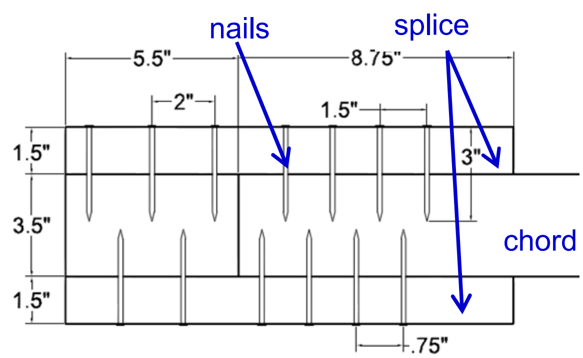


Figure 5. Cross Sectional View of an Example Splice Connection

Shear Wall Design

The walls carry vertical gravity loads and lateral wind and seismic forces and were to be made of clay fired bricks with mortar. The team sized the walls by computing the demand and capacity for the walls for in plane shear (where the lateral force is parallel to the plane of the wall) and for out of plane shear (where the lateral force is perpendicular to the wall). Table 2 shows the critical demand-capacity values for the three structures. Based on this analysis, the exterior walls were to be of double wythe (or thickness) of 8 in. while the interior walls had a single wythe of 4 in.

Ring Beam and Roof-Wall Connection Design

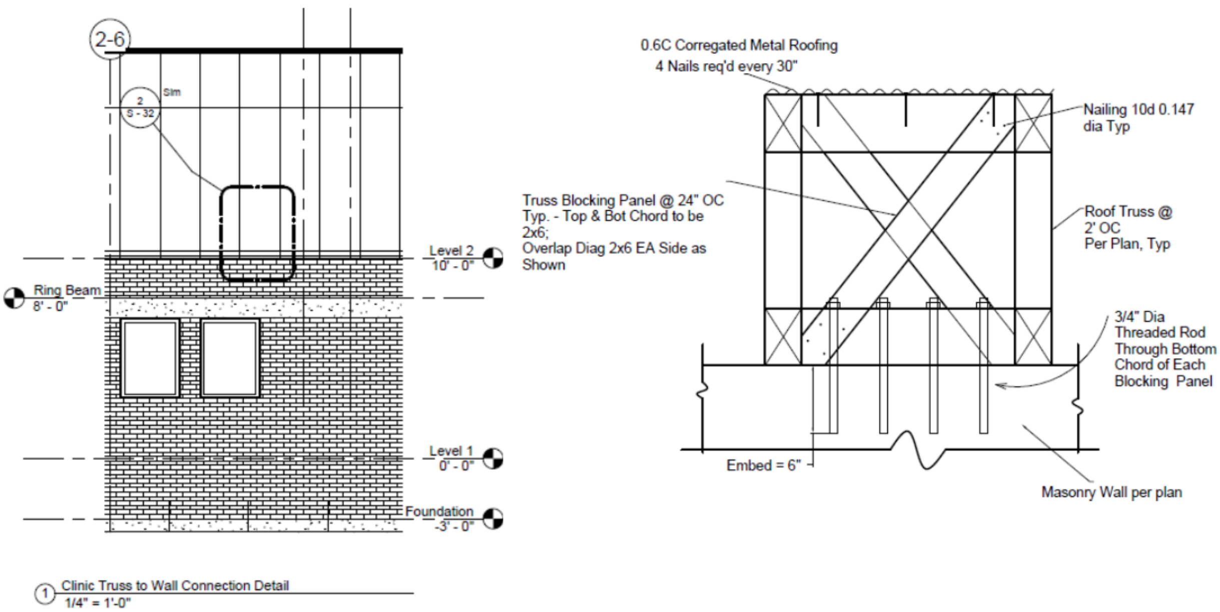
An 8 in wide, 12 in deep reinforced concrete ring beam located 8 ft above the ground served as a header above doors and windows and rested on top of the clay fired brick wall as shown in

Figure 6a. The ring beam wrapped around the outer walls of each of the three buildings was designed to withstand the seismic forces and ensured that each building acted as a single unit.

Table 2. Demand (D) to Capacity (C) Ratio for the Shear Walls

Failure mode	Facility	Demand	Capacity	DCR*
In-plane bending	Education center	19 kip	120 kip	0.16
	Clinic	120 kip	175 kip	0.69
	Convent	48 kip	55 kip	0.87
Out-of-Plane bending	All three structures	14.1 psi	30.6 psi	0.46

* Demand to Capacity ratio



a) b)

Fig 6. Elevation View of the Clinic showing a) Ring Beam Placement; b) Blocking Panel and Cross Bracing

The team designed blocking panels and cross bracings to prevent rotation and lateral displacement of the roof truss members. Blocking panels are small rectangular cross bracings installed between two main roof trusses to transfer the lateral forces acting on the roof system in to the shear walls. Figure 6b shows the blocking panel and cross bracing placement.

Foundation Recommendations

The team could not obtain the soil properties at the project site. Therefore it assumed a conservative allowable bearing capacity of 2000 psf and recommended a strip footing along the shear walls of the buildings. The team provided two options: one for a foundation that could rest directly on bed rock or a competent stratum located within 3 feet from the ground surface and another if the bed rock were deeper. Figure 7 shows the recommended foundation options.

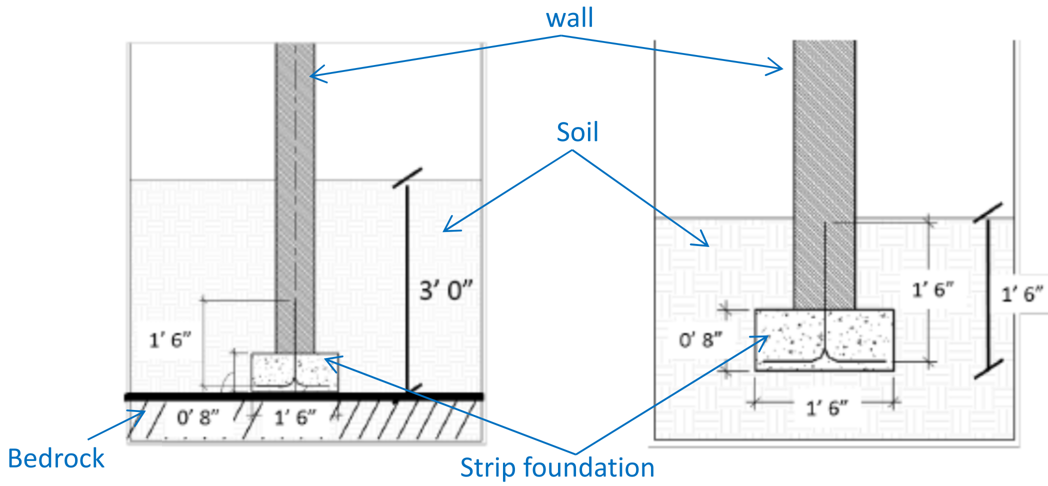


Figure 7. Recommended Foundation Options, a) if Bedrock is near Ground Surface, b) if Bedrock is Deeper

II. Collaboration of Faculty, Students and Licensed Professional Engineers

All engineering students are required to successfully complete a team-based, nine month-long capstone project for an external client. In this project a three-person student team was supervised by two civil engineering faculty members both licensed professional engineers. In addition, two engineers from a company near the university served as consultants to the team – one of them is registered structural engineer (SE) and the other a professional engineer (PE). The students met with the faculty member weekly and with their industry engineers every two to three weeks. The faculty members provided technical assistance and provided feedback on several drafts of the proposal in fall quarter and the final report in spring quarter. The practicing engineers educated the team of US construction practices and how these practices could be modified for Uganda.

It is mandatory for all capstone teams to participate in an annual ASCE local section presentation competition. These presentations were judged by a panel of five licensed civil engineering practitioners. The format for this competition is a 15 minute oral presentation followed by questions and answers. In addition, the team presented their proposal to the local Structural Engineering Association at one of their monthly meetings.

Our department has an active industrial advisory board consisting of about ten professional engineers. The board meets twice a year to discuss industry-academic partnership issues. The team made an oral presentation to the board in fall describing their project scope and plan of action. In spring quarter the team presented their final design and recommendations to the advisory board.

III. Benefit to Public Health, Safety and Welfare

Research shows that the health and wellbeing of a child is directly correlated to that of the mother's health and education. At the start of the academic year the nun from Uganda narrated stories of young mothers to the team – some of them sad, resulting in the death of the mother and some with happy ending where the mother and the baby were eventually reunited with their families. This made the students aware of the positive impact their work could have on a marginalized group. The project made the students aware of global and cultural issues in other countries and exposed them to human-centered engineering.

IV. Multidiscipline and Allied Professional Participation

The structural engineer (SE) who was advising the team from the local company also happened to be a Leadership in Energy and Environmental (LEED) certified professional. This was useful when the team was trying to optimize the ventilation and lighting for the buildings. The nun from the Ugandan Catholic Church was in the US during the project initiation to meet with the team and to discuss the Client needs. She returned to Uganda at the end of fall quarter and was in touch with the team via email. She introduced an architect from Uganda to serve as a consultant to the team to answer any questions related to local construction practices. An electrical engineer who is an alumnus of the university was a friend of the Ugandan nun. He served as the Client's local representative in her absence. He also established a non-profit organization to raise funds to eventually implement the project. The team's final design package was useful in raising funds. Since graduating one of the students serves on the Board for this non-profit organization.

V. Knowledge and Skills Gained

Students developed the following knowledge and skills through this project: technical expertise, communication and project management skills, ability to work in a team setting and to interact with a non-engineering, international client. They also learned about US construction practices and how they could be modified to meet the needs of developing countries.

a) Technical Expertise Gained

The students learned how to carry out an owner's dream of a project from the conceptual stage through architectural drawings to engineering design. Through the design process they acquired the skills to use the following tools:

- <u>Design Manuals</u>: International Building Code 2012 (IBC 2012), American Society of Civil Engineers standard 7-10 (ASCE 7-10), American Concrete Institute 318 (ACI 318-08), 2012 National Design Specification for Wood Construction,
- <u>Computer aided drafting</u> with AutoCAD 2015, Revit 2016
- <u>Design Software</u>: SAP2000 for load distribution analysis

b) Communication skills

The students gained experience working for a non-engineering client. The team had to translate the Client's "language" of needs and functional requirements to engineering "language" of design parameters and constraints. Then the team had to prioritize the functional requirements of the owner, convert them into measurable parameters prior to the design.

The students were required to make formal oral presentations to their peers twice a quarter. Each student had to make at least one of these presentations each quarter. The team members also gave brief informal oral progress reports to the class every other week. The College of Engineering held an on-campus mini-conference style event which was attended by university and local community, industry representatives, alumni and families and friends of team members. The team also prepared a tri-fold poster for this event and learned how to do a poster presentation. As mentioned earlier, the students also made presentations to the professional community in several occasions.

Improving technical writing skills of our graduates is an important focus in our program. Therefore, the team was required to submit a written proposal to the Client at the end of fall quarter, describing the scope of work, plan of implementation, and schedule. At the end of spring quarter, they submitted a final submittal package to the Client. This consisted of a written report describing the work done, engineering calculations and a 32-page engineering plan set.

c) Project Management skills

The project gave the students an opportunity to develop some of the project management skills – time management, scheduling and team work. Each student played the role of a project manager (PM) for a trimester. The PM was responsible for: organizing weekly meetings, coming up with meeting agendas based on project needs, running the meetings, keeping track of action items and following up on them at the next meeting. In addition, the project manager was in charge of communicating with the Client, the engineering consultants from the local company and the faculty members between team meetings.

d) Global Awareness and Human Centered Engineering

Students were exposed to construction materials and practices in Uganda which are different than in the US. They also learned how to improvise the US and international design codes for a developing country and to research design parameters for countries outside the US. At the end of the project the students had a renewed sense of appreciation for human centered engineering where they focused on the people for whom they carried out the design.

VI. Summary

As part of the capstone requirement, three civil engineering seniors designed a building complex consisting of a clinic, education center and a convent for unwed, pregnant women for a catholic church in Uganda. A nun from Uganda served as the client. Two professional civil engineers from a US civil engineering company, one a SE and a LEED professional and the other a PE, served as consultants to the team. Two faculty members, both licensed civil engineers, guided the team throughout the year. The project, when implemented, will provide a safe haven to women and their babies who are abandoned by their families. This project provided the students an opportunity to offer engineering services to a marginalized community while developing the team's project management, leadership and communication skills, understanding consultant-client relationships, and an appreciation for global issues and human centered engineering.