

# **TEAM 16: CAMBODIANFINITY**

## **Final Design Report**



**Jon Cooper, Mike Vance, Aaron VanProyen, Mark Volle**

**Engineering 339/340**

**May 7, 2008**

© 2008 Calvin College & Jonathan Cooper, Michael Vance, Aaron Van Proyen, and Mark Volle

## Table of Contents

|                                     |    |
|-------------------------------------|----|
| 1. Executive Summary .....          | 2  |
| 2. Introduction.....                | 4  |
| 2.1 Background.....                 | 4  |
| 2.2 Requirements .....              | 4  |
| 2.3 Team Cambodianfinity .....      | 5  |
| 3. Problem Specification.....       | 5  |
| 3.1 Background of Cambodia .....    | 5  |
| 3.1.1 The People .....              | 5  |
| 3.1.2 Climate.....                  | 6  |
| 3.2 Problem Background .....        | 7  |
| 3.3 Project Requirements .....      | 8  |
| 3.3.1 Cultural .....                | 8  |
| 3.3.2 Structural.....               | 8  |
| 3.3.3 Building Use .....            | 9  |
| 3.4 Prior Work .....                | 9  |
| 4. Proposed Solution .....          | 10 |
| 4.1 Project Management .....        | 10 |
| 4.1.1 Team Organization.....        | 10 |
| 4.1.2 Task and Time Breakdown ..... | 10 |
| 4.1.3 Design Schedule.....          | 11 |
| 4.2 Cost .....                      | 11 |
| 4.3 Design .....                    | 13 |
| 4.3.1 Beam Design .....             | 13 |
| 4.3.2 Column Design .....           | 14 |
| 4.3.3 Slab Design .....             | 16 |
| 4.3.4 Septic Design .....           | 17 |
| 4.3.5 Lateral Bracing.....          | 19 |
| 4.3.6 Lintel Design.....            | 20 |
| 4.3.7 Truss Design .....            | 21 |
| 4.3.8 Stair Design.....             | 23 |

4.3.9 Foundation Design ..... 24

4.3.10 Site Development..... 26

4.4 Addendum #1..... 27

4.5 Construction Management ..... 28

4.5.1 Constructability..... 28

4.5.2 Construction Schedule ..... 29

5. Conclusion ..... 29

5.1 Recommendation ..... 29

5.2 Future Work..... 30

6. Acknowledgements..... 30

**Table of Appendices..... 34**

**Table of Tables**

Table 3.1.2: Average Monthly Temperatures, Rainfall, and Rainy Days.....7

Table 3.3.2: Building Loads.....9

Table 4.1.2: Task Time Summary..... 11

Table 4.2.1: Cost Analysis..... 12

Table 4.3.4 Water Use Estimate..... 18

**Table of Figures**

Figure 4.3.1: Beam Detail..... 14

Figure 4.3.2 (a): Typical Column Connection Detail..... 15

Figure 4.3.2 (b): Column Cross Section Detail..... 16

Figure 4.3.3: Elevated Slab Detail..... 17

Figure 4.3.4: Septic Lateral Cross Section..... 19

Figure 4.3.6: Lintel Connection..... 21

Figure 4.3.7 (a): Pratt Truss.....22

Figure 4.3.7 (b): Final Truss Design.....23

Figure 4.3.8: Typical Stair Detail.....24

Figure 4.3.9: Large Spread Footing.....25

## 1. Executive Summary

The goal of this project was to design a structure for Bethany International University (BIU) that will be used for agricultural education and research. The building was designed using reinforced concrete, clay bricks, and fabricated steel as the principal construction materials. These can be typically found in Cambodia, and are common in construction practice. The academic building is two stories, which includes classroom and office space, a large agricultural research space, and adequate room for storage of tools and other farming implements. In addition to a complete set of structural plans and site plans, Addendum #1 was issued in the project blueprints and includes the addition of a wheelchair ramp for handicap access to the second floor. Work included in Addendum #1 involves the addition of reinforced concrete columns, relocation of windows and vents, and revised masonry work. Rather than including the ramp in the bid design, the “owner” is provided with a designed alternative should they choose to furnish the building with full handicap access. This work is presented as an addendum because a ramp is not typically built in Cambodia, but is important to provide access to all potential occupants of the building. As BIU develops and grows, their use of the building may change so the building was designed with flexibility and multi-use space as priorities.

The land on which the agricultural facility is to be built is heavily vegetated, with scrub trees and vines throughout. Heavy site work will be needed to clear the building pad and other developed areas, which includes a parking lot, septic leach field, and retention pond. Soils that are excavated and approved for reuse will need to be stored on site for subsequent backfilling. Also, extra space will need to be cleared for staging of materials, such as brick, concrete formwork, rebar, and clay roof tiles. Once the site is cleared, the building pad will need to be prepared by building up the material so that upon completion any precipitation runs away from the building and toward the retention pond where possible. Following completion of the building pad, footing excavation may begin and the area surrounding the building may be graded to follow the contours in the site plan.

A cost estimate was performed following the design of the building and property. The total cost of the facility in Cambodian riel is KHR 870,419,374. The equivalent cost is US\$ 217,844. This part of the project was very difficult to assess, as many of the materials costs are not provided for

Cambodia. As a result, costs were determined in various countries in Southeast Asia, such as India, Malaysia, and China. It is assumed that costs from these countries are similar to that of Cambodia. Also, labor costs were difficult to determine and were estimated based on figures for skilled laborers in Malaysia and Singapore. A 25% contingency was figured into the total cost for engineering fees and potential changes during the construction phase. Pricing for Addendum #1 is not included in this cost, but should the owner choose, the added cost would be KHR 17,424,041. The equivalent cost is US\$ 4,379.

## 2. Introduction

### 2.1 Background

Bethany International University (BIU), formerly known as Asia International University, is a biblically based university to be built in Siem Reap, Cambodia. The vision for the university is to “raise up change agents who will see their world transformed.” BIU will have a strong emphasis on their agricultural program because they are seeking to provide their students with applicable skills that they can use to affect their communities. The vision is to attract farmers from rural areas of the country to equip them with new rice farming technologies such as a System of Rice Intensification (SRI). This is one farming technique that is very counter intuitive. There are a number of different practices that qualify rice as “SRI” rice, but a few of them include planting a single shoot and spacing them farther apart in the paddy. This technique has been shown to produce about double the rice harvest as opposed to traditional farming techniques. Once the farmers complete a program of study and application, they can impart the new techniques in the rice paddies around their villages. Because of this, an agricultural research and education facility is a very important component of the campus, and has been prioritized as one of the first buildings to be constructed. Since it is planned as the first building of the campus, versatility is a big priority as the building may need to be used for special events.

### 2.2 Requirements

Team Cambodianfinity established the following goals that will be used to determine the success of the project.

- The building must provide sufficient space for BIU students to conduct various agricultural labs and experiments in a controlled environment.
- The building must include office and classroom space.
- The building must be designed using culturally appropriate building materials and construction methods.
- The building must be architecturally consistent with the BIU master plan and buildings from the Siem Reap area.
- The design must include site development.

## **2.3 Team Cambodianfinity**

Team Cambodianfinity is comprised of four Calvin College senior Civil Engineering students. The team members share a desire to change the world they live in and make a difference in lives of others, all in God’s name with His help. The members are Jon Cooper (Kalamazoo, MI), Mike Vance (St. Clair Shores, MI), Aaron VanProyen (Canton, MI) and Mark Volle (Colorado Springs, CO). Academically, the group has two years of both structural and hydraulic experience, which was beneficial to the design of the building presented in this project. Some team members also have experience working on construction projects through various internships, which has helped in the design process.

## **3. Problem Specification**

### **3.1 Background of Cambodia**

#### **3.1.1 The People**

The population of Cambodia is very young, with 50% of the population younger than age 25. Also, only 3.1% of the population is age 65 or older. Most of the residents speak Khmer, while some of the older Cambodians speak French as a second language. 95% are Buddhists, while 3% are Islamic, and only 2% are Christian.

In recent decades, Cambodia has suffered many losses as a result of war and political unrest. In the early 1970’s, the United States was at war against the Viet Cong army from Vietnam. The Viet Cong were found in Cambodia, and the U.S. conducted bombings to drive them out. Nearly 2 million Cambodians were made refugees by the bombings and fled to the capital, Phnom Penh.

Then, in mid 1975, Phnom Penh was overtaken by the Khmer Rouge, led by Pol Pot. This group consisted of radical communists who forced the Cambodian society into working on collective farms and labor projects. During this time, Pol Pot forced schools, hospitals, factories, churches, and banks to close, shutting down the educational system, finances, and outlawing all religions. He also took private property for himself, and forced all city dwellers into manual labor camps. An estimated 1.5 million people died from execution, forced labor, and starvation. In 1979, the Khmer Rouge was attacked by Vietnam from the west; an attempt by the Vietnamese to keep

communism out of their country. They were successful, and took over rule once the Khmer Rouge was gone.

Through this hardship, many families and communities were split apart. Children grew up as orphans, communities and society fell apart, and the way Cambodians related to each other became strained. The country of Cambodia has suffered immensely. The overall goal of this project and of Bethany International University is to bring restoration to a small facet of everyday life of many Cambodians. Through a more sophisticated understanding of farming and agricultural practices, building relationships with one another, and developing agents of renewal in their society, BIU can bring change to a devastated nation.

Since the 1990's, when Cambodia became a Constitutional Monarchy, the country has moved toward rebuilding infrastructure and housing, particularly in the impoverished country sides. Many developed nations have aided Cambodia economically, and are helping with its stability. Just recently, the Angkor Wat temple was opened to public viewing. The temple was designated a World Heritage Site, and receives much tourism. This inflow of outside visitors has helped bring money into the Siem Reap area, and helped with modern development. However, only a few people realize the economic boost from the tourism. Land developers and hotel owners are often international entrepreneurs and the money generated from this industry does not return to the local economy. As a result, the majority of the population still lives in poverty.

### **3.1.2 Climate**

The climate in Cambodia is dictated by its proximity to the equator. It can be best described as tropical weather with seasonal monsoons. During the rainy season months of May through October, winds from the southwest blow off the Gulf of Thailand and the Indian Ocean, bringing an average of 220 mm of rain per month. There is an average of 20 days of rain for each month during the monsoon season, with temperatures ranging from 25° C to 32° C. November through March is the dry season, with temperatures ranging from 20° C to 31° C. A specific breakdown of monthly mean temperature and rainfall is provided in Table 3.1.2 (below). Winds come from the northeast and are dry and cooler. Throughout the year, the humidity remains relatively high, around 60% during the rainy season, 50% during the dry season, and about 90% at night. The overall average rainfall in Cambodia is 150 cm. The table also shows average daily minimum and maximum temperatures, as well as mean rainfall and mean number of rain days for each month throughout the year.

| <b>Month</b> | <b>Mean Temperature °C</b> |                      | <b>Mean Total Rainfall (mm)</b> | <b>Mean Number of Rain Days</b> |
|--------------|----------------------------|----------------------|---------------------------------|---------------------------------|
|              | <b>Daily Minimum</b>       | <b>Daily Maximum</b> |                                 |                                 |
| <b>Jan</b>   | <b>19.7</b>                | <b>32.0</b>          | <b>0.7</b>                      | <b>0.8</b>                      |
| <b>Feb</b>   | <b>20.8</b>                | <b>33.3</b>          | <b>3.5</b>                      | <b>2.0</b>                      |
| <b>Mar</b>   | <b>26.1</b>                | <b>34.6</b>          | <b>28.0</b>                     | <b>3.8</b>                      |
| <b>Apr</b>   | <b>25.1</b>                | <b>35.5</b>          | <b>61.2</b>                     | <b>8.0</b>                      |
| <b>May</b>   | <b>25.4</b>                | <b>35.2</b>          | <b>175.9</b>                    | <b>17.2</b>                     |
| <b>Jun</b>   | <b>24.8</b>                | <b>33.5</b>          | <b>221.3</b>                    | <b>20.4</b>                     |
| <b>Jul</b>   | <b>24.8</b>                | <b>32.7</b>          | <b>236.6</b>                    | <b>21.8</b>                     |
| <b>Aug</b>   | <b>25.0</b>                | <b>32.0</b>          | <b>151.0</b>                    | <b>19.2</b>                     |
| <b>Sep</b>   | <b>24.5</b>                | <b>32.2</b>          | <b>276.1</b>                    | <b>21.4</b>                     |
| <b>Oct</b>   | <b>23.9</b>                | <b>31.3</b>          | <b>248.0</b>                    | <b>21.4</b>                     |
| <b>Nov</b>   | <b>22.4</b>                | <b>30.6</b>          | <b>81.7</b>                     | <b>10.4</b>                     |
| <b>Dec</b>   | <b>20.3</b>                | <b>31.0</b>          | <b>10.1</b>                     | <b>3.0</b>                      |

(\*Climate Data found at <http://www.worldweather.org/145/c00347.htm>)

Winds in the area of Siem Reap are relatively light. Wind speeds range from 5.5 m/s to 8.5 m/s, with a yearly average speed of 6.0 m/s.

### **3.2 Problem Background**

BIU is to be located in Siem Reap, Cambodia. BIU received a land grant from the governor of Siem Reap, which was later revoked due to a perceived lack of progress. While BIU does not currently have a site for their campus, they are guardedly optimistic that the governor of Siem Reap will grant them a smaller parcel of land in the near future. BIU will focus their efforts on agricultural development and education because that is the most essential and valuable service that they can provide to Cambodians. Cambodia has an agrarian society; however, Cambodians do not utilize modern, more efficient farming techniques. BIU hopes to raise the standard of

living of many Cambodians by providing them with the education and skills to practice more sustainable farming practices.

Developing a campus is currently BIU's foremost goal. In order to achieve their goals, they believe that having a campus is necessary. This project was based on the idea that the design of this building could provide BIU with the first component of their campus, and allow them to begin holding classes and having an impact on Cambodians.

### **3.3 Project Requirements**

#### **3.3.1 Cultural**

Since the purpose of BIU, and therefore also this design, is to serve Cambodians, it was decided that the building must be consistent with the Cambodian culture. This meant that the design had to be done using materials and building methods local to the Siem Reap area. Also, the building must be architecturally consistent with other buildings in the area.

#### **3.3.2 Structural**

The building clearly needed to be designed so that it would be stable and lasting. Care was taken to ensure the structural integrity of the design. The wind will exert forces on the building which will be taken into account when calculating design loads. The area of Siem Reap, according to the Minister of Water Resources and Meteorology, does not have natural disasters such as earthquakes and tsunami, so these design loads will not be included in this project. The design loads used for the building are shown in Table 3.3.2.

| <b>Table 3.3.2: Building Loads</b> |       |                   |     |                      |      |
|------------------------------------|-------|-------------------|-----|----------------------|------|
| <b>Loads (kN/m<sup>2</sup>)</b>    |       |                   |     |                      |      |
| <b>Dead Loads</b>                  |       | <b>Live Loads</b> |     | <b>Weather Loads</b> |      |
| Decking                            | 0.144 | Classroom         | 1.9 | Wind                 | 1.02 |
| Shingles                           | 0.57  | Office            | 2.4 | Rain                 | NONE |
| Miscellaneous                      | 0.24  | Corridors         | 3.8 |                      |      |
| Mech./Elect.                       | 0.24  | Storage           | 5.9 |                      |      |
| Floor Slabs                        | 3.59  | Bathroom          | 3.8 |                      |      |
|                                    |       | Stairs            | 4.8 |                      |      |

### 3.3.3 Building Use

Since this building was designed with the intent for it to be the first building on BIU's campus, it was important to maximize the flexibility of the building. BIU's use of the building would change as the university grows and develops, so the building was designed in a way that will allow BIU to use it differently as the university changes. Some of the potential uses for the building include research space for plant seedlings in a controlled environment, worship space for campus chapels, community meals and fellowship space, and classroom or administration space.

## 3.4 Prior Work

There has been a considerable amount of work toward the design of BIU's campus. However, many of the designs have been too extravagant for BIU's extremely limited budget. A site master plan designed by Engineering Missions International in 2006 was proclaimed obsolete this year by the board of directors of BIU for various reasons, but primarily relating to cost. Despite the fact that the master plan was obsolete, it did still prove a valuable resource in providing insight into the architecture desired for the campus.

There have also been several Calvin College Senior Design projects that have been done for Asia International University, the university which preceded BIU, in previous years. While none of these projects have yet been used by BIU, they did still aid in the design and research for this project. Most notably, the All for Angkor project from 2006 was very helpful for this project. The goal of the All for Angkor project was similar to Cambodianfinity's. Their goal was to "propose a preliminary design for the first academic building" for Asia International University.

Because of the similarities in the two projects, Cambodianfinity was able to gather much information about the site from All for Angkor.

## **4. Proposed Solution**

### **4.1 Project Management**

#### **4.1.1 Team Organization**

The tasks for this project were divided among the team members according to task length and member interest. Jon Cooper did the primary structural design including the beam, column and slab design. Aaron VanProyen performed the primary design of the foundation, truss and stairs. Mike Vance did the hydraulic analysis and site development and Mark Volle designed the septic system and various structural components such as the lateral bracing. Each team member was primarily responsible for the AutoCAD drawings of their own design; however, there was shared responsibility for the timely completion of the drawing set.

All of the major design tasks were checked by another team member for accuracy.

#### **4.1.2 Task and Time Breakdown**

Table 4.1.2 shows the breakdown of the time spent on each task. The majority of the research was done during the first semester. Also, all the hours spent on the Project Proposal and Feasibility Study (PPFS) were from the first semester. The time spent in meetings and preparing presentations was distributed between the two semesters. The vast majority of the design work and Auto CAD drawings was done during the second semester. The Miscellaneous category includes tasks such as creation and maintenance of the website, poster design, and team descriptions for the banquet. Miscellaneous Design included components such as load calculations, lintel design, and addendum design. Design categories that show very few hours (<3) for an individual indicates that team member checked that design component.

| <b>Table 4.1.2 Time Summary</b> |                |                |                |                |                  |
|---------------------------------|----------------|----------------|----------------|----------------|------------------|
| Tasks                           | AVP<br>(hours) | JSC<br>(hours) | MTV<br>(hours) | MBV<br>(hours) | Total<br>(hours) |
| Misc                            | 8.5            | 3.75           | 5.5            | 6              | 23.75            |
| Research                        | 1.5            | 11.75          | 8              | 6              | 27.25            |
| Meetings                        | 7.5            | 8.75           | 11             | 9              | 36.25            |
| PPFS                            | 16.5           | 5.75           | 29             | 13.5           | 64.75            |
| Presentations                   | 2              | 21.75          | 18             | 5.5            | 47.25            |
| Truss Design                    | 7.5            | 2              | 12             |                | 21.5.5           |
| Column Design                   |                | 38.25          | 1              |                | 39.25            |
| Beam Design                     |                | 29             | 1              |                | 30               |
| Slab Design                     |                | 15.5           | 2              |                | 17.5             |
| Foundation Design               | 9              |                | 2.5            |                | 11.5             |
| Septic Design                   | 2              |                | 14             |                | 16               |
| Hydraulic/Grading               |                |                | 1              | 28.5           | 29.5             |
| Auto CAD                        | 48.5           | 9              | 51             | 81.5           | 190              |
| Final Report                    | 13             | 42             | 25             | 12             | 92               |
| SketchUp                        | 9              |                |                |                | 9                |
| Misc Design                     | 12             | 20.5           | 34             |                | 66.5             |
| <b>Total</b>                    | <b>137</b>     | <b>208</b>     | <b>215</b>     | <b>162</b>     | <b>722</b>       |

### 4.1.3 Design Schedule

At the beginning of first semester, the team developed a working schedule to establish a pace for the semester. The scheduling aspect of this project has been one of the greatest improvements from first to second semester. The importance of developing and maintaining a good working schedule was stressed to the team during a meeting with the industrial consultant. Although the first semester schedule was not adhered to consistently, this habit was not repeated during second semester. One advantage of the second semester schedule was including float time at the end of the project to wrap up miscellaneous tasks and any other unfinished work. Both semester schedules can be found in Appendix A.

## 4.2 Cost

A detailed cost analysis was included as part of this project. The analysis included the materials and labor to complete the entire design. The cost analysis was very challenging because the design site is in Cambodia. As much as possible, costs were used from Cambodia, however, this was not always possible. When costs from Cambodia were not available, costs from other locations in Asia were used. Many of the costs for accessories were from China because that

information was readily available. Other countries from which costs were used include India and Malaysia. There were some instances when even costs in Asia could not be obtained. In these cases, costs for materials in the US were used. Table 4.2.1 below shows a breakdown of the cost by item.

| <b>Table 4.2.1: Cost Analysis</b> |                |            |        |                     |
|-----------------------------------|----------------|------------|--------|---------------------|
|                                   | Measure        | Unit Price | Value  | Cost (US\$)         |
| Concrete                          | m <sup>3</sup> | 200        | 193.27 | \$38,654.00         |
| Rebar                             | m <sup>3</sup> | 3,577      | 1.04   | \$3,721.25          |
| Labor <sup>1</sup>                | man-hours      | 5          | 6,913  | \$34,565.00         |
| Septic                            |                |            |        | \$2,700.00          |
| Brick                             | m <sup>3</sup> | 4.96       | 637.35 | \$3,161.26          |
| Roof Tiles                        | m <sup>3</sup> | 2.89       | 512.35 | \$1,480.69          |
| Stucco                            |                |            |        | \$24,000.00         |
| Plumbing                          |                |            |        | \$7,712.00          |
| Fabricated Steel <sup>2</sup>     | kg             | 1.1        | 10772  | \$11,849.20         |
| Decking <sup>3</sup>              | m <sup>3</sup> | 9.69       | 512.35 | \$4,964.67          |
| Accessories <sup>4</sup>          |                |            |        | \$10,000.00         |
| Excavation                        |                |            |        | \$25,000.00         |
| Fill Dirt                         | m <sup>3</sup> | 22.22      | 469.38 | 10429.6236          |
| 3/4 in gravel                     | m <sup>3</sup> | 32         | 103.1  | \$3,299.20          |
| Contingency<br>(20%)              |                |            |        | \$36,307.38         |
| <b>Total</b>                      |                |            |        | <b>\$217,844.27</b> |

Footnotes:

1. Cost estimate from Malaysia
2. Cost estimate from India
3. Cost estimate from United States
4. Cost estimate from China

While this total may appear quite low, it should be noted that this is for construction in Cambodia. This is a reasonable to slightly high cost for a building of this size in Cambodia. The primary reason that the cost may be higher than normal for a building of this size is that it was assumed that laborers would be paid five dollars per hour. This is considerably higher than the two dollars an hour they might typically be paid, however, this seemed a much more just wage that they could support a family on.

## 4.3 Design

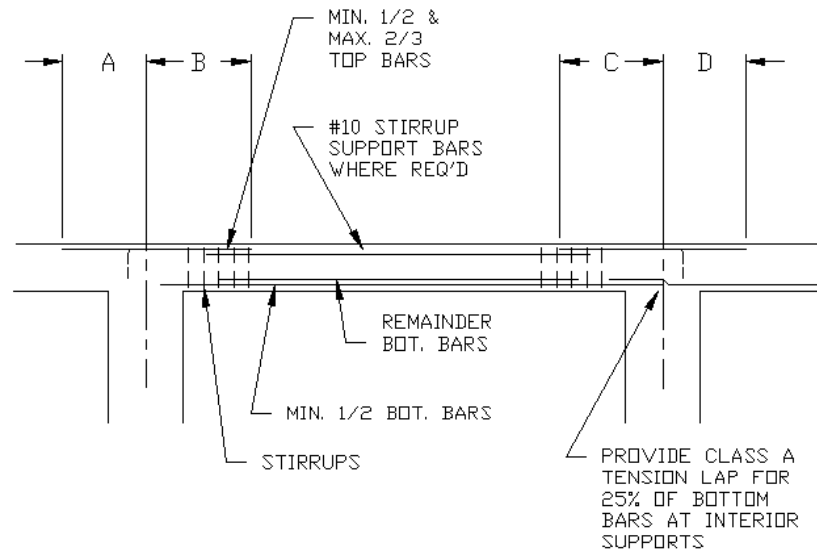
### 4.3.1 Beam Design

Beams in the agricultural studies facility are to be constructed of reinforced concrete, which is typical in Cambodian architecture and also reflects what skilled laborers are used to building. The system of beams and columns make up the skeleton of the building, so that masonry brick was not relied upon to handle structural integrity. The beam design consisted of an iterative approach using a design spreadsheet and structural modeling software, STAAD.Pro. The beam was designed to withstand the maximum moments applied by combination load cases using Load and Resistance Factor Design (LRFD) methods. The building materials selected for construction consist of 24 MPa concrete compressive strength and 420 MPa steel yield strength. The design of beams adheres to Building Code Requirements for Structural Concrete and Commentary (ACI 318M-05). First, beam width and height were selected for initial calculations. The nominal moment in the beams was calculated and a moment distribution was determined from the dead load and live load contributions. The minimum required cross sectional area of steel was found using the reinforcing ratio, which was used in determining the number and size of the rebar in the beam. Using the beam sizes from the initial design, a space frame model was created in STAAD.Pro and each member was loaded with the design dead and live loads. Additionally, a live load “checkerboard” was analyzed using the software to evaluate unbalanced live loads within the building. In this case, the live load was distributed on beams in a “checkerboard” fashion. The maximum moments from the STAAD.Pro analysis were then entered into the beam design spreadsheet and the area of steel was recalculated. The width and depth were also optimized to meet the moment requirements.

In order to make efficient use of steel in the reinforced concrete, the placement of longitudinal reinforcement was terminated following inflection points of the moment distribution. For areas corresponding to negative moments, the reinforcement was placed in the top of the beam and developed past the inflection point as required by the code. For areas with positive moments, the reinforcement was placed in the bottom of the beam.

In addition to longitudinal reinforcement, stirrups are also required to relieve the concrete of shear forces. The shear in the beam was also found in STAAD.Pro, and the size and spacing for the stirrups was selected in accordance with ACI 318M-05. For simplicity of construction, #10 rebar will be used for all stirrups. The number, size, and spacing requirements for both

longitudinal and stirrup reinforcement is presented in the beam schedule in the building plan set. Finally, the selected rebar was checked to be sure that it fit within the selected dimensions of the beam. The spacing and concrete cover around each bar is specified in the code. Figure 4.3.1 shows details of the beam design. The lengths A through D are specified in the Beam Schedule, which is included in the project blueprints on sheet S3.1.



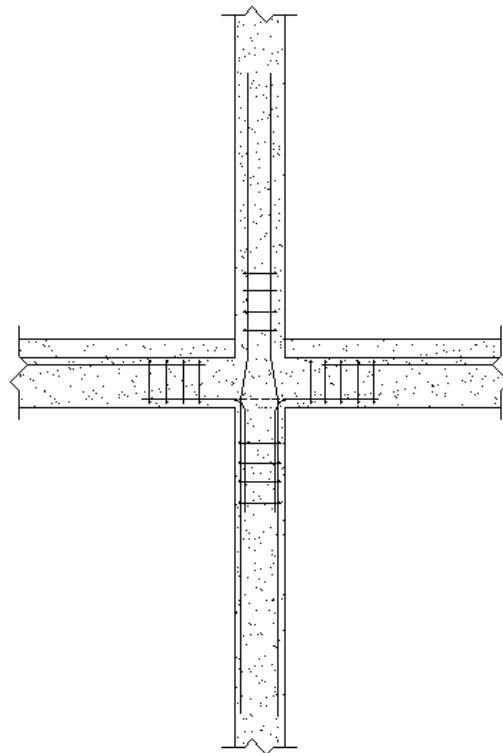
**Figure 4.3.1: Beam Detail**

### 4.3.2 Column Design

Each column for the agricultural studies building was also designed using principles for reinforced concrete. Again, the design of concrete columns was an iterative process between a design spreadsheet and structural modeling software, STAAD.Pro. The compressive strength of concrete is 24 MPa and the yield strength of the steel is 420 MPa. From these material properties, the column dimensions are specified and the required steel reinforcement area was calculated. The design of the columns follows the constraints laid out in ACI 318M-05. Following the STAAD analysis, the axial load and moment calculated were used to optimize the column dimensions and steel reinforcing in the column. Another aspect of the design taken into consideration was the eccentricity of the load on the top of the column. If the primary load carried by the column is not loaded directly on its centerline, the resultant forces will be magnified and spalling of the concrete can occur. Interaction diagrams showing the relationship between axial force and moment in the column were created by evaluating these forces for a

range of eccentricities. The size and reinforcement in the column are selected to handle the worst case combination from the interaction diagrams.

As a result of these design procedures, three column types were chosen to be utilized in the agricultural studies building. The three types of columns are presented in the column schedule in the building plan set. The largest of the three types is to be 40 cm square and will be used in the first floor to support the classroom above. All of the columns have square cross sections for ease of constructability. The placement of reinforcing steel in the columns is held together by steel ties. Following the sizing of each column, the dimensions were checked to make sure the rebar would fit in the column and adhere to the constraints set in ACI 318M-05. The columns above the second floor elevated slab are reduced in size and reinforcement to match the other columns supporting the trusses. By resizing the columns above the second floor slab, costs are minimized so as to limit the amount of concrete and steel used in the building. Figure 4.3.2 (a) shows the column detail and the connection to the reinforced concrete beams at the second floor elevated slab. Figure 4.3.2 (b) shows a typical column cross section with reinforcing.



**Figure 4.3.2 (a): Typical Column Connection Detail**

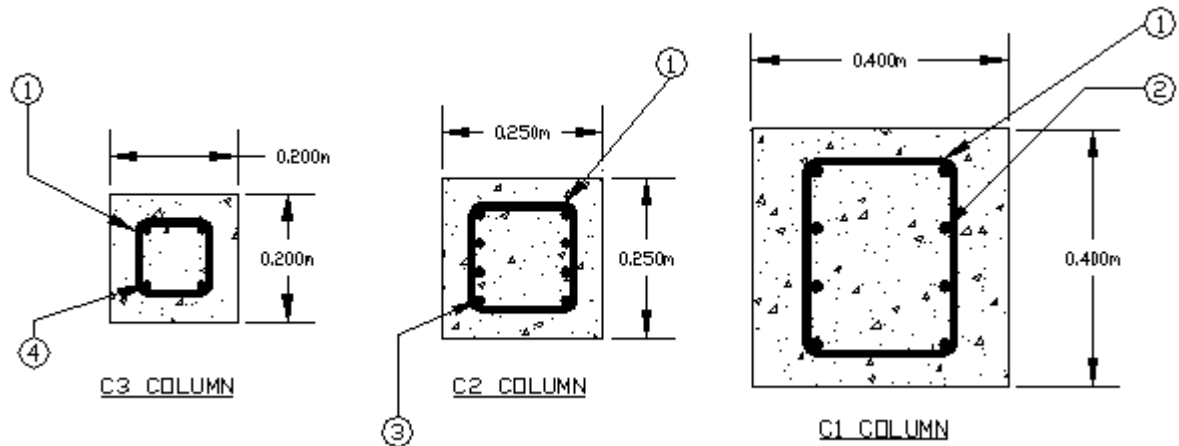


Figure 4.3.2 (b): Column Cross Section Detail

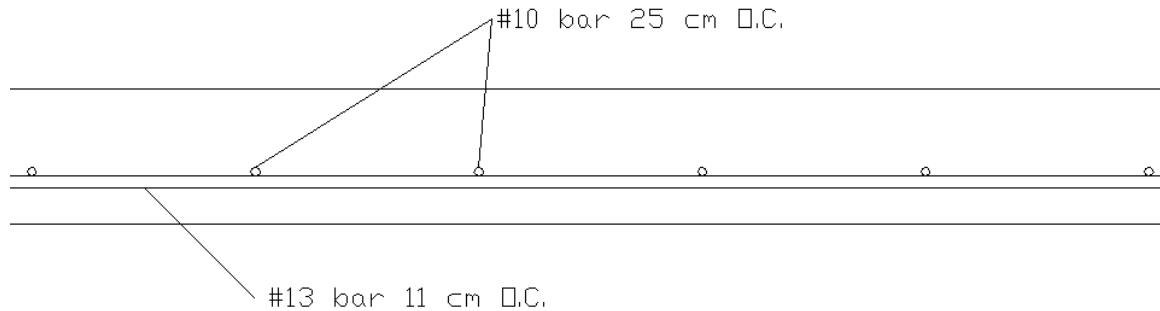
### 4.3.3 Slab Design

The elevated slab for the academic building was designed using ACI 318-05 as the governing code. The slab thickness was first assumed using Table 9.5(a) from ACI manual. This table uses the slab span length as a basis for determining the thickness. For this design, a span length of 3.5 m was assumed. Also, the slab is assumed to be continuous on at least one end, which determines the worst case thickness. From Table 9.5(a), the slab thickness shall be 150 mm.

The worst case loading on the slab was determined using LRFD design standards. The slab weight was taken into account as contributing to the dead load of the system. For the slab design, the dead load was calculated to be  $3.59 \text{ kN/m}^2$ , and the live load was calculated to be  $5.9 \text{ kN/m}^2$ . The next step in the slab design is to determine the ultimate load and moment acting on the slab. The ultimate load was found to be  $13.75 \text{ kN/m}^2$ , and the ultimate moment was found to be  $21.05 \text{ kN-m}$ . Next, the coefficient of resistance was determined. From this value, the reinforcing ratio was calculated which dictates the sizing of the rebar in the slab. Following the selection of the main reinforcing steel, which runs in a direction normal to the beam, shrinkage steel was chosen to reinforce the slab in a direction parallel to the beam. The slab was checked to make sure that the tension forces were dictating the design. The ratio of tensile forces in the extreme layer of steel exceeded the minimum required by ACI 318M-05. Therefore, the design approach is suitable for this slab.

The elevated slab shall be reinforced with #13 bars in a direction normal to the beams, spaced at 11 cm on center. The temperature and shrinkage reinforcement will be placed parallel to the beams and shall be #10 bars spaced at 25 cm. The detail of the second floor slab construction is

shown below in Figure 4.3.3. Because the first floor slab construction is a slab on grade, there is no need for reinforcement. The entire slab is supported by the earth, and tensile forces are negligible. However, construction joints must be placed in the slab. These joints shall be saw cut after the concrete has set up, and shall be cut at 2.5 m intervals in each direction.



**Figure 4.3.3: Elevated Slab Detail**

#### 4.3.4 Septic Design

The site for BIU's campus will most likely not have an existing sewer system to link to. Therefore, this project included the design of a septic system. There were several difficulties faced during the design of the septic system. The first and foremost was that, without a definite site, the ground water elevation was unknown. Also, the soil type and infiltration rate was also unknown. Assumptions regarding these unknown site characteristics were made as reasonably as possible while erring on the conservative side. Also, gathering design information for septic systems was somewhat difficult and time consuming because most information readily available was in the form of metrics for residential use. However, after some more in depth research, a satisfactory design method was found.

The most limiting constraint for the septic system was the groundwater elevation. If the soil has a percolation rate between 1 minute per inch and 60 minutes per inch, at least 1m must be maintained between the drainage pipes and the ground water. Because the site characteristics were not known, it was assumed that the soil has a percolation rate in that range. It was also assumed that the groundwater elevation was half a meter below grade. This assumption was made conservatively because during the rainy season, the water table rises considerably.

Water use was a constraint used to determine the leach field area, so daily water use estimates for the building were made. Table 4.3.1 shows the water use calculations and assumptions. 160 uses

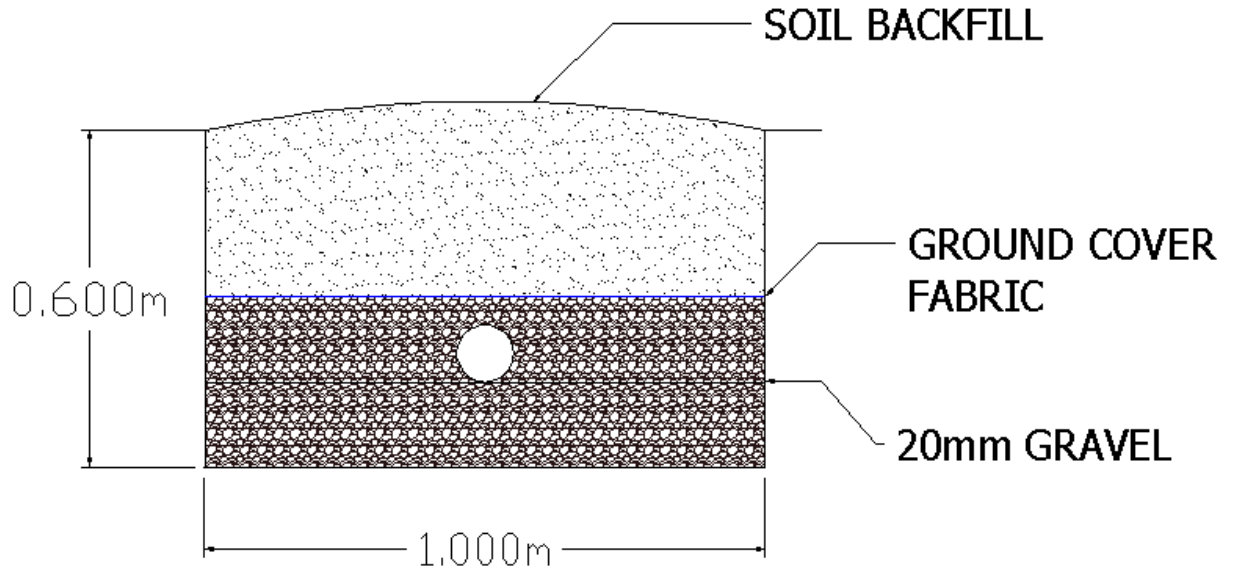
of the toilets and sinks were based on an occupancy of 80 and each person using the toilet and sink twice per day.

| <b>Table 4.3.4 Water Use Estimate</b> |                |                 |                |                          |
|---------------------------------------|----------------|-----------------|----------------|--------------------------|
|                                       | <b>Per Use</b> | <b>uses/day</b> | <b>gal/day</b> | <b>m<sup>3</sup>/day</b> |
| <b>Toilets</b>                        | 1.6 gal/flush  | 160             | 256            | 0.969                    |
| <b>Sinks</b>                          | 0.5 gal/use    | 160             | 80             | 0.303                    |
| <b>Total</b>                          |                |                 | 336            | 1.272                    |
| <b>Contingency</b>                    |                |                 | 100            | 0.379                    |
| <b>Total + Contingency</b>            |                |                 | <b>436</b>     | <b>1.650</b>             |

The other factor which determined the size of the leach field was the soil loading rate. From Table D-1 (Appendix D), the loading rate was assumed to be  $.012 \text{ m}^3/\text{m}^2\text{-day}$  which was the upper end of the range for sand. To determine the trench area, the water use estimate was divided by the soil loading rate. The required trench area was  $134.8 \text{ m}^2$ . Since the trenches were 1m wide, 134.8 linear meters of trench was needed. The leach field was then sized based on 3m spacing between parallel trenches. This resulted in a leach field area of  $364 \text{ m}^2$ .

The distribution system for the drainage field consists of a manifold line running from the septic tank to the end of the field, with five, lateral, perforated pipes off of it every 3 m on center. The main line is set to a slope of 1.1% which will maintain a 2 ft/s flow, preventing sediments from settling during transport. The laterals will have nearly zero slope to create even distribution. At each connection between the laterals and the main line will be a drop box. All pipes in the drainage field should be .1 m PVC pipe, while the line from the septic tank to the field should be .2 m PVC pipe.

Each lateral will be buried in a trench as shown in Figure 4.3.4 below.



**Figure 4.3.4: Septic Lateral Cross Section**

The septic tank was sized based the following guideline found in The Royal Government of Cambodia, Anukret 86 section 31.3:  $3\text{m}^3$  of tank volume for each  $80\text{m}^2$  of floor space. Based on that guideline, the minimum volume of the tank below the outlet must be  $16.7\text{m}^3$ . The tank was sized accordingly and designed based on the septic tank drawings from the eMI master plan.

#### **4.3.5 Lateral Bracing**

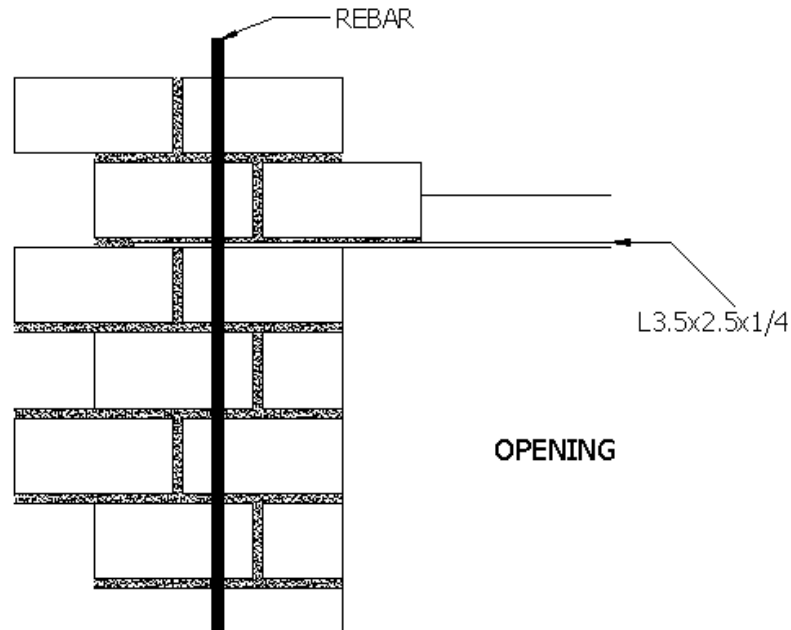
Lateral bracing between the roof trusses is necessary to prevent lateral shifting due to any vertical loads that might exert a moment if they are not centered. The bracing was designed using the Load and Resistance Factor Design (LRFD) method described in American Institute of Steel Construction (AISC) (Appendix 6). Two diagonal,  $2 \times 2 \times \frac{1}{4}$  double angles will be placed between each truss. The cross bracing shall be placed 4.5m inside of the ends of the truss. Gusset plates, the sizes of which are specified in the drawing set on sheet S4.1, will be required for the attachment of the bracing to the trusses. This is considerably over-designed, however, that is often the case for lateral bracing. Since lateral bracing is placed primarily as contingency should a load shift, it is typically not needed from a theoretical design standpoint. However, because it is known that nothing can be built perfectly, cross bracing is necessary to ensure the building's integrity should a load be applied in a way differently than what was designed for.

#### 4.3.6 Lintel Design

All doors and windows required a lintel to support the brick above the opening. For the lintel design, a steel angle with one side length of 90 mm was desired because the bricks being used for this design have a width of 90 mm. After calculating the distributed load across the lintel, the maximum moment was calculated. This moment was used to calculate the parameter  $z$ , according to the method described in AISC 16.1-58. Once the required  $z$  was determined, AISC Table 1-7 was used to select an angle to match the desired criteria. The smallest angle that had one side length of 90mm and still provides the minimum  $z$  was an L 3.5x2.5x $\frac{1}{4}$  for each opening requiring a lintel.

After an angle had been selected, the deflection was to be calculated. For door and window openings, deflections up to  $L/360$  are acceptable where  $L$  is the length of the span. The deflection for each lintel was checked and all of them were within the acceptable range. The longest span was 2 m over the double door and the deflection in that case was 5.4 mm while the maximum acceptable deflection for that case was 5.5 mm.

The lintels must extend 20% of the span length past either edge of the opening. This will allow ample length to tie the lintel into the reinforcing steel in the masonry walls. A hole shall be drilled in the angle to allow the rebar to pass through the lintel. Figure 4.3.6 shows the lintel connection to the masonry wall.



**Figure 4.3.6: Lintel Connection**

#### **4.3.7 Truss Design**

The building was designed to utilize trusses to support the roof system. A single truss must be able to span 13.5m with a 2.5m overhang on each side, and must be 2.25 m tall. Since the building will be 27m long, there will need to be 10 trusses total spaced at 3m on center. The trusses will be made from steel instead of wood, because steel has predictable behavior and is more culturally appropriate than wood. The layout of the truss will be modeled after a Pratt truss, because it was determined that the Pratt design would require less steel than a Howe design. Other designs were deemed too complicated for this building. A sample Pratt truss is shown in Figure 4.3.7 (a).



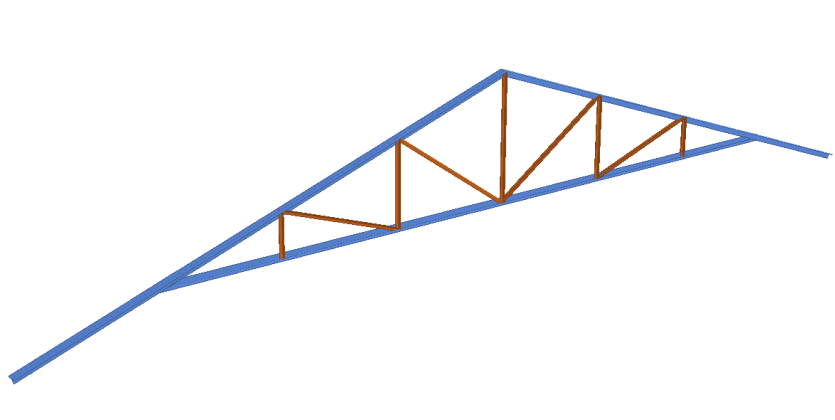
**Figure 4.3.7 (a): Pratt Truss**

Once these decisions were made, modeling in STAAD.Pro began. First, the height of the truss was in question. Original plans from Engineering Missions International for AIU showed a steep truss slope of 1:1, but group member Jon Cooper noted that in his experience from Cambodia, this was not the case. So another slope of 1:3 was designed for the truss. After modeling was completed, it was found that the truss with the 1:3 slope required less steel than the 1:1 slope and was more efficient at carrying the loads on smaller members. This is because a taller truss would have more affect in the wind, would physically require more steel, and therefore be heavier. Second, it had to be determined how many bays would create the most efficient truss. The initial designs were between a 4 bay and a 6 bay truss. An 8 bay truss was ruled out as having too much steel and too short of a bay distance. Modeling proved that a 6 bay truss was the best option for this truss length and overhang.

Hand calculations were performed and checked by group members for accuracy of the computer program. The truss was modeled as a space frame in STAAD.Pro because this performs a statically indeterminate analysis. This is much more accurate than a statically determinate analysis. However, it is not possible to check a statically indeterminate analysis using any methods known to team members. In cases like this, it is acceptable to use approximate methods.

First, the reactions were checked. The sum of the loads on the truss is equal to the sum of the reactions. After confirming this, the forces in the members were checked using the following approximate method. The truss was assumed to act as a deep beam and the maximum moment was calculated. This moment was then assumed to act as a force couple at the top and bottom of the center of the beam. Knowing the depth of the beam is the height of the center of the truss, the force couple was calculated. This force was then compared to the axial force in the members in the center of the bottom chord of the truss. The calculated force was approximately 10kN less than the forces from the STAAD.Pro output. This is an acceptable difference using this method. It is especially reassuring that the force from STAAD.Pro is greater than the hand calculation

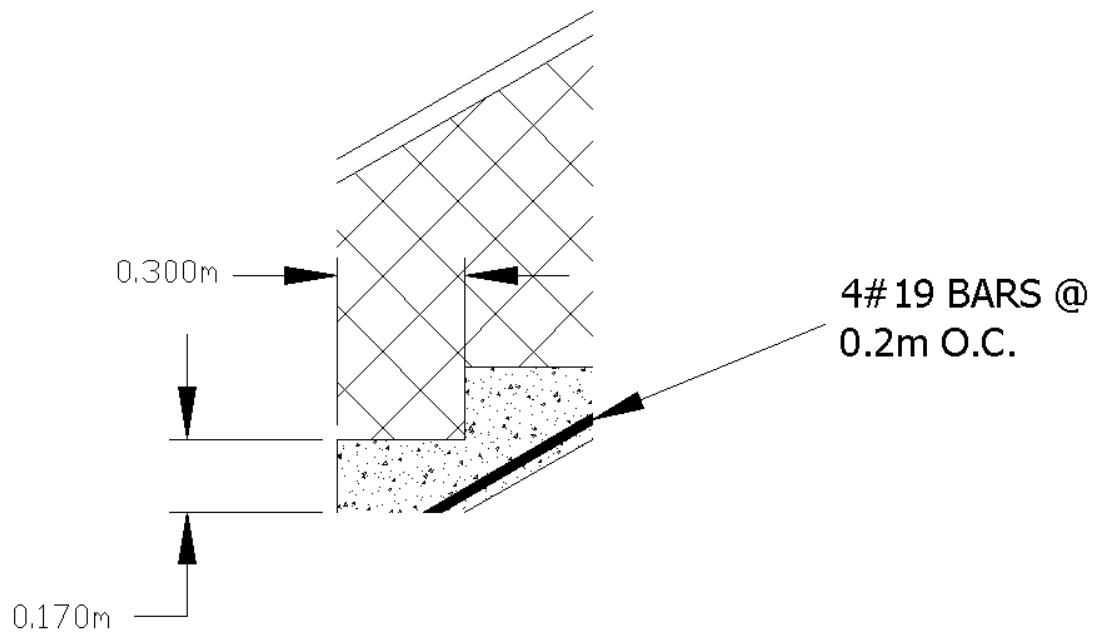
because the force from STAAD.Pro is what the members were sized from. Figure 4.3.7 (b) below shows the final design of the truss.



**Figure 4.3.7 (b): Final Truss Design**

#### **4.3.8 Stair Design**

Since the building is laid out with a two story floor plan, stairs are necessary for transit between the floors. The stairs will be made of concrete with reinforcing steel. They will be formed on site and cast in place. The requirements for the stairs are that they are 1 meter wide, have a 17cm rise and a 30cm landing for each step, which is within the standards from the International Building Code. They need to rise a total of 3.57m, and span 6.3m. This requires 21 stairs. The loading is 1.5 100-kg students on each step at one time. Also, a loading of one student stepping down onto the middle most step and the self weight of concrete was applied. The detail of the stair construction is shown below in Figure 4.3.8.



**Figure 4.3.8: Typical Stair Detail**

Using a spreadsheet developed by one of the group members, the stairs were modeled as a beam, and the correct amount of reinforcing steel was calculated. It was determined that four #19 bars would suffice.

There will be three staircases, one on each side of the building on the outside, and one on the inside near the men's bathroom. The railing and railing connections on the stair cases are shown in the drawing set, but are to be chosen by the architect to match the Cambodian styles.

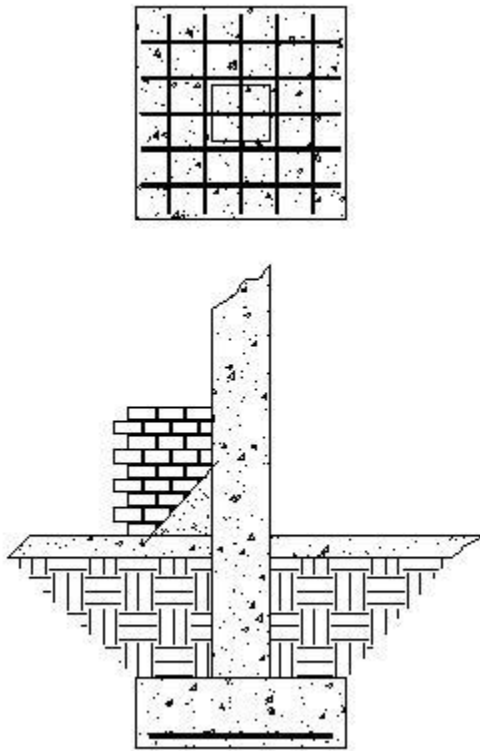
#### 4.3.9 Foundation Design

For this project, it was decided that the building will have interior columns that support beams, floors, walls, and trusses and have exterior columns that support the truss and roof overhang. The columns will be placed on top of footings that were sized according to the loading they support and the type of soil they are in.

To start the design, the type of soil had to be determined. From group member Jon Cooper's experience in Cambodia, the soil in the area of Siem Reap is dry, loose sand. Using the book by Braja M. Das, Table 15.1 shows the soil's  $\Phi'$ ,  $N_c$ ,  $N_q$ , and  $N_\gamma$  values. Using these values, a load of 445 kN on the largest interior columns and 25 kN on the smaller columns, a standard factor of

safety of 3, and an estimated length for the sides of the square footing, the soil bearing capacity could be determined.

Using the steel concrete design book (MacGregor, pp. 805-810), the size and number of reinforcing bars could be found. Using the equations in the book, it was found that for the given load and soil bearing capacities, the footings would have to be  $2.08 \text{ m}^2$ , or  $1.44\text{m}$  on each side, and  $0.98 \text{ m}^2$ , or about  $1\text{m}$  on each side. These numbers were rounded to  $1.5\text{m}$  and  $1\text{m}$  for ease of construction. Next, the  $0.5\text{m}$  thickness of the footing was determined to be sufficient by checking if the factored load is greater than the actual load. Lastly, using moments, the necessary area of steel was calculated. It was determined that five #19 bars each way would be sufficient for the larger footing, while four #19 bars each way would work well in the smaller footing. These are the same size bars that are used in the stair cases. The larger spread footing detail is presented in Figure 4.3.9.



**Figure 4.3.9: Large Spread Footing**

The maximum bearing on the bottom of the column was checked and turned out to be more than 3 times the actual load. This helped in determining that dowels would not be needed.

#### 4.3.10 Site Development

To complete the project goals, site development was necessary to include in the design. This includes gathering soil data, grading, an earth balance and a hydraulic analysis. In order to perform these designs a reasonable amount of geologic and topographic data must be known for the proposed site. In Cambodia there is little demand for this type of data making it very limited and difficult to obtain. However, since there is not an actual site location for our project, collecting this data becomes impossible. In order to continue on with the site design some major assumptions had to be made.

The first assumption that was made was the size and dimensions of the site. A two acre square plot of land was assumed for the site.

Next, assumptions regarding the soil characteristics were to be made. Upon beginning the project Team 16 received Geographic Information System (GIS) data from Professor De Rooy. This data contained soil information for most of the Siem Reap region. With this data an assumption of sandy loam was made according to the most common type found in the area. When Jon Cooper was in Cambodia he was able to observe the soil and confirm our assumption. This type of soil has a low runoff potential and high infiltration rates even when thoroughly wetted.

The topography of the site was another assumption that had to be made. The GIS data also provided some information on the topography of the region. The majority of the land is very flat with little changes in elevation. For the project site it was assumed to be flat. In order to provide runoff away from the building and offsite, the fill under the building would need to be built up.

Some other site design features are the addition of a parking lot, a retention pond, and a gravel swale around the perimeter of the building. The parking lot is designed to be made of compacted soil rather than asphalt or concrete to be consistent with the culture in Cambodia and reduce cost. The size of the parking area will be able to accommodate 20 cars and 40 motorcycles.

The hydraulic analysis of the site is based on a 24 hour 30 year storm with 177 mm of rainfall. The percentage of impervious area was calculated and was used to derive a curve number for the site. Using the afore mentioned assumptions and data, the volume of runoff can be calculated. The volume of runoff was then used to size the retention pond. The basin will be able to hold a volume of 970 m<sup>3</sup>, with a maximum height of 1 m. The basin has a weir outlet to maintain a depth of .5 m. By maintaining a depth of .5 m, when the basin is full it can be used as a rice paddy. The

pond will be fed by two drainage ditches. One will run along the entrance road to collect runoff from the road and parking lot and the other will drain the swale around the building. The swale around the building shall be 1m across and varying depth from .25 to .75m to allow an adequate slope for water to drain around the building.

#### **4.4 Addendum #1**

Included in Addendum #1 is provision for handicap access to the second floor of the agricultural facility. Handicap access is a rarity in Cambodia, and there is no code providing regulation for design in that country. As observed by Jon Cooper during his visit to Cambodia, buildings that have elevators are limited to hotels occupied by tourists or foreign residents. The population of handicapped persons in Cambodia is often overlooked, and limited to the ground floor of most buildings.

Although it is not required by law, the members of Cambodianfinity felt it necessary to design a wheelchair ramp on one side of the agricultural facility to allow access to all persons regardless of physical ability to the classrooms located on the second floor. The wheelchair ramp follows the slope guidelines in the American Disability Act (ADA), as well as the clearance requirements for turns and platforms at the recommended intervals for rest. Also, the handrail along the inside of the ramp is to be continuous, and all of the doors in the building have been sized according to the ADA requirement. As a Christian University, BIU ought to provide the necessary accommodations for anyone who might occupy the building. It would not be fitting with the school's mission to discriminate against the handicap population by not enabling access to the second floor.

Team 16 has packaged the design of the wheelchair ramp as an Addendum to the original bid set of plans. A complete set of drawings has been included and the changes to the original plans are bubbled to show differences in the plan view and elevations. The Board of Directors of BIU will have the option of constructing the wheelchair ramp or another staircase. Their decision is trusted to be what is best for the university. Team 16 did not want to limit their ability to include handicap access. In addition, the cost analysis for the work added in Addendum #1 is provided in Table E.10.

## 4.5 Construction Management

### 4.5.1 Constructability

One of the main goals of this project throughout the year has been the utilization of local construction materials and methods. The team did not want to wrongly assume American standards or notions of construction practices and therefore design a building that was not practical to build in Cambodia. A great benefit to the team in this part of the design process was the experience that Jon Cooper was able to gain during a visit to Cambodia during the month of January. While in Cambodia, he was able to visit two construction sites and saw firsthand some of the methods and materials used in typical building projects. As a result, the building designed by Team Cambodianfinity is consistent with what was observed in construction practice in Cambodia.

Of note in the design of the agricultural facility is the use of reinforced concrete to compose the overall structural shell of the building. Concrete is a material that is commonly used all over the world and was seen as one of the primary constituents of many buildings in Cambodia. Also reinforced concrete was selected as the main building material for its advantages over steel in cost and workability. Laborers are used to working with concrete as it is used in a large number of buildings.

Also, clay bricks will be used to infill the walls and spaces between the reinforced concrete columns and beams. These bricks are produced locally, as Mr. Cooper learned while in Cambodia. Laying brick is a common technique that is also widely used in Cambodia. Typically, clay tiles are also used for the roof, and are produced locally as well. Using clay tiles also has architectural advantages as the look will remain consistent with others in the region.

The team selected steel trusses to make up the roof structure and support the clay tiles, which will be placed on a metal decking. This material was observed in a number of buildings in Cambodia, but was not seen at either of the construction sites because that phase of construction was not ready. It is assumed that a crane will be used for the steel erection. The steel will be fabricated to be bolted atop the reinforced concrete columns.

Other heavy equipment that is anticipated for use during construction is a bulldozer and an excavator. These machines were observed to be used near the city of Siem Reap, but the scope of

the projects they were used on was unclear. The bulldozer will be used for grading the site and finishing the contours that are designed in the site plans. The excavator will dig the foundations and the retention pond. Should these machines be unavailable for use, the footings may be dug by hand. It must be noted that in this situation, the estimated cost of labor would increase substantially.

#### **4.5.2 Construction Schedule**

A working construction schedule was prepared for start to finish construction and is a rough estimate of the time necessary for completion. The schedule assumes government cooperation and financial consistency throughout the project. This may be a stretch due to the nature of the project, but these assumptions were necessary to produce a schedule. The only instance of scheduling that Mr. Cooper was able to observe while in Cambodia was at the construction of a church. In this situation, a new church was in the middle of construction and the progress was dictated by the donations of the congregation. The budget was not always reliable and was the number one driving factor on this particular project. The projected time span from start to finish is six months. Factored into the construction schedule is time allotted for concrete to cure. Since concrete is the primary structural element, the time estimate for each task includes formwork, pour, and cure time.

The construction schedule can be found in Appendix F.

## **5. Conclusion**

### **5.1 Recommendation**

This design fulfills the requirements set out at the beginning of the project. These requirements are that the building must provide sufficient space for Bethany International students to conduct various agricultural labs and experiments in a controlled environment, include office and classroom space, be designed using culturally appropriate building materials and construction methods, be architecturally consistent with the BIU master plan, include site development, and include a plan for connecting the building to the campus electrical grid and utilities.

The final drawing plan set for the agricultural facility shows how the requirements affected the design of the building. There is an open area that is 21m by 13.5m on the first floor, providing

plenty of space for education, community functions, storage, or anything that the university might need it for. Also, on the first and second floor are three offices, three classrooms and bathrooms for men and women. As specified previously, the building will be constructed using steel reinforced concrete columns and slabs, steel trusses, clay brick walls and clay roof tiles. This will all be put together by local Cambodian laborers who are very familiar with these practices and materials. Although BIU has no real master plan since the land was revoked, the design chosen by Cambodianfinity was suited for the area of Siem Reap as a whole, as confirmed by Jon Cooper and pictures.

Since the building has met all the requirements, Team 16 recommends this building to be built as the first facility for Bethany International University.

## 5.2 Future Work

The work that Team 16 put in to the agricultural facility at Bethany International is a solid beginning to BIU's campus. However, some work still remains before the campus could be started. A well would need to be drilled to provide the campus with potable water. Also, until an electrical grid is available, the any power to the building will be provided by a generator. This generator needs to be sized. Also, since the site development was done based off assumptions, this will need to be reviewed once the specific site is known. Since these assumptions were worst case, it may be possible to reduce the cost when the site is factored into the design.

## 6. Acknowledgements

Team 16 – Cambodianfinity would like to thank those who have helped us make this project the success that it is. They have each offered great advice and assistance.

Professor David Wunder, Team Advisor

Professor Leonard DeRooy, Project Consultant

Mr. Roger Lamer, Industrial Consultant

Professor S.K. Lee, Handong International Law School

Professor Ezra Kim, Handong Global University

Engineering Ministries International, AIU Master Planners

A thank you also goes to the other Calvin senior design teams who provided us with ideas and insight.

### **References:**

American Concrete Institute. Building Code Requirements for Structural Concrete and Commentary. ACI 318-05. October 27, 2004.

American Institute of Steel Construction, Inc. "Steel Construction Manual" 13<sup>th</sup> Edition. December, 2005

American Society of Civil Engineers. Minimum Design Loads for Buildings and Other Structures. ASCE 7-98. 2000.

Butler, Rhett. "Cambodia Environmental Profile." *MongaBay.com*.  
<http://rainforests.mongabay.com/20cambodia.htm>.

*Cambodia*. <http://en.wikipedia.org/wiki/Cambodia> (12 November 2007).

Cambodia Royal University of Agriculture. "Research Center." *Royal University of Agriculture*.  
[http://www.rua.edu.kh/research\\_center.html](http://www.rua.edu.kh/research_center.html).

"Climatic Conditions in Cambodia." *All Wonders of the World*.  
<http://www.allwondersoftheworld.com/seven-forgotten-medieval-wonders/cambodia/climatic-conditions-cambodia.html>.

ICC Evaluation Service Inc. "ES Report: Clay Roof Tiles." [http://www.icc-es.org/reports/pdf\\_files/ICC-ES/ESR-2101.pdf](http://www.icc-es.org/reports/pdf_files/ICC-ES/ESR-2101.pdf).

Japan Bank For International Cooperation. "Support for Thailand under the New Miyazawa Initiative."  
<http://www.jbic.go.jp/english/base/release/oecf/1999/0929-e.php>.

MacGregor, James G., and James K. Wight. Reinforced Concrete: Mechanics and Design. 4th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2005.

Nawy, Edward G. Reinforced Concrete: A Fundamental Approach. 5th ed. Upper Saddle River, NJ: Pearson Prentice Hall, 2005.

P&A Tents, Inc. "AIU Presentation." <http://www.choufamily.com/gabe/wp2/>.

The Royal Government of Cambodia, "Anukret 86/ANK/BK." December 19, 1997.

Rozemuller, Bas. "An Overview of the Brick and Tile Manufacturing Industry in North West Cambodia." (1999). [http://www.cascambodia.org/brick\\_tile.htm](http://www.cascambodia.org/brick_tile.htm).

Voice of America. "People's Reactions to Cambodia's Earthquake." *Voice of America News*. <http://www.voanews.com/Khmer/archive/2005-11/2005-11-09-voa3.cfm>.

The World Bank. "Wind Energy Resource Atlas of South East Asia." *Asia Alternative Energy Program*. [http://siteresources.worldbank.org/EXTEAPASTAE/Resources/wind\\_atlas\\_ch6-map4.pdf](http://siteresources.worldbank.org/EXTEAPASTAE/Resources/wind_atlas_ch6-map4.pdf).

World Meteorological Organization. "Siem Reap Climatological Information." *World Weather Information Service*. <http://www.worldweather.org/145/c00347.htm>.

## Table of Appendices

### *Appendix A: Project Schedule*

|                                   |    |
|-----------------------------------|----|
| Figure A-1. Project Schedule..... | 35 |
|-----------------------------------|----|

### *Appendix B: Calculations*

|   |    |
|---|----|
| Table B-1. Wind Load Calculations.....          | 37 |
| Table B-2. Beam Calculations.....               | 39 |
| Table B-3. Column Calculations.....             | 41 |
| Table B-4. Footing Calculations.....            | 43 |
| Table B-5. Slab Calculations.....               | 45 |
| Table B-6. Truss Calculations.....              | 48 |
| Table B-7. Bracing Calculations.....            | 50 |
| Table B-8. Lintel Calculations.....             | 51 |
| Table B-9. Hydraulic Analysis Calculations..... | 52 |
| Table B-10. Septic Tank Calculations.....       | 53 |
| Table B-11. Septic Field Calculations.....      | 53 |
| Table B-12. Stair Calculations.....             | 54 |
| Table B-13. Earth Balance Calculations.....     | 56 |

### *Appendix C: Software Output*

|                                   |    |
|-----------------------------------|----|
| C-1. Staad Pro Truss Output.....  | 57 |
| C-2. Staad Pro Column Output..... | 60 |
| C-3. Staad Pro Beam Output.....   | 79 |

### *Appendix D: Supporting Documents*

|                                    |    |
|------------------------------------|----|
| Table D-1. Soil Loading Rates..... | 92 |
|------------------------------------|----|

### *Appendix E: Cost Analysis*

|                                       |     |
|---------------------------------------|-----|
| Table E-1. Concrete Cost.....         | 93  |
| Table E-2. Rebar Cost.....            | 94  |
| Table E-3. Fabricated Steel Cost..... | 95  |
| Table E-4. Brick and Stucco Cost..... | 96  |
| Table E-5. Roof Tile Cost.....        | 96  |
| Table E-6. Plumbing Cost.....         | 97  |
| Table E-7. Septic System Cost.....    | 98  |
| Table E-8. Accessories Cost.....      | 99  |
| Table E-9. Labor Cost.....            | 100 |
| Table E-10. Addendum #1 Cost.....     | 101 |

### *Appendix F: Construction Documents*

|  |                  |
|--|------------------|
| Figure F-1. Projected Construction Schedule..... | 102              |
| Figure F-2. Construction Plan Set.....           | Bound Separately |

| <b>Table B.1: Wind Load Calculations</b>  |         |                         |  |
|---|---------|-------------------------|--|
| Minimum Design Loads for Buildings and other Structures                               |         |                         |  |
| ASCE 7-98   |         |                         |  |
| 6.5.3 Design Procedure  |         |                         |  |
| <b>1. Basic Wind Speed</b>  |         |                         |  |
| V   | 49      | mps                     | *Estimate given for 3 second wind gusts,<br>due to monsoon season and proximity to Coast |
| K <sub>d</sub>  | 0.85    |                         | (Section 6.5.4)  |
| <b>2. Importance Factor</b>   |         |                         |  |
| I   | 1       |                         | (Section 6.5.5)  |
| <b>3. Exposure Category and Velocity Pressure Exposure Coefficient</b>                |         |                         |  |
| **Exposure Category: C, Open terrain with scattered obstructions having heights < 30m |         |                         |  |
| Average Height of Building  |         |                         |  |
| h   | 12.36   | m                       | 8.125 3.5m floors with 2.25 to peak of truss   |
| α   | 9.5     |                         | (Table 6-5)  |
| Z <sub>g</sub>  | 900     | ft                      | (Table 6-4)  |
| K <sub>h</sub>  | 1.04    |                         |  |
| K <sub>z</sub>  | 0.98    |                         |  |
| <b>4. Topographic Factor</b>  |         |                         |  |
| **Assume flat open country without hills ridges or escarpments                        |         |                         |  |
| K <sub>zt</sub>   | 1       |                         | (Section 6.5.7)  |
| <b>5. Gust Factor</b>   |         |                         |  |
| G   | 0.85    |                         | (Section 6.5.8)  |
| <b>6. Enclosure Classification: Enclosed</b>  |         |                         |  |
| (Section 6.5.9)   |         |                         |  |
| <b>7. Internal Pressure Coefficient</b>   |         |                         |  |
| GC <sub>pi</sub>  | 0.18    |                         | (Section 6.5.11.1)   |
|   | -0.18   |                         |  |
| <b>8. External Pressure Coefficient</b>   |         |                         |  |
| Walls: C <sub>p</sub>   |         |                         | (Section 6.5.11.2)   |
| Windward  | 0.8     | use with q <sub>z</sub> |  |
| Leeward   | -0.5    | use with q <sub>h</sub> | (L/B = 0.48)   |
| Side  | -0.7    | use with q <sub>h</sub> |  |
| Roof: C <sub>p</sub>  |         |                         | *Assume θ=25°  |
| Windward  | -0.5    | (h/L = 1.0)             |  |
| Leeward   | -0.6    |                         |  |
| <b>9. Velocity Pressure</b>   |         |                         |  |
| q <sub>z</sub>  | 1,226.0 | N/m <sup>2</sup>        | (Section 6.5.10)   |
| q <sub>h</sub>  | 1,301.1 | N/m <sup>2</sup>        |  |
| <b>10. Design Wind Load</b>   |         |                         |  |
| (Section 6.5.12)  |         |                         |  |

|                      |                |                        |
|----------------------|----------------|------------------------|
| <b>Windward Wall</b> |                |                        |
| <b>P</b>             | <b>1,067.9</b> | <b>N/m<sup>2</sup></b> |
| <b>Leeward Wall</b>  |                |                        |
| <b>P</b>             | <b>1,118.9</b> | <b>N/m<sup>2</sup></b> |
| <b>Side Walls</b>    |                |                        |
| <b>P</b>             | <b>1,118.9</b> | <b>N/m<sup>2</sup></b> |

Calculated By: JSC

Checked By: MTV

**Table B.2: Beam Design Calculations**

Designed: JSC  
Checked: MTV

**Beam No. 94**

| Variables      | Value    | Units             | Description                         | Procedure:   |
|----------------|----------|-------------------|-------------------------------------|--|
| b              | 0.25     | m                 | Beam width                          | 1. Calculate required $m_n, R_n, m$ (assume $d$ )<br>$M_n = M_u / \Phi$<br>$R_n = M_n / bd^2 = \rho f_y (1 - .5 \rho m)$<br>$m = f_y / 0.85 f_c'$<br><br>Given: $M_{DL}, M_{LL}, f_c', f_y, b,$ and $h$<br><br>2. Calculate $\rho$ , check with $\rho_{min}$ & $\rho_{max}$<br>$\rho = (1/m) * (1 - (1 - ((2mR_n)/f_y)^{1/2}))$<br>$\rho_{min} < \rho < \rho_T (0.75 \rho_{bal})$<br><br>3. Calculate req'd $A_s = \rho b d$<br><br>4. Choose $A_{st}$<br><br>5. Check $M_n = (C \text{ or } T) * (d - a/2) \geq M_n \text{ req'd}$<br>$M_n = A_s f_y (d - a/2)$<br><br>6. Check $\rho$<br><br>7. Check $\Phi \sim$ Tension control? |
| h              | 0.25     | m                 | Beam height                         |  |
| d              | 0.23     | m                 | Depth of Steel ( <b>ACI 7.7.1</b> ) |  |
| $f_c'$         | 24133    | kN/m <sup>2</sup> | Concrete Strength                   |  |
| $f_y$          | 413702   | kN/m <sup>2</sup> | Yield Strength of Steel             |  |
| $A_{s, req'd}$ | 202.18   | mm <sup>2</sup>   | Area of Steel                       |  |
| $\Phi$         | 0.9      |                   | Strength Reduction Factor           |  |
| l              | 3        | m                 | Span Length                         |  |
| DL             | 9.42375  | kN/m              | Dead Load                           |  |
| LL             | 15.4875  | kN/m              | Live Load                           |  |
| $M_n$          | 18.6     | kN-m              | Nominal Strength                    |  |
| $M_u$          | 16.7     | kN-m              | Required Strength                   |  |
| $R_n$          | 1403.067 | kN/m <sup>2</sup> | coefficient of resistance           |  |
| m              | 20.2     |                   |                                     |  |
| $\rho$         | 0.0035   |                   |                                     |  |
| $\rho_{min}$   | 0.0011   |                   |                                     |  |
| tw             | 2.625    | m                 | tributary width                     |  |

**Check  $M_n$** 

Compression

5128.26 a kN/m

Tension

146.86 kN

a 0.03 m

 $d_T$  0.216 m **\*\*ACI 7.7.1** $M_n$  29.6 kN-m

OK

**Check if Tension Controls** $\epsilon_s$  0.016211**TENSION CONTROLS****Check  $\Phi M_n > M_u$** 

OK

Check  $\rho_{\min} < \rho < \rho_{\max}$

$\rho_{\max}$  0.005  
OK

| ASTM Standard Rebar (metric) |                         |               |
|------------------------------|-------------------------|---------------|
| Rebar Sizes                  | Area (mm <sup>2</sup> ) | Diameter (mm) |
| 10                           | 71                      | 9.5           |
| 13                           | 129                     | 12.7          |
| 16                           | 199                     | 15.9          |
| 19                           | 284                     | 19.1          |
| 22                           | 387                     | 22.2          |
| 25                           | 510                     | 25.4          |
| 29                           | 645                     | 28.7          |
| 32                           | 819                     | 32.3          |
| 36                           | 1006                    | 35.8          |
| 43                           | 1452                    | 43            |
| 57                           | 2581                    | 57.3          |

#### Select Steel Reinforcing

| Number of Bars | Bar Size | $A_{st}$ mm <sup>2</sup> | $A_{st,\min}$ mm <sup>2</sup> |
|----------------|----------|--------------------------|-------------------------------|
| 5              | 10       | 355                      | 293.0135                      |

Check if  $A_{st} > A_{s,\text{req'd}}$

OK

Check if steel fits in Beam (Assume #10 bar for stirrup)

Width 65.5 OK

\*\*\*Check with ACI 7.6 - Spacing limits for reinforcement

#### Development Length

|                                   |           |  |                   |               |
|-----------------------------------|-----------|--|-------------------|---------------|
| $\Psi_t$                          | 1         | * ACI 12.2.4 (a)   |                   |               |
| $\Psi_e$                          | 1         | *ACI 12.2.4 (b) Assume uncoated reinforcement            |                   |               |
| $\Psi_s$                          | 0.8       |  |                   |               |
| $\lambda$                         | 1         | *ACI 12.2.4 (d) $\lambda=1.0$ for normal weight concrete |                   |               |
| db                                | 9.5       | mm   |                   |               |
| Cover (measured to center of bar) |           |  |                   |               |
| Top                               | 20        | mm   | *ACI 7.7.1        |               |
| Side                              | 20        | mm   |                   |               |
| Bottom                            | 20        | mm   |                   |               |
| Center to Center Spacing          | 25        | mm   | *ACI 7.6.1        |               |
| ACI 12.2.2                        |           | No. 19 and smaller                                       | No. 22 and larger |               |
| CASE 1                            | $l_d$ (m) | 0.381  | N/A               | Designed: JSC |
| CASE 2                            | $l_d$ (m) | 0.571  | N/A               | Checked: MTV  |

**Table B.3: Column Design Calculations**

## Design of Reinforced Concrete Columns

| Variable  | Value              | Units             | Code Checking  |
|---|--------------------|-------------------|--|
| e   | 0.04               | m                 | OK   |
| h   | 0.4                | m                 |  |
| b   | 0.4                | m                 |  |
| f <sub>c</sub>  | 24133              | kN/m <sup>2</sup> |  |
| f <sub>y</sub>  | 413702             | kN/m <sup>2</sup> |  |
| I   | 0.85               |                   |  |
| Bar Size  | 19                 |                   |  |
| Diameter  | 19.1               | mm                |  |
| Area  | 284                | mm <sup>2</sup>   |  |
| No. of Bars   | 8                  |                   | OK <b>ACI 10.9.2</b>                                     |
| A <sub>st</sub>   | 2272               | mm <sup>2</sup>   |  |
| A <sub>g</sub>  | 160000             | mm <sup>2</sup>   |  |
| A <sub>st,optimal</sub>                                   | 9600               | mm <sup>2</sup>   |  |
| P <sub>o</sub>  | 4175.413294        | kN                |  |
| P <sub>n,max</sub>  | 3340.330636        | kN                |  |
| P <sub>u</sub>  | 2171.214913        | kN                | Code P <sub>u</sub> ≤ φ * P <sub>n</sub>                 |
| <b>M<sub>n</sub></b>                                      | <b>133.6132254</b> | <b>kN-m</b>       |  |
| ρ <sub>g</sub>  | 0.0142             |                   | OK <b>ACI 10.9</b>                                       |
| φ   | 0.65               |                   | <b>ACI 9.3.2</b> for tied columns (if spiral, then =0.7) |
|   | 0.8                |                   |  |
| <b>Bar Spacing</b>  |                    |                   |  |
| Distance Between Longitudinal Reinforcing, d <sub>s</sub> |                    |                   |  |
| d <sub>s</sub>  | 40                 | mm                | <b>ACI 7.6.3</b>   |
| Tie Size  | 10                 |                   | <b>ACI 7.10.5.1</b>                                      |
| Tie Diameter  | 9.5                | mm                |  |
| Tie Spacing   | 267.4              | mm                | <b>ACI 7.10.5.2</b>                                      |
| Will Steel Fit in Beam?                                   |                    |                   |  |
| Concrete Cover  | 40                 | mm                |  |
| Min. b  | 177.2              | mm                | <b>Steel Fits</b>  |

**Column Design Procedure**

ACI Notations

 $A_g$ =gross area of col. Section $A_{st}$ =total area of longitudinal reinforcement $P_o$ =Nominal, or theoretical, axial load strength at  $e=0$  $P_n$ =Nominal, or theoretical, axial load strength at given eccentricity $P_u$ =Factored applied load at given eccentricity $\rho_g$ =ratio of the longitudinal reinforcement area to cross sect. area ( $A_{st}/A_g$ )

$$P_o = 0.85 \cdot f_c' \cdot (A_g - A_{st}) + f_y \cdot A_{st}$$

**Code Requirements:** $0.01 < \rho_g < 0.08$  (should be  $< 0.06$ )**ACI 10.9**Min. # of bars = 4 for rectangular or circular tied cols. (**ACI 10.9.2**)Clear Distance Between Bars = Max. of  $1.5 \cdot d_b$  or 40 mm (**ACI 7.6.3**)Concrete Cover = 40 mm min. (**ACI 7.7.1**)Ties (**ACI 7.10.5.1**): For longitudinal bars #32 and smaller → Use #10 ties

For longitudinal bars #36, #43, or #57 → Use #13 ties

Tie Spacing (**ACI 7.10.5.2**): Not to exceed  $14 \cdot d_b$  (longitudinal dia.),  $48 \cdot d_b$  (tie dia.), or least dimension of columnMinimum ecc. for design: Tied col.  $e = 0.1 \cdot h$ **LOOK AT 9.3.2.2 for  $\phi$  considerations**

Calculated By: JSC

Checked By: MTV

**Table B.4: Footing Design Calculations**

| SOIL BEARING CAPACITY |          |
|-----------------------|----------|
| □'                    | 32       |
| □                     | 111.12   |
| c'                    | 0        |
| F <sub>s</sub>        | 3        |
| Q <sub>all</sub>      | 99879.25 |
| Depth                 | 3.28     |

lb/ft<sup>3</sup>  
  
  
  
  
lb<sub>f</sub>  
ft

| □'        | N <sub>c</sub> | N <sub>q</sub> | N <sub>□</sub> |
|-----------|----------------|----------------|----------------|
| <b>32</b> | 44.04          | 28.52          | 26.87          |

Table 15.1 B. Das

$$q_{all} = \frac{Q_{all}}{B^2} (1/F_s) * (1.3c'N_c + qN_q + 0.4 \square BN_\square)$$

$$Eqn (1) = \frac{q_{all}}{\square \cdot Depth}$$

$$Eqn (1) = 3464.929 + 398.1059 B$$

To solve, plug q<sub>all</sub> = Eqn (1) into a solver, and solve for B.

B = 4.38 ft                      q<sub>all</sub> = 5208.2 lb/ft<sup>2</sup>  
 B<sup>2</sup> = 19.2 ft<sup>2</sup>                      5208.3 **OK**

**DESIGN OF A SQUARE SPREAD FOOTING**

|           |       |               |
|-----------|-------|---------------|
| Dead Load | 69.04 | kip           |
| Live Load | 30.84 | kip           |
| □         | 0.75  | (ACI 9.3.2.3) |

U = 96.656 kips  
 U = 132.192 kips

|                |          |                 |                  |               |
|----------------|----------|-----------------|------------------|---------------|
| q <sub>n</sub> | 4.456588 | ksf             | Average          |               |
| Area req'd     | 22.41176 | ft <sup>2</sup> | d                | 15.68 in      |
| Factored       | 6.893116 | ksf             | V <sub>u</sub>   | 48.29413 kips |
| USE =          | 4.734106 | ft              | b <sub>o</sub>   | 125.68 in     |
|                |          |                 | □ V <sub>c</sub> | 485.7193 kips |
|                |          |                 |                  | 363.903 kips  |
|                |          |                 |                  | 323.8129 kips |
|                |          |                 |                  | <b>OK</b>     |
| M <sub>u</sub> | 53.11008 | ft-kips         |                  |               |

$A_s$             0.836327 in<sup>2</sup>  
                  **2.012412 in<sup>2</sup>**

**Try 5 #6 Bars (19 in metric, to match stair bars)**

#6            0.441786    2.208932    in<sup>2</sup>            **OK**

a            0.915696

a/d           0.058399    <<0.319    **TENSION CONTROLLED**

**Max Bearing on Column bottom**

684.40275 kips            > 132.192 kips

**No Dowels Needed**

|                    |
|--------------------|
| <b>CONVERSIONS</b> |
|--------------------|

4.73 ft --> 1.44 m    (rounded to 1.5 m)

Calculated By: AVP

Checked By: MTV

**Table B.5: Slab Design Calculations****Using ACI 318M-05**

| Loads and Assumptions  |                          | Conversion Factors |                      |                           |
|--|--------------------------|--------------------|----------------------|---------------------------|
| Slab Thickness   | 150 mm                   |                    |                      | 2.54 cm/in.               |
| Concrete Unit Wt., $w_c$                                     | 2320 kg/m <sup>3</sup>   |                    |                      | 100 cm/m                  |
| Modulus, $E_c$   | 23604.923 MPa            |                    | <b>(8.5.1)</b>       | 224.8 lb <sub>f</sub> /kN |
| Tributary Width  | 3.5 m                    |                    |                      | 1000 mm/m                 |
| <i>Live Load</i>   |                          |                    |                      |                           |
| Lightweight Storage  | 5.9 kN/m <sup>2</sup>    |                    |                      |                           |
| <i>Dead Load</i>   |                          |                    |                      |                           |
| Floor Slabs  | 348.00 kg/m <sup>2</sup> |                    |                      |                           |
|  | psi                      | kN/m <sup>2</sup>  | MPa                  |                           |
| $f'_c$   | 3500                     | 24133              | 24.1                 |                           |
| $f_y$  | 60000                    | 413702             | 413.7                |                           |
| Span Length, $l$   | 3.5 m                    |                    |                      |                           |
| <b>Minimum Slab Thickness (ACI 9.5.2) <math>h</math> (m)</b> |                          |                    |                      |                           |
|  | Simply Supported         | One End Continuous | Both Ends Continuous | Cantilever                |
| Member   |                          |                    |                      |                           |
| Solid One Way Slabs  | 0.175                    | 0.146              | 0.125                | 0.350                     |
| Beams or Ribbed One Way Slabs                                | 0.219                    | 0.189              | 0.167                | 0.438                     |
| <i>Assume</i>  |                          |                    |                      |                           |
| $h$  | 0.146 m                  |                    |                      |                           |
| $d$  | 0.117 m                  |                    |                      |                           |
| <b>Slab Weight</b>   |                          |                    |                      |                           |
| width, $b$   | 3.5 m                    |                    |                      |                           |
| slab weight  | 1184.1667 kg/m           |                    |                      |                           |
| $w_u$ (LRFD)   | 13.748 kN/m <sup>2</sup> |                    |                      |                           |
| <b>Maximum Moments</b>                                       |                          |                    |                      |                           |
| <b>Mu</b>  | 21.051625 kN-m           |                    |                      |                           |

|   |                     |                       |
|---|---------------------|-----------------------|
| <b>R<sub>n</sub></b>                    | 486.26481           | kN/m <sup>2</sup>     |
| m                                       | 20.168067           | unitless              |
| <b>ρ</b>                                | 0.0011897           | unitless              |
| req'd Ast                               | 0.0004881           | m <sup>2</sup>        |
| req'd Ast                               | 488.1419            | mm <sup>2</sup>       |
| Number of Bars                          | 4                   |                       |
| Select Rebar                            | 13                  |                       |
|   | 516                 | mm <sup>2</sup>       |
| Max Steel Spacing                       | 437.5               | mm                    |
| <b>Steel large enough?</b>              | <b>OK</b>           |                       |
| Temp. Shrinkage Steel                   | 918.75              | mm <sup>2</sup>       |
| Temp Steel Size                         | #13                 |                       |
| Is Main Steel Area >= Temp. Steel Area? |                     |                       |
| <b>Absolutely</b>                       | 765 mm <sup>2</sup> | > 129 mm <sup>2</sup> |
| Does Tension Control?                   |                     |                       |
| a                                       | 0.0029733           | m                     |
| c                                       | 0.0034981           | m                     |
| ε <sub>s</sub>                          | 0.0975415           |                       |

Is ε<sub>s</sub> >= .005?

**TENSION CONTROLS**

Design Summary

1. Compute min. h - ACI Table 9.5
2. Clac. Slab weight and calc. w<sub>u</sub>
3. Calc. M<sub>u</sub>
4. Calc. d - assume #6 bar & 3/4" cover (1.905 cm) (no stirrups)

$$d = h - 1.905 - \#6/2$$

$$d = h - 1.905 - \#6/2$$

$$d = h - 2.86 \quad \text{cm}$$

5. Calc. R<sub>n</sub>

$$R_n = M_u / \Phi b d^2 \quad M_u = f_y / 0.85 f_c'$$

assume Φ=0.9

6. Calc. ρ = (1/m) \* (1 - (1 - 2m(R<sub>n</sub>/f<sub>y</sub>))<sup>.5</sup>)

7. Calc. req'd

$$A_{st} = \rho b d$$

8. Select main steel (max. spacing = 450mm or 3\*h)

ACI  
7.6.5

9. Select temp. shrinkage steel

10. Main steel  $\geq$  temp. steel
11. Check if tension controls
12. Sketch design

Calculated By: JSC

Checked By: MTV



Because the overhang was not considered, and the fact that this is an approximate method, the calculation was close enough to assume the STAAD model is correct.

Calculated By: AVP

Checked By: MTV

| <b>Table B.7: Cross Bracing Calculations</b> |                                     |                  |
|--|-------------------------------------|------------------|
| LRFD Truss Loading (kN/m)                    |                                     |                  |
| $w_{u1}$ (kN/m)                              | 3.06                                |                  |
| $w_{u2}$ (kN/m)                              | 1.73                                |                  |
| $L_{T1}$ (m)                                 | 14.23                               |                  |
| $L_{T2}$ (m)                                 | 18.98                               |                  |
| $C_d$  | 1.0                                 | Single Curvature |
| $P_{br}$ (kN)                                | $.02(w_{u1}L_{T1}+w_{u2}L_{T2})C_d$ | Horizontal Load  |
|  | 1.53                                |                  |
| $P_{br}$ (kips)                              | 0.34                                |                  |
|  |                                     |                  |
| $\theta$ (degrees)                           | 0.46                                |                  |
|  |                                     |                  |
| $P_{axial}$ (kN)                             | $P_{br}/\cos\theta$                 |                  |
|  | 1.71                                |                  |
| $P_{axial}$ (kips)                           | 0.38                                |                  |
|  |                                     |                  |
| Effective Length (m)                         | 3.35                                |                  |
| Effective Length (ft)                        | 11.0                                |                  |
|  |                                     |                  |
| <b>LD 2X2X1/4</b>                            | 19.26 kips                          | AISC Table 4-8   |

Calculated By: MTV

Checked By: MBV

| <b>Table B.8: Lintel Design Calculations</b>                        |                                    |                     |                                     |            |
|---|------------------------------------|---------------------|-------------------------------------|------------|
| <b>Door 1 Lintel Design</b>   |                                    | <b>Single Angle</b> |                                     |            |
| L (m)   | 2                                  |                     |                                     |            |
| DL (kN/m)   | 1.681272331                        |                     |                                     |            |
| w <sub>u</sub> (kN/m)   | 1.4*DL                             | LRFD                |                                     |            |
|   | 2.353781264                        |                     |                                     |            |
| M <sub>u</sub> (m*kN)   | (w <sub>u</sub> L <sup>2</sup> )/8 | AISC 3-211          |                                     |            |
|   | 1.176890632                        |                     |                                     |            |
|   |                                    |                     |                                     |            |
| M <sub>n</sub> (m*kN)   | 1.5*M <sub>u</sub>                 | AISC 16.1-58        |                                     |            |
|   | 1.765335948                        |                     |                                     |            |
|   |                                    |                     |                                     |            |
| Z <sub>required</sub> (m <sup>3</sup> )                             | M <sub>n</sub> /F <sub>y</sub>     |                     | F <sub>y</sub> (ksi)                | 50         |
|   | 5.11933E-06                        |                     | F <sub>y</sub> (kN/m <sup>2</sup> ) | 344837.099 |
| Z <sub>required</sub> (in <sup>3</sup> )                            | 0.312400643                        |                     |                                     |            |
| AISC Table 1-7 for listing of angles with corresponding values of Z |                                    |                     |                                     |            |
| Desired angle has at least one side length of 3.5 in                |                                    |                     |                                     |            |
| <b>L</b>  | <b>3.5*2.5*.25</b>                 |                     |                                     |            |
| Z <sub>actual</sub> (in <sup>3</sup> )                              | 0.728                              |                     |                                     |            |
| <b>Angle is sufficient</b>  |                                    |                     |                                     |            |
| Check for Deflection  |                                    |                     |                                     |            |
| E (ksi)   | 29000                              |                     |                                     |            |
| E (kN/m <sup>2</sup> )  | 200005517.4                        |                     |                                     |            |
| I (in <sup>4</sup> )  | 0.775                              | AISC 1-45           |                                     |            |
| I (m <sup>4</sup> )   | 3.22579E-07                        |                     |                                     |            |
|   |                                    |                     |                                     |            |
| Δ (m)   | (5*DL*L <sup>4</sup> )/(384*E*I)   |                     |                                     |            |
|   | 0.005428981                        |                     |                                     |            |
| Δ <sub>allowable</sub> (m)  | L/360                              |                     |                                     |            |
|   | 0.005555556                        | Calculated By: MTV  |                                     |            |
| <b>Deflection is acceptable</b>                                     |                                    | Checked By: AVP     |                                     |            |

**Table B.9 Hydraulic Analysis Calculations**

Volume of Runoff

$V = K_u C i A t_D$  (Eqn. 15.4.7 Water Resources Engineering, 2005 Edition)

$V = 27.4 \text{ m}^3$

$K_u = 0.28$

$C = 68.3 \text{ site}$

$i = 177 \text{ mm/day}$

$A = 0.0081 \text{ km}^2$

$t_D = 1 \text{ day}$

Basin Volume Calculations

|        | bottom<br>(m) | top<br>(m) |
|--------|---------------|------------|
| Width  | 18            | 24         |
| Length | 42            | 48         |

| Depth<br>(m) | Area<br>(m <sup>2</sup> ) |
|--------------|---------------------------|
| 0            | 756                       |
| 0.25         | 784                       |
| 0.5          | 811                       |
| 1            | 869                       |
| 1.5          | 927                       |

basin volume    971 m<sup>3</sup>

ditches            83 m<sup>3</sup>

building ditch    51 m<sup>3</sup>

Calculated By: MBV

Checked By: MTV

| <b>Table B.10: Septic Tank Calculations</b> |                                   |                                   |            |           |
|---|-----------------------------------|-----------------------------------|------------|-----------|
| RGC Code (31.3)                             |                                   | Water Usage (m <sup>3</sup> /day) |            |           |
| 3 m <sup>3</sup> per 80 sq m                |                                   | 1.65                              |            |           |
| Floor Area (m <sup>2</sup> )                | Required Volume (m <sup>3</sup> ) | Height (m)                        | Length (m) | Depth (m) |
| 445.5                                       | 16.70625                          | 2.03                              | 4.06       | 2.03      |
|   |                                   | meets min height                  |            |           |

Calculated By: MTV

Checked By: JSC

| <b>Table B.11: Septic Field Calculations</b>         |   |                        |            |                    |
|--|---|------------------------|------------|--------------------|
| Soil Loading Estimate*<br>(gal/ft <sup>2</sup> /day) | Soil Loading<br>(m <sup>3</sup> /m <sup>2</sup> /day) | Area (m <sup>2</sup> ) | L (m)      | Number of Laterals |
| 0.3  | 0.012238668   | 134.818593             | 134.818593 | 5                  |
|  |   |                        |            |                    |
| Field Area (sq m)                                    | Dimensions (m)  |                        |            |                    |
| 364  | 13  | by                     | 28         |                    |

Calculated By: MTV

Checked By: JSC

**Table B.12: Stair Calculations**

**Concrete Stair Stringer Beam**

| Variables      | Value    | Units           | Description                | Procedure  |
|----------------|----------|-----------------|----------------------------|--|
| b              | 1        | m               | Beam width                 | 1. Calculate required $m_n$ , $R_n$ , m (assume d)<br>$M_n = M_u / \Phi$<br>$R_n = M_n / bd^2 = \rho f_y (1 - .5 \rho m)$<br>$m = f_y / 0.85 f_c'$<br><br>Given: $M_{DL}$ , $M_{LL}$ , $f_c'$ , $f_y$ , b, and h<br><br>2. Calculate $\rho$ , check with $\rho_{min}$ & $\rho_{max}$<br>$\rho = (1/m) * (1 - (1 - ((2mR_n) / f_y)^{1/2}))$<br>$\rho_{min} < \rho < \rho_T (0.75 \rho_{bal})$<br><br>3. Calculate req'd $A_s = \rho bd$<br>4. Choose $A_{st}$<br><br>5. Check $M_n = (C \text{ or } T) * (d - a/2) \geq M_n \text{ req'd}$<br>$M_n = A_s f_y (d - a/2)$<br><br>6. Check $\rho$<br><br>7. Check $\Phi \sim$ Tension control? |
| h              | 0.17     | m               | Beam height                |  |
| d              | 0.15     | m               | Depth of Steel (ACI 7.7.1) |  |
| $f_c'$         | 24133    | kN/m            | Concrete Strength          |  |
| $f_y$          | 413702   | 2               | Yield Strength of Steel    |  |
| $A_{s, req'd}$ | 694.80   | mm <sup>2</sup> | Area of Steel              |  |
| $\Phi$         | 0.9      |                 | Strength Reduction Factor  |  |
| l              | 7.2412   | m               | Span Length                |  |
| DL             | 1.51663  | kN/m            | Dead Load                  |  |
| LL             | 3.7127   | kN/m            | Live Load                  |  |
| $M_n$          | 41.1     | kN-m            | Nominal Strength           |  |
| $M_u$          | 36.9918  | kN-m            | Required Strength          |  |
| $R_n$          | 1826.756 | 2               | coefficient of resistance  |  |
| m              | 20.2     |                 |                            |  |
| $\rho$         | 0.0046   |                 |                            |  |
| $\rho_{min}$   | 0.0011   |                 |                            |  |
| tw             | 0.5      | m               | tributary width            |  |

**Check  $M_n$**

Compression

20513.1 a kN/m

Tension

469.965 kN

a 0.02 m

$d_T$  0.131 m **\*\*ACI 7.7.1**

$M_n$  56.2 kN-m

OK

**Check if Tension Controls**

$\epsilon_s$  0.011575

**TENSION CONTROLS**

**Check  $\Phi M_n > M_u$**

OK

**Check  $\rho_{min} < \rho < \rho_{max}$**

$\rho_{max}$  0.007

OK

**Select Steel Reinforcing**

| Number of Bars | Bar Size | $A_{st}$ mm <sup>2</sup> | $A_{st,min}$ mm <sup>2</sup> |
|----------------|----------|--------------------------|------------------------------|
| 4              | 19       | 1136                     | 1049.9166                    |

Check if  $A_{st} > A_{s,req'd}$ 

OK

Check if steel fits in Beam (Assume #10 bar for stirrup)

Width 807.3 OK

**\*\*\*Check with ACI 7.6 - Spacing limits for reinforcement**

Calculated By: AVP

Checked By: MTV

| <b>Table B-13: Earth Balance Calculations</b> |   |       |                   |
|---|---|-------|-------------------|
|   | Positive  |       | Negative          |
|   | Building Raised<br>1.4 m above<br>current ground<br>level |       | Retention<br>Pond |
| Volume (m <sup>3</sup> )                      | <b>900.9</b>  |       | <b>(971.00)</b>   |
|   | Septic Mound  |       | Swales            |
| Volume (m <sup>3</sup> )                      |   |       |                   |
| Field   | 459.2   |       |                   |
| Sides   | 124.46  |       |                   |
| Total   | <b>583.66</b>   |       | <b>(81.00)</b>    |
|   | Pipe/Tank Cover   |       | Footings          |
|   |   | Small | (17.00)           |
|   |   | Large | (29.25)           |
| Volume (m <sup>3</sup> )                      | <b>40.4</b>   | Total | <b>(46.25)</b>    |
| Subtotal                                      | <b>1524.96</b>  |       | <b>(1098.25)</b>  |
|   | Soil Needed (m <sup>3</sup> )                             |       |                   |
| Total   | 426.71  |       |                   |
| 10% Contingency                               | 42.671  |       |                   |
| Total + Contingency                           | <b>469.381</b>  |       |                   |
|   | Drain Rock  |       |                   |
|   | Volume (m <sup>3</sup> )                                  |       |                   |
| Septic  | 42.7  |       |                   |
| Swales  | 51  |       |                   |
| Total   | 93.7  |       |                   |
| 10% Contingency                               | 9.37  |       |                   |
| <b>Total + Contingency</b>                    | <b>103.07</b>   |       |                   |

Calculated By: MTV

Checked By: MBV

| <b>Table D-1: Soil Hydraulic Loading Rates</b> |                       |                                  |                      |                                  |                      |
|--|-----------------------|----------------------------------|----------------------|----------------------------------|----------------------|
| <b>Soil Textures</b>                           | <b>Soil Structure</b> | <b>Maximum Monthly Average</b>   |                      | <b>Maximum Monthly</b>           |                      |
|  |                       | <b>BOD5 &gt; 30mg/L</b>          |                      | <b>Average</b>                   |                      |
|  |                       | <b>BOD &lt; 220mg/L</b>          |                      | <b>BOD5 &lt; 30mg/L</b>          |                      |
|  |                       | <b>(gal./ft<sup>2</sup>/day)</b> | <b>(gal./LF/day)</b> | <b>(gal./ft<sup>2</sup>/day)</b> | <b>(gal./LF/day)</b> |
| Course sand or courser                         | N/A                   | .3 - .4                          | .6 - .8              | .3 - 1.6                         | .6 - 3.2             |
| Loamy coarse sand                              | N/A                   | .25 - .3                         | .5 - .6              | .25 - 1.4                        | .5 - 2.8             |
| Sand   | N/A                   | .25 - .3                         | .5 - .6              | .25 - 1.2                        | .5 - 2.4             |
| Loamy sand                                     | Weak to strong        | .25 - .3                         | .5 - .6              | .25 - 1.4                        | .5 - 2.4             |
|  | Massive               | .15 - .2                         | .3 - .4              | .15 - .7                         | .3 - 1.4             |
| Fine sand                                      | Moderate to strong    | .25 - .3                         | .5 - .6              | .25 - .9                         | .1 - 1.8             |
|  | Massive or weak       | .15 - .2                         | .3 - .4              | .15 - 0.6                        | .3 - 1.2             |
| Loamy fine sand                                | Moderate to strong    | .2 - .3                          | .4 - 0.6             | .2 - 0.9                         | .4 - 1.8             |
|  | Massive or weak       | .15 - .2                         | .3 - .4              | .15 - .6                         | .3 - 1.2             |
| Very fine sand                                 | N/A                   | .15 - .2                         | .3 - .4              | .15 - .6                         | .3 - 1.2             |
| Loamy very fine sand                           | N/A                   | .15 - 0.2                        | .3 - .4              | .15 - .6                         | .3 - 1.2             |
| Sandy loam                                     | Moderate to strong    | .15 - 0.2                        | .3 - .4              | .15 - 1                          | .3 - 2               |
|  | Weak, weak platy      | .15 - 0.2                        | .3 - .4              | .15 - .6                         | .3 - 1.2             |
|  | Massive               | < .1                             | < .2                 | .1 - .5                          | .2 - 1               |
| Loam   | Moderate to strong    | .15 - .2                         | .3 - .4              | .15 - .9                         | .3 - 1.8             |
|  | Weak, weak platy      | .1 - 0.2                         | .2 - .4              | .1 - .6                          | .2 - 1.2             |
|  | Massive               | < .1                             | < .2                 | .1 - .5                          | .2 - 1               |
| Silt loam                                      | Moderate to strong    | .15 - .2                         | .3 - .4              | .15 - .8                         | .3 - 1.6             |
|  | Weak, weak platy      | < .1                             | < .2                 | .1 - .3                          | .2 - .6              |
|  | Massive               | 0                                | 0                    | .1 - .2                          | .2 - .4              |
| Sandy clay loam                                | Moderate to strong    | .15 - .2                         | .3 - .4              | .15 - .6                         | .3 - 1.2             |
| Clay loam                                      | Weak, weak platy      | < .1                             | < .2                 | .1 - .3                          | .2 - .6              |
|  | Weak, weak platy      | < .1                             | < .2                 | .1 - .3                          | .2 - .6              |
|  | Moderate to strong    | .1 - .2                          | .2 - .4              | .1 - .6                          | .2 - 1.2             |
| Silty clay loam                                | Weak, weak platy      | < .1                             | < .2                 | .1 - .3                          | .2 - .6              |
|  | Massive               | 0                                | 0                    | 0                                | 0                    |
|  | Moderate to strong    | .1 - .2                          | .2 - .4              | .1 - .6                          | .2 - 1.2             |
| Sandy clay                                     | Moderate to strong    | < .1                             | < .2                 | .1 - .3                          | .2 - .6              |
|  | Massive to weak       | 0                                | 0                    | 0                                | 0                    |
| Clay   | Moderate to strong    | < .1                             | < .2                 | .1 - .3                          | .2 - .6              |
|  | Massive to weak       | 0                                | 0                    | 0                                | 0                    |
| Silty clay                                     | Moderate to strong    | < .1                             | < .2                 | .1 - .3                          | .2 - .6              |
|  | Massive to weak       | 0                                | 0                    | 0                                | 0                    |

| <b>Table E.1: Concrete Cost</b>                  |                               |                         |                          |                          |
|--|-------------------------------|-------------------------|--------------------------|--------------------------|
| <b>Columns</b>                                   | Type C1                       | Type C2                 | Type C3                  | Volume (m <sup>3</sup> ) |
| Level 1 (l=4.575)                                | 6                             | 2                       | 55                       | 15.0                     |
| Level 2 (l=3.425)                                | 0                             | 8                       | 55                       | 12.4                     |
| <b>Beams</b>                                     | .25x.25 (m)                   | .4x.4 (m)               | .2*.2 (m)                | Volume(m <sup>3</sup> )  |
| l=2  | 6                             | 0                       | 38                       | 3.8                      |
| l=3  | 22                            | 0                       | 18                       | 6.3                      |
| l=3.25   | 16                            | 0                       | 8                        | 4.3                      |
| l=6  | 0                             | 3                       |                          | 2.9                      |
| Total  | 44                            | 3                       | 64                       | 17.2                     |
| <b>Column Pads ( Footing &amp; Foundations )</b> |                               |                         |                          |                          |
| Size   | Number                        | Volume(m <sup>3</sup> ) |                          |                          |
| 1.5x1.5x.5                                       | 8                             | 9                       |                          |                          |
| 1x1x.5   | 55                            | 27.5                    |                          |                          |
| Total  | 63                            | 36.5                    |                          |                          |
| <b>Slabs</b>                                     | Thickness (m)                 | Area (m <sup>2</sup> )  | Volume (m <sup>3</sup> ) |                          |
| 1st Floor  | 0.15                          | 527                     | 79.05                    |                          |
| 2nd Floor  | 0.15                          | 136                     | 20.4                     |                          |
| <b>Stairs</b>                                    | Volume (m <sup>3</sup> )      |                         |                          |                          |
| Estimate   | 1                             | each                    |                          |                          |
| Total  | 3                             |                         |                          |                          |
| <b>Septic Tank</b>                               | (includes tank and dropboxes) |                         |                          |                          |
| Total  | 9.7                           | m <sup>3</sup>          |                          |                          |
| <b>Total Concrete Volume</b>                     |                               |                         |                          |                          |
| 193.3 m <sup>3</sup>                             |                               |                         |                          |                          |
| <b>Estimate Cost for Concrete</b>                |                               |                         |                          |                          |
| 200 US\$ per m <sup>3</sup>                      |                               |                         |                          | <b>\$38,655.28</b>       |

| <b>Table E-2: Rebar Cost</b>  |                                     |                                 |                             |                     |
|---|-------------------------------------|---------------------------------|-----------------------------|---------------------|
| <b>Structural Element</b>   | <b>Steel Volume (m<sup>3</sup>)</b> | <b>Unit Cost (ringgits/ton)</b> | <b>Unit Cost (US\$/ton)</b> | <b>Total (US\$)</b> |
| Beams   | 0.183                               | 1320                            | 420.95                      | \$666.45            |
| Columns   | 0.348                               | 1320                            | 420.95                      | \$1,263.46          |
| Masonry Walls   | 0.061                               | 1320                            | 420.95                      | \$222.73            |
| 2nd Floor Slab  | 0.197                               | 1320                            | 420.95                      | \$714.33            |
| Footings  | 0.181                               | 1320                            | 420.95                      | \$659.69            |
| Septic Tank   | 0.054                               | 1320                            | 420.95                      | \$194.59            |
| Stairs  | 0.016                               | 1320                            | 420.95                      | \$59.79             |
| <b>TOTAL</b>  | <b>1.040</b>                        |                                 |                             | <b>\$3,721.25</b>   |
| *Rebar costs found in Malaysia from <a href="http://www.icoste.org/laborsteel.htm#steel">http://www.icoste.org/laborsteel.htm#steel</a> |                                     |                                 |                             |                     |

| <b>Table E.3: Fabricated Steel Cost</b> |                    |            |
|---|--------------------|------------|
| <b>Truss</b>                            |                    |            |
| <i>Size</i>                             | WT 4X14            | LD 2X2X1/4 |
| Weight (lb/ft)                          | 14.0               | 6.4        |
| Weight (kg/m)                           | 20.8               | 9.5        |
| <i>Length (m)</i>                       | 32.5               | 16.9       |
| Weight (kg)                             | 676.5              | 160.5      |
| 10 Trusses                              | 6765.3             | 1604.6     |
| <b>Lintels</b>                          |                    |            |
| <i>Size</i>                             | LD 3.5X2.5X1/4     |            |
| Weight (lb/ft)                          | 9.8                |            |
| Weight (kg/m)                           | 14.6               |            |
| <i>Lengths</i>                          |                    |            |
| Door 1 (m)                              | 16.8               |            |
| Door 2 (m)                              | 2.8                |            |
| Windows                                 | 66.5               |            |
| Total Length (m)                        | 86.1               |            |
| Weight (kg)                             | 1255.5             |            |
| <b>Bracing</b>                          |                    |            |
| <i>Size</i>                             | LD 2X2X1/4         |            |
| Weight (lb/ft)                          | 6.4                |            |
| Weight (kg/m)                           | 9.5                |            |
| Length (m)                              | 120.7              |            |
| Weight (kg)                             | 1146.3             |            |
| Total Fabricated Steel (kg)             | 10771.7            |            |
| Fabrication and Erection (\$/kg)        | 1.10               |            |
| Fabrication and Erection                | <b>\$11,848.84</b> |            |

|                                   |                    |
|-----------------------------------|--------------------|
| Wall Area                         |                    |
| Exterior (m <sup>2</sup> )        | 567                |
| Ext. Windows (m <sup>2</sup> )    | 59.38              |
| Ext. Doors (m <sup>2</sup> )      | 23.26              |
| Interior (m <sup>2</sup> )        | 170.59             |
| Int. Windows (m <sup>2</sup> )    | 0                  |
| Int. Doors (m <sup>2</sup> )      | 17.6               |
| Filled Area (m <sup>2</sup> )     | 637.35             |
| Brick Area (m <sup>2</sup> )      | 0.02               |
| Bricks                            | 37272              |
| 25% Contingency                   | 9318.02            |
| Total Bricks                      | 46590              |
| Price/brick (Baht)                | 2.02               |
| Cost (Baht)                       | 94162.75           |
| Brick Cost (\$)                   | \$2,989.29         |
| Stucco Price (\$/m <sup>2</sup> ) | 38.86              |
| Stucco Cost                       | \$24,767.52        |
| <b>Total Cost</b>                 | <b>\$27,756.81</b> |

|                             |                   |
|-----------------------------|-------------------|
| Roof Area (m <sup>2</sup> ) | 512.35            |
| Tile Area (m <sup>2</sup> ) | 0.07              |
| Tiles                       | 7624              |
| 10% Contingency             | 1906.07           |
| Total Tiles                 | 9530              |
| Price/Tile (Baht)           | 4.89              |
| Cost (Baht)                 | 46596.33          |
| <b>Cost (\$)</b>            | <b>\$1,479.25</b> |

| <b>Table E.6 Plumbing Cost</b> |       |           |                   |
|--------------------------------|-------|-----------|-------------------|
|                                | Units | cost/unit | Cost (\$)         |
| Toilets                        | 7     | 430       | \$3,010.00        |
| Urinals                        | 3     | 500       | \$1,500.00        |
| Sinks                          | 6     | 200       | \$1,200.00        |
| Toilet Compartments            | 7     | 286       | \$2,002.00        |
| <b>Total</b>                   |       |           | <b>\$7,712.00</b> |

| <b>Table E.7: Septic Cost</b>            |                                |                   |
|--|--------------------------------|-------------------|
| <i>PVC</i>                               |                                |                   |
|  | Perforated (m)                 | Solid (m)         |
| Diameter                                 |                                |                   |
| .1 m                                     | 140                            | 10.8              |
| .15 m                                    | 0                              | 3                 |
| .2 m                                     | 0                              | 7                 |
| Costs                                    | \$366.80                       | \$57.82           |
| <i>Concrete</i> (*included in Table E.1) |                                |                   |
|  | Drop Box                       | Tank              |
| Volume (m <sup>3</sup> )                 |                                |                   |
| Per Box                                  | 0.05                           | 9.5               |
| Total                                    | <b>0.25</b>                    | <b>9.5</b>        |
| <i>Rebar</i> (*included in Table E.2)    |                                |                   |
| Length                                   | 415 m                          |                   |
| <i>Sealant</i>                           |                                |                   |
|  | 60 m <sup>2</sup> Surface Area |                   |
|  | 12.2 L "first coat"            |                   |
|  | 8.1 L "second coat"            |                   |
|  | 20.4 L sealant                 |                   |
| Price (\$/L)                             | 7.93                           |                   |
| Cost (\$)                                | \$161.40                       |                   |
| <i>Drainage Rock</i>                     |                                |                   |
| Quantity                                 | 42.7                           | m <sup>3</sup>    |
| Unit Cost                                | 32                             | \$/m <sup>3</sup> |
| Rock Cost                                | \$1,366.40                     |                   |
| <i>Ground Cloth Fabric</i>               |                                |                   |
| Quantity                                 | 140                            | m <sup>2</sup>    |
| Unit Cost                                | 1.24                           | \$/m <sup>2</sup> |
| Fabric Cost                              | \$173.00                       |                   |
| <b>Total Cost</b>                        | <b>\$2,125.42</b>              |                   |

| <b>Table E.8: Accessories Cost</b> |                   |
|------------------------------------|-------------------|
| <i>Doors</i>                       |                   |
| Number                             | 14                |
| Price (\$/item)                    | 95.83             |
| Cost (\$)                          | \$1,341.62        |
| <i>Windows</i>                     |                   |
| Number                             | 38                |
| Price (\$/item)                    | 95.83             |
| Cost (\$)                          | \$3,641.54        |
| <i>Decking</i>                     |                   |
| Price (\$/ft <sup>2</sup> )        | 0.9               |
| Price (\$/m <sup>2</sup> )         | 9.69              |
| Roof Area (m <sup>2</sup> )        | 512.35            |
| Cost (\$)                          | \$4,963.58        |
| <b>Total Accessories</b>           | <b>\$9,946.74</b> |

| <b>Figure E.9: Labor Cost</b>  |                  |
|--|------------------|
| <b>Labor Items</b>   | <b>Man-hours</b> |
| <b>Earthwork/Excavation</b>  |                  |
| Site Clearing - Brush, Vegetation  | 144              |
| Trenching the site   | 10               |
| Preparing the Building Pad   | 120              |
| Digging Footings   | 24               |
| Excavating the Retention Pond  | 200              |
| Backfilling Foundation   | 160              |
| Digging Sewer Trenches for Septic Tank                                   | 80               |
| Grading the Site   | 160              |
| <b>Concrete</b>  |                  |
| (includes formwork, reinforcement, placement, finishing, and sawcutting) |                  |
| 63 Footing Pads (8-1.5x1.5x.5; 55-1x1x.5; Vol.=36.5 m <sup>3</sup> )     | 840              |
| 63 Level 1 Columns (6 C1, 2 C2, 55 C3; Vol.=15.03 m <sup>3</sup> )       | 600              |
| Beams at Level 2 Floor (Vol.=11 m <sup>3</sup> )                         | 450              |
| Columns at Level 2 (8 C2, 55 C3; Vol.=12.35 m <sup>3</sup> )             | 600              |
| Beams at Level 3 (Vol.=6.24 m <sup>3</sup> )                             | 500              |
| Floor 1 S.O.G. (A=527 m <sup>2</sup> ; Vol. = 79.05 m <sup>3</sup> )     | 800              |
| Floor 2 Slab (A=136 m <sup>2</sup> ; Vol. = 20.4 m <sup>3</sup> )        | 500              |
| Stairs (Vol.=3 m <sup>3</sup> )  | 100              |
| Septic Tank (Vol.=9.7 m <sup>3</sup> )                                   | 200              |
| <b>Masonry</b>   |                  |
| Exterior - Lay 567 m <sup>2</sup>  | 240              |
| Interior - Lay 171 m <sup>2</sup>  | 75               |
| Wall Finishes - Stucco   | 140              |
| <b>Steel</b>   |                  |
| Truss Erection   | 240              |
| Cross Bracing  | 60               |
| <b>Roofing</b> (Roof Area = 512.4 m <sup>2</sup> )                       |                  |
| Metal Deck   | 160              |
| Clay Tiles ( # = 9530)   | 240              |
| <b>General Items</b>   |                  |
| Window and Door Install  | 60               |
| Plumbing- Bathrooms and Septic   | 80               |
| Handrails  | 30               |
| Site Cleanup   | 100              |
| Man-hours  | 6913             |
| Average Wage (US \$/hr)  | 5                |
| <b>Labor Cost</b>  | <b>\$34,565</b>  |

| <b>Figure E.10: Addendum #1 Cost</b>    |                             |                   |
|---|-----------------------------|-------------------|
| <b>Issue: 2nd Floor Handicap Access</b> |                             |                   |
| <i>Trades Affected</i>                  |                             |                   |
| Concrete                                |                             |                   |
| Masonry                                 |                             |                   |
| Building Accessories                    |                             |                   |
| <b>Pricing</b>                          |                             |                   |
| <i>Concrete</i>                         | Volume<br>(m <sup>3</sup> ) | Cost              |
| Remove (1) Stair                        | -1                          | -\$200.00         |
| Add 50.5 linear meters of ramp          | 6.06                        | \$1,212.00        |
| Add 6 concrete columns                  | 2.56                        | \$512.00          |
| Add 6 footings                          | 3                           | \$600.00          |
| Change                                  | 10.62                       | \$2,124.00        |
| <i>Masonry</i>                          |                             |                   |
| Remove 2 Lintels                        |                             | -\$65.78          |
| Remove 2 Masonry Vents                  |                             | -\$56.00          |
| Add 3.94 m <sup>2</sup> of brick        |                             | \$12.61           |
| Add 7.88 m <sup>2</sup> of stucco       |                             | \$306.22          |
| Change                                  |                             | \$197.05          |
| <i>Building Accessories</i>             |                             |                   |
| Remove 2 Windows                        |                             | -\$191.66         |
| Add 75 meters of railing                |                             | \$2,250.00        |
| Change                                  |                             | \$2,058.34        |
| <b>Total Change</b>                     |                             | <b>\$4,379.39</b> |