SAME POLYTECHNIC COLLEGE – PHASE ZERO

SPRING 2020

Hester Lui, Nicole O’Connor, Amber Sutherland
Project Advisor: Kevin Dong

(Renderings created by Architecture Grad. Student, Nooshin Shafiee)
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1.0—NARRATIVE

The Same Polytechnic College, located in Same (Sah-may), Tanzania, is an on-going project that has been worked on by approximately 600 Cal Poly students over the past decade. Same is a rural town located in northern Tanzania that is near Mt. Kilimanjaro as shown in Figure 1. The college is being designed for the Mbesese Initiative for Sustainable Development (MISD), a nonprofit organization working towards alleviating poverty in rural East Africa through the expansion of access to education. The organization believes that through tertiary education in a vocational school, people can develop the knowledge and skills necessary to increase human capital and economic growth.

Countless hours have been spent on the design of the Same Polytechnic College since 2014 by students and faculty. Within the past two years, construction in Tanzania has begun and has informed many of the decisions made throughout this project. The beginning of progress on site has been marked by the construction of the Same Polytechnic College sign as seen in Figure 4. In 2018 the Test Structure, see Figure 2, was built on the outskirt of the main campus site. This test structure consisted of masonry walls and a timber roof, which is similar to the design of this senior project. Not only did the Test Structure allow visualization of a built product, but it provided context for many of the logistical and constructability aspects of building in Tanzania. For example, local builders helped with construction and this allowed MISD to evaluate the adaptability of the builders and the quality of their work. Information was also collected on the cost of the materials that were used for the Test Structure and this helps with future estimates of material and labor costs. The following summer in 2019, a steel pedestrian bridge, see Figure 3, was constructed at the Majevu Primary School to replace a dilapidated wooden bridge. This outreach project helped to define MISD’s presence in Same and gave children safer access across a deep ravine on their way to school. The steel bridge brought new challenges to construction as it was the first experience using electrically powered tools on steel and maneuvering such heavy sections. Both structures have contributed to the design of this project in terms of how feasible it is with respect to time, material, and labor.
As an interdisciplinary team of architectural engineering, architecture, and landscape architecture students, the master plan of the college was refined and the design of "Phase Zero" was created as the first step towards the organization’s goals. Figure 8 shows the size of Phase Zero with respect to the size of one of the five colleges. The proposed location is within the business college, as illustrated in the master plan shown in Figure 5. Figure 7 shows a detailed master plan design of a single college, which was influenced by weaving patterns, as shown in Figure 6, that are typically observed in Same. Additional benefits to this design include enhancement of passive ventilation, a clear circulation path and the ability to incorporate private and public outdoor spaces. Passive ventilation was a primary influencer on the design of the master plan, as it governed the spacing between the building modules, or horizontal bars, in addition to the location of the agriculture fields. The use of passive ventilation allows for an energy saving and low maintenance design. Since the wind enters the campus from the south-west direction, the agriculture fields were placed in the top right portion of the campus. This ensures that as the wind blows through the college, the odors from the fields do not enter campus. Another important design aspect was the landscaping, which focused on creating private versus public outdoor spaces since Tanzanians value spending time outdoors. It was developed and enhanced by landscape architecture student, Eliana Parkerton, who used the location of plants to create both exclusive zones as well as large gathering places.

Within the master plan, the location of Phase Zero was chosen due to its proximity to the main road, future city housing, and the proposed future administration building and campus housing. Special attention was given to the overall layout of Phase Zero to ensure that it can be considered an independent design, while also seamlessly connecting into future additions from the master plan. Figure 8 illustrates the temporary placement of agriculture fields in the area envisioned for future additions of the college during Phase Zero. As the college continues to be built, the agriculture fields will be relocated to the location shown in the master plan.
2.0 – PROJECT DESCRIPTION

Phase Zero, illustrated below in Figure 9, consists of the initial workshop and classroom spaces on campus that can be built in one summer. Building the first classroom and community spaces on site will help establish the presence of the nonprofit in Same and encourage locals to continue their education at the school.

Passive design strategies were incorporated throughout the design of Phase Zero with the help of Architecture students, Nooshin Shafiee and Chaomin Chen. Solar studies, as shown in Figure 11, were performed on the modules to determine the required overhang of the roof to provide proper shading from the sun. This keeps heat and direct sunlight out of the building to protect the materials and ensure occupant comfort. Perforated walls were incorporated into the design to allow for natural lighting and ventilation as well as aesthetic appeal. An additional opening in the middle of the main roof structure, as seen in Figure 10, also provides natural lighting into the classroom spaces while creating an architecturally captivating design.

The main roof system consisting of large overhangs to optimize shading will be supported by trusses and cantilevered columns. The enclosed spaces will exist underneath the roof overhang with reinforced masonry walls and a secondary timber roof. The foundation will consist of a slab, pad footings, and grade beams. The cantilevered columns act as the lateral load-resisting system while the trusses and masonry walls are a part of the gravity load-resisting system. An important aspect of this structural design includes detailing the connections to ensure proper fit and constructability. Figure 10 highlights each element designed in Phase Zero.
A significant amount of information and assumptions about the materials used were from past experience building in Same. Figure 12 displays materials that were used in the Test Structure and the pedestrian bridge. The steel sections were comparable to what can be found in the U.S., however the timber was often warped and still green which could pose as an issue for fit up during installations. The cement block is not what is typically used in the U.S., but rather a solid block with grooves carved out along the perimeter to allow rebar to sit inside. In past projects, concrete has been hand-mixed due to unreliable access to machinery; this was also taken into account when considering the strength of the concrete.

Communicating the design effectively is always an integral aspect to any project. It is a focal point for this project because it will be constructed by a team of Cal Poly students, MISD volunteers, and local builders. The deliverables for this senior project include design development drawings and a schematic design booklet. The goal this year has been to develop portions of the design so that members of industry and the nonprofit can complete the construction documents.

The language barrier will make it more difficult to communicate verbally, therefore it is important to have tools which show the design visually. Not only does this project have the typical design development documents consisting of plans and details, but it also includes visual representations of the project. An overall construction sequencing 3D animation was made and envisioned to be viewed onsite with a tablet or laptop for clarity, as seen in Figure 14 on the following page. This animation can be seen on YouTube with the following link: https://youtu.be/R7UVa3F-pXQ. Additionally, a booklet has been created as a tool to provide quick preliminary member sizes based off of different configurations. Figure 13 displays one of the three-dimensional drawings that can be found in the Schematic Design Booklet; it was put together to help clarify the design of the grade beam reinforcement in relationship to the slab reinforcement. By creating documents to show the construction sequencing and detailing three-dimensionally, a realistic design can be ensured by evaluating its constructability.
Figure 14 – Navisworks Clips
3.0 – DESIGN ASSUMPTIONS

The past construction projects in Tanzania helped influence many of the design decisions of Phase Zero. The two most notable decisions include reducing the expected strength of the materials as well as taking constructability of the member shape and size into consideration.

The following values were used for the expected strengths of various materials:

**Concrete:**
- 28-day compressive strength, $f'_c = 3,000$ psi

**Masonry:**
- Specified compressive strength, $f'_m = 500$ psi
- Modulus of rupture, $f_r = 145$ psi
- Modulus of elasticity, $E_m = 450$ ksi

**Reinforcement:**
- Specified yield strength, $f_y = 40$ ksi
- Modulus of elasticity, $E = 29,000$ ksi

**Steel:**
- Specified yield strength, $f_y = 36$ ksi
- Modulus of elasticity, $E = 29,000$ ksi

**Timber:**
- Reference tension design value parallel to grain, $F_t = 675$ psi
- Reference compression design value parallel to grain, $F_c = 1500$ psi
- Modulus of elasticity, $E = 1700$ ksi

*Note: Eucalyptus is the typical timber used for construction in Tanzania, which is often warped and still green. Due to the lack of available information on the species of eucalyptus and its mechanical properties, Douglas-Fir Larch was used.*

Because of the lack of information on the site conditions, Sacramento, CA was used to determine site and design parameters for both wind and seismic forces. The landscape and weather conditions in Sacramento are comparable to what is found in Same. As seen in Figure 15 & 16, Sacramento actually has slightly larger wind speeds which allow for a conservative design.

For the lateral load-resisting system, wind design governed over seismic design. The wind forces on the trusses were determined using the components and cladding procedure in Chapter 30 of ASCE 7-16, while the cantilevered columns were designed using the directional procedure for the main wind force resisting system in Chapter 27 of ASCE 7-16.

The following codebooks/design references were used for minimum values and properties:

- IBC 2018
- ACI 318-19
- AISC 14th ed.
- ASCE 7-16
- NDS 2018
- TMS 402/602-16

*Figure 15 – Sacramento, California USA Wind Speed*

*Figure 16 – Same, Tanzania Wind Speed*
The goal of the Mbesese Initiative for Sustainable Development is to help alleviate poverty in rural East Africa through better access to education. Many elementary and secondary schools currently receive help from organizations around the world, however there is a reduced effort to help expand access to tertiary education. While it is more alluring to donors to help support children going through primary school, it is equally important to continue their education into adulthood because that is a key factor in helping societies advance forward.

Working on a project in Tanzania has exposed us to global issues such as the quality of construction and materials. There are many existing structures in Tanzania consisting of mud and branches, and while this provides temporary shelter, it does not lead to a long-lasting structure. Not only has this project helped to solidify our concepts of structural engineering, but it will help expose local builders in Tanzania to alternate building practices using indigenous materials with new technologies. It is important to not only assist with design and construction of this vocational school, but to educate locals on why our practices differ and how this could be incorporated into their work to help promote self-sufficiency. An integral aspect to this project is incorporating Tanzanian influences and styles into the design of the campus in order to better connect with the community. Simply building a western style structure in a Tanzanian town does not show an appropriate amount of appreciation for Tanzanian culture. Aspects of this can be found in the design for Phase Zero, including integrating a weaving pattern into the building layouts to mimic textiles found in the country as well as ensuring ample amounts of shaded outdoor spaces as Tanzanians can be found spending much of their time outside.

A highly influential factor in the building design was the overall cost of Phase Zero. This project is financed through fundraising and donations, thus leaving a tight budget. Tanzania differs from the U.S. as labor is typically cheaper than materials. Because of this, design decisions were based off which option was the most economical and efficient. For example, we chose to explore a composite truss made of wood and steel in order to get the benefits of building with steel, while also saving material costs with wooden members. It also forced us to weigh the importance of different factors in terms of cost and constructability. As an example, when designing the large trusses, we could space them more closely together resulting in smaller loading and therefore smaller member sizes. However, this would also cause a need for more trusses, hence more labor and materials.
The constructability of this design as well as the timeline to construct were taken into consideration throughout this project. Due to time constraints of student trips, the timeline for students to be involved with construction in country is limited to about four weeks. A primary focus of this project was deciding what Phase Zero would consist of, and if this could be built in a reasonable time period. The scope of the project had to be thoughtfully planned out in order to produce a project that can stand alone and look complete while also connecting seamlessly to future additions. The details of the trusses forced us to consider the constructability as well as the sequencing of construction of this project. This posed many issues as we hit roadblocks in our design when considering available materials and how easily they could be constructed. One surprise that came from this project was that many of the member sizes in the trusses were governed by the geometry of the connections rather than the strength or allowable deflection.

Due to the COVID-19 pandemic, representatives of MISD were not able to travel to Same, Tanzania this year to gather additional information on some of the material that would be used. Instead, past projects were depended on for information about available materials, however new information was not collected on the feasibility of using different member sizes. More informed decisions could have been made if there was more in-depth information on the cost and availability of specific materials. For instance, this would have influenced the decision on which steel sections should be used for the columns or which 2x members should be used for the roof joists; these decisions affect the overall spacing of the elements.

Many lessons were learned from this project, and we hope that future students can benefit from this work. In retrospect, it would have been more logical for us to develop schematic drawings and details before starting the calculations to first explore factors of constructability. For example, the design of the truss connections seemed straightforward while doing the calculations based on strength and deflection, but ultimately the minimum spacing of the bolts governed the design. Because the bolts had to be properly spaced, the members on the wooden truss had to be significantly upsized to accommodate the connections. Most importantly, as engineering students, it is easy to get caught up in the numbers and leave the organization of the design package as the last step. However, this is an incredibly important aspect of any project, especially this project because of the cultural and language differences. The presentation of our design and how we communicated it should have been developed earlier in the project so that it could be refined throughout the project timeline.
5.0 – DESIGN DEVELOPMENT DRAWINGS

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A.1 Master plan
A.2 Phase Zero Plan
S.1 Foundation Plan
S.2 Building Framing Plan
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S.7 Composite Typ. Details
S.8 Foundation Typ. Details
S.9 Masonry Typ. Details


BUILDING FRAMING LEGEND:

FOR LENGTHS ≤ 12'-0"

J1: 2X4 ROUGH CUT LUMBER @ 24" O.C.

FOR 12'-0" < LENGTHS ≤ 18'-6"

J2: 2X6 ROUGH CUT LUMBER @ 24" O.C.

FOR 18'-6" < LENGTHS ≤ 29'-6"

B1: 5-1/8"X18" GLULAM

C1: PIPE 6-STD COL.

1/8" PLYWOOD SHEATHING TYP.

2X4 BLOCKING @ 36" O.C. TYP.

1/16" = 1'-0"
NOTE: ALL ELEVATIONS ARE MEASURED FROM TOP OF SLAB
NOTE: DESIGN IS FOR A 30' SPAN BETWEEN COLUMNS
**COLUMN TO TRUSS - COMPOSITE**

- 1/4" CLNR. CAP
- STL PIPE COLUMN
- STL CRUCIFORM
- 2L6X3.5X3/8 STL. DBLE. ANGLE CHORDS WELDED TOGETHER

**NOTE:**

1. DESIGN IS FOR A 30' SPAN

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**COLUMN TO GIRDER TRUSS - COMPOSITE**

- 1/4" CLNR. CAP
- 2L6X3.5X3/8 STL. DBLE. ANGLE CHORDS WELDED TOGETHER T&B
- 1/4" CLNR. CAP
- 7D HEB BOLTS TYP. U.N.O.

**NOTE:**

1. DESIGN IS FOR A 20' GIRDER TRUSS SPAN

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**COMPOSITE CROSS-SECTION**

- 1 1/2" = 1'-0"
- COLUMN TO TRUSS - COMPOSITE
- 1/8" = 1'-0"
- COLUMN TO GIRDER TRUSS - COMPOSITE

**NOTE:**

1. DESIGN IS FOR A 30' SPAN

---

**REVISIONS:**

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**DRAWN BY:**

ACS

**DATE:**

05/19/20

**SCALE:** As indicated

**TITLE:**

COMPOSITE TYP. DETAILS

**SHEET No.:**

S.7
6.0 – SCHEMATIC DESIGN BOOKLET
### JOIST TRUSS

**Diagram:**
- Chord
- Vertical Web
- Diagonal Web

### GIRDER TRUSS

**Diagram:**
- Chord
- Vertical Web
- Diagonal Web

### TWO WAY TRUSS

**Diagram:**
- W
- L

### JOIST TRUSS WITH CANTILEVER

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<th>Material</th>
<th>Chord Size</th>
<th>Diagonal Web Size</th>
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<tr>
<td>20' - 0&quot;</td>
<td>Wood</td>
<td>(2) 2x6</td>
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<td>1/4x2 Flat Plate</td>
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<td>30' - 0&quot;</td>
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<td>(1) 2x8</td>
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***Assuming 10' - 0" Trib. Width***

### GIRDER TRUSS

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<tr>
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<th>Diagonal Web Size</th>
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<tr>
<td>20' - 0&quot;</td>
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<td>(2) 2x10</td>
<td>(1) 2x8</td>
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<td>2L6x3.5x3/8</td>
<td>(2) 2x6</td>
<td>(2) 2x6</td>
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<tr>
<td>30' - 0&quot;</td>
<td>Wood</td>
<td>(2) 2x10</td>
<td>(1) 2x10</td>
<td>(1) 2x8</td>
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<td>24&quot;</td>
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<td>2L6x3-1/2x5/16</td>
<td>1/4x3-1/2 Flat Plate</td>
<td>1/4x2-1/2 Flat Plate</td>
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<td>30' - 0&quot;</td>
<td>Wood</td>
<td>(2) 2x10</td>
<td>(1) 2x10</td>
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***Assuming 25' - 0" Trib. Width***

### TWO WAY TRUSS

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MASTERY WALL

Masonry Wall
Horizontal Reinforcement: #3 @ 36" O.C.
Vertical Reinforcement: #3 @ 36" O.C.
Mortar Joint Thickness: 3/8"

SECONDARY FRAMING

SECONDARY ROOF FRAMING

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<th>Max. Length</th>
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<td>24&quot; o.c.</td>
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<td>14’ - 0”</td>
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<tr>
<td>18’ - 6”</td>
<td>24&quot; o.c.</td>
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<tr>
<td>29’ - 6”</td>
<td>9’ - 6” o.c.</td>
<td>5.125x18 GLULAM</td>
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GRADE BEAM

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<td>Masonry Wall</td>
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<td>Grade Beams</td>
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*** ASSUMING TRIAL AREA OF 30'-0" X 25'-0"***

COLUMN FOOTING

COMBINED FOOTING

CANTILEVERED COLUMNS

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*** ASSUMING PERPENDICULAR DISTANCE IS SET AT 30'-0"***