Bridge in Africa

Project description

This project was the location, design and construction of a pedestrian suspension bridge in rural Africa. Seasonal flooding from heavy rain makes it difficult for residents to cross the river and has resulted in injuries and deaths in previous years. The restriction in travel limits the educational opportunities for the youth, patients are unable to reach a nearby hospital at all times and the lack of access causes a decrease in labor and economic opportunities. The solution to the inadequacy of transportation is to construct a pedestrian foot bridge that will create a safe option for crossing over to either sides of the river. The bridge was designed and built approximately three meters above the high flood stage of the river. The completion of this bridge has led to improvements in the economy and overall well-being of residents.

Figure 1 and Figure 2 show the left and right terrain conditions, which are where the left and right foundations of the bridge were constructed. The left and right sides for the terrain are determined by standing at the center of the river and looking downstream. The terrain on the left side is composed of sandy soil, while the right side is composed of gravelly soil. The geotechnical classification and conditions are significant in indicating the location and design of the foundations

Figure 3 shows the current crossing of the river, which is composed of rocks that have been placed as steppingstones. Accidents that have resulted in injuries and deaths by pedestrians attempting to cross the river during the flood season in Manzini. Figure 4 shows how the water line can drastically rise and how the current crossing is not adequate for pedestrians who attempt to cross the river. Figure 5 is an aerial view of the site location. The map presents the current site conditions that are present near the bridge. The new bridge was offset from the current crossing since the left abutment might interfere with the current placement of the power poles.

The students worked with faculty and two design engineers to complete the design of the bridge. The importance considerations were:

- Safety - Safety was the most important aspect to consider. It includes structural integrity, adequate railings, walkways materials consider bare foot use, mesh fencing that will not allow small children or objects to pass through, and flood protection.
- Durability - The materials that are to be used should be of suitable quality that will be resistant to its crossing pedestrians and various weather conditions.
- Serviceability - The suspended cable bridge will not have lateral stability, so it susceptible to swaying from the wind and from the loads of the crossing pedestrians. Therefore the design must be tolerant to the physical deformations that it will encounter and reduce sway. Considering the users point of view, the design must have a limit on the acceptable slope of the walkway and the on-ramps prior to the walkway.
- Maintainability -The design of the bridge must consider that each structural component will ultimately require maintenance, and possibly replacement for the fencing, decking, crossing beams and suspenders.
- Constructability - The constructability aspects to consider when designing a bridge is assuring that it can be fabricated and executed.
- Economy -The design must be constructed to the best economical method.
- Aesthetics -The aesthetic appeal of the bridge is conducted through decorative aspects, such as painting the bridge according to the resident's color preferences

The following are the components of the bridge. Because people are involved in various parts, it was essential to identify and understand these components to facilitate the communication between members of the design and construction team to minimize mistakes.

- Anchor - The anchor is made of a reinforced concrete beam that anchors the cables so that when they get pulled, they do not get pulled out of the abutment.
- Approach - The approach is a ramp/wall that connects the anchor to the foundation, tier, and tower.
- Abutment - The abutment is the entire structure, composed of the approach, anchor, tower, tiers, and foundation. The abutment supports the cables and anchors them to the ground. There are two abutments, one on each side of the bridge.
- Saddle The saddle is the center line of the tower, tiers, and foundation. This line is utilized to address the point that the handrail and walkway cables change angles.
- Foundation - The foundation is the first building block that is below the ground (i.e. the subgrade), that the tiers and towers will be built on. The foundation is measured as one (1) meter in height, and this one (1) meter will be placed below the terrain. The height measurement is taken from the front of foundation. The back of the foundation may not necessarily be also one (1) full meter below ground. The front foundation is only required to be (1) meter below the surface. The number of tiers used determines the size of the foundation.
- Tiers - The tiers are similar to the foundation blocks. They are built on top of the foundation. They are typically one (1) meter in height. Their purpose is to increase the height of the cable, which creates a higher elevation from the bottom of the bridge to the highest water line of the water body, known as the freeboard.
- Tower - The tower is the top block of the foundation. The tower is constructed from a reinforced concrete column that holds the compressive load of the cables and distributes the load to the tiers, foundation, and the ground.
- Handrail Cable - The handrail cable runs along the entire span of the bridge. The cables are held by the towers. They are connected to the anchors that are buried underneath the approach ramp. The cables are under tension. The handrail cables are one of the components responsible for holding the suspended bridge.
- Fencing - The fencing of the bridge is composed of metal mesh that is placed on both sides on the bridge, running along the entire span length. The mesh is placed for the safety purposes, such as preventing pedestrians or items from falling off of the bridge. The fencing also prevents any incoming objects or debris to pass through and across the fencing.
- Suspender - The suspenders are the components that tie to the handrail cables and the walkway cables, while simultaneously supporting and holding the crossbeams in place.
- Decking - The decking is the component that makes up the walkway of the bridge. It is placed on top of the crossbeams and secured onto them, who are in turn secured to the suspenders and walkway cable.
- Crossbeam - The crossbeams are members that cross perpendicular to the cables. These crossbeams members are separated at a determined distance. They stand as the main support for the deck, supported onto the walkway cables and the suspenders.
- Walkway Cable - The walkway cables, similar to the handrail cables, run along the entire span length of the bridge and are supported by the towers. They are connected to the anchors that are buried underneath the approach ramps on each side of the entire structure. These cables support the crossbeams that support the deck and are also attached to the suspenders.

The permanent loads to consider when designing a bridge are those that always remain constant over the life of the bridge, such as the weight of the structure itself. The most significant to consider is dead load (DL). For the suspended cable bridge, a predetermined 1.0 kilonewtons per meter has been established as a safe assumption, considering suspenders, fencing, and a one 1-meter-wide walkway.

Lateral earth pressure is the pressure that the soil applies horizontally and is included with the abutment, wall, and retaining structure design. A type of lateral earth pressure to consider is at-rest and should be used when the resisting structural component is not tolerable of movement. A second type of lateral earth pressure is active soil pressure, and this occurs when a mass is allowed for movement and deform laterally, creating its shear resistance to be mobilized while trying to resist lateral deformation.

The span of the bridge was calculated to be approximately 47 meters. The difference in height is 1.12 meters; which is a value below the 4 percent of the Bridge span length. The provided survey of the terrain indicated that the left side of the terrain was significantly lower than the right terrain. Therefore, the design of the Bridge was created with consideration of this elevation difference to achieve the four percent (4%) change in height parameter. To fulfill this requirement, the tower on the left side had to be designed with the foundation, three (3) tiers, and the tower was designed to the maximum possible height. The tower on the right had to be designed with the foundation, the tower, with only one (1) tier in order to create it to the minimum possible height. Thus, the four percent (4%) height difference based on the span length was achieved.

Figure 6 shows the handrail cable, fencing, suspenders, decking, crossbeams, and walkway cables of the bridge. Figure 7 shows the top view of the design. The bridge was completed in September 2021 (Figure 8).

Collaboration of faculty, students, and licensed professional engineers

The project provides the opportunity for a group of civil engineering majors to work together with civil, environmental and geomatics engineering faculty, practicing professional consulting engineers involved in the structural and geotechnical fields, professional engineers, and field staff working across continents. A variety of deliverables were provided in class, and to the project sponsors for review and ground truthing. Except for covid limitations, the intent was for the students to travel to Africa to participate in, and oversee construction of the bridge. However, the project manager did oversee construction from the US while construction commenced in the summer of 2021. Concepts of long-term planning, sustainability, and creative solutions to water shortages were issues incorporated into the challenge.

Because the student were working in a covid world, the interactions were primarily via zoom and phone conversations. Dropbox was used as a means to exchange drawings and reports, and the gain feedback on the design details.

Classroom activities permitted interaction between students, faculty and alumni ambassadors. This project required this communication to occur. This is unique to this type of project where reliability and sustainability are the driving forces for the design.

Multi-discipline and/or allied profession participation

The students worked with faculty staff, people in Africa and people traveling to Africa to secure the necessary information to facilitate the design. These included a structural engineer in Colorado, field staff in Africa, local construction, and logistics persons to get steel to the site while gathering information from locals on available materials and equipment (very limited). Faculty were from 3 disciplines, and the field and vendor people came from business, construction and other fields that are distinctly not engineering.

Knowledge or skills gained

The project included the consideration of professional practice concepts such as project management, ethics and regulatory standards and laws. The students organized themselves like a consulting firm, picked a project manager and created a schedule to accomplish the work each semester. The students developed skills in:

Figure 1: Left survey Limit, Photo by EIA

Figure 2: Right survey limit, Photo by EIA

Figure 3: Current crossing, Photo by EIA

Figure 4: High water line, Photo by EIA

- Designing a bridge and its foundations
- Conducting an ESA of the site to gather data to determine site limitations
- Communicating with different audiences to obtain useful solutions, like vendors, engineers, and manufacturers
- Conducting research on their own to obtain answers to difficult questions
- Understanding the need to listen and cooperate among the various parties having input to the process
- Managing a large project to competition
- Learning about other cultures
- Understanding the priority of the public health safety and welfare as the primary ethical responsibility in the profession

They created hundreds of pages of documentation of the design that was conveyed to the stakeholders. All of these are knowledge and skills that are important to profession.

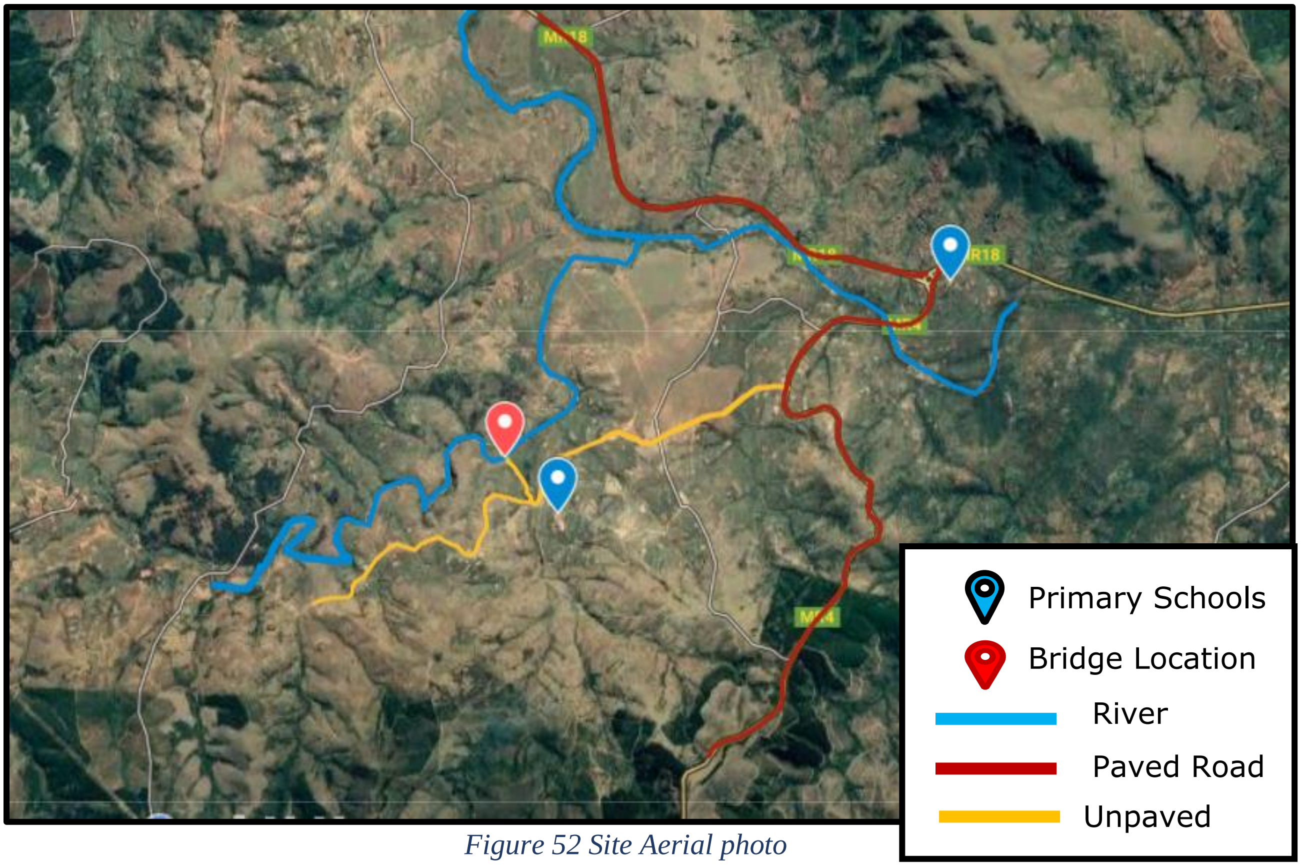

Figure 52 Site Aerial photo

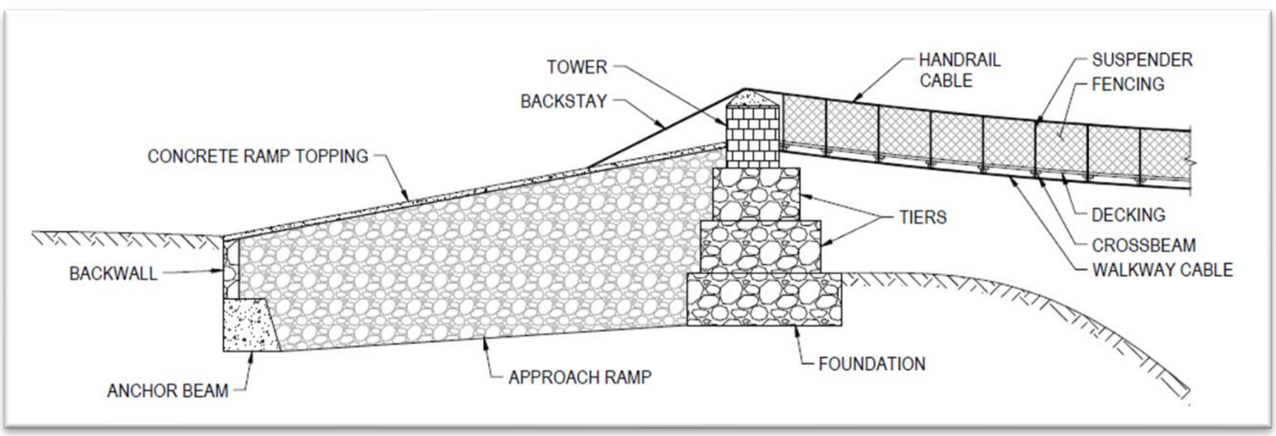

Figure 6: Handrail Cable, Fencing, Suspender, Decking, Crossbeam, Walkway Cable

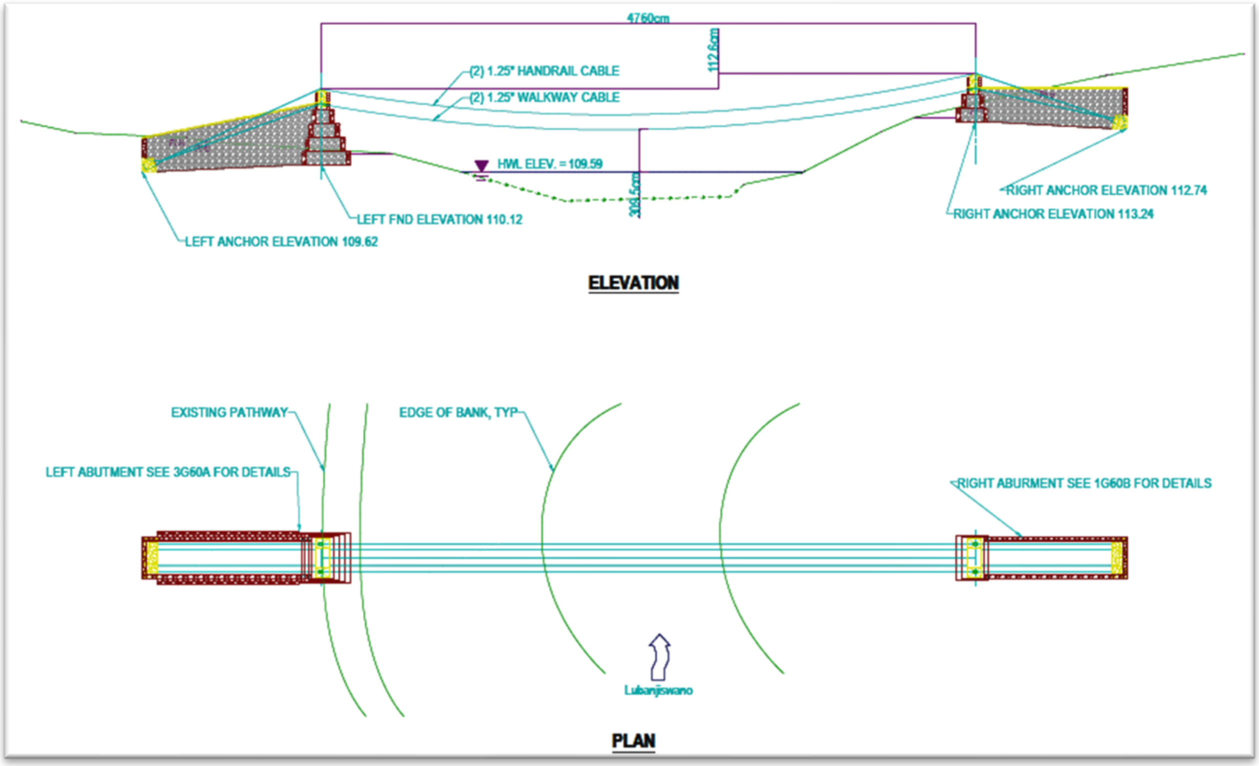

Figure 7: Top View of bridge Design

Figure 8. Final Constructed Bridge

Protection of public health, safety, and/or welfare of the public

The safety of all the workers on site, and the pedestrians who desire to utilize the bridge after construction, was the primary focus during the construction phase of the bridge. The students also earned certification through the completion of a medical training course and an OSHA course designed to recognize and avoid potential safety and health hazards that could exist on the job site. Included in the safety during construction includes finding water, providing sanitation for workers, locating the nearest medical facility around the community and making sure there was no lack in communication at any point given. The safety manager created a list of the proper personal protective equipment (PPE) and an organized schedule. Lastly, the student participated in a cross-cultural competency module designed to provide an understanding of the cultural barriers and social customs that would be encountered.