Sechum Vehicle Bridge

Providing safe, consistent access to communities in Guatemala's Highlands

Project description

The Sechum Vehicular Bridge is a student-led project encompassing the design and construction of a vehicular bridge over the Rio Pasaguay in Guatemala. Located near the rural, Mayan community of Sechum, the project directly impacts approximately 1,300 people in three (3) rural communities seeking safe, reliable crossing of the Rio Pasaguay to access education, markets, and health care. This particular project was presented by the mayor and hospital of the municipality as a highly critical project as six women had recently died in childbirth because they could not reach the hospital. The project was also heavily advocated for by the primary teachers of the impacted communities as their graduates were unable to further their studies at the junior high and high schools located in the nearby city because they could not cross the river. The community described the project as "breaking the barrier" – the barrier to higher education, medical care and economic prosperity. These passionate stories reinforced to the Team the positive change that engineering projects can have on the health, safety and welfare of the public.

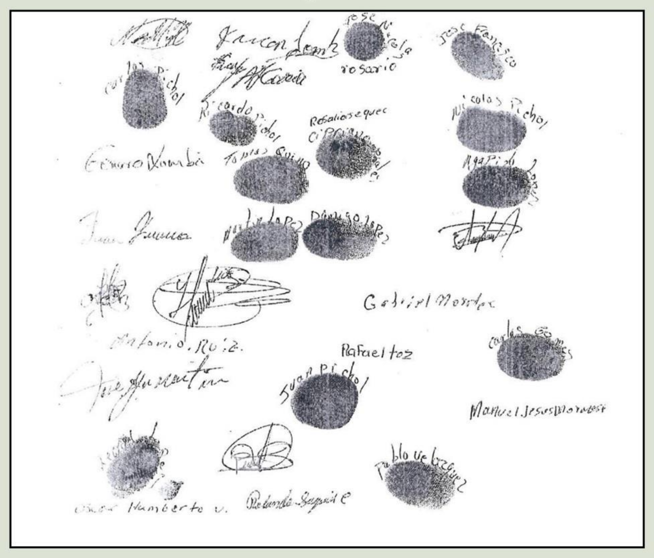
The team consisted of four senior undergraduate students in the civil engineering discipline, with mentorship from eight (8) professional engineers and specific technical backgrounds to support each discipline on the project. The project team met weekly so students could interact with their professional engineering mentors on a regular basis. An additional eleven engineering students, along with over 100 community volunteers, helped with the construction of the bridge which was completed in February 2015.

Project cooperation

As the Mayor stated at the ribbon cutting, "This project required everyone's total dedication and commitment to be realized. The Municipality, student team or community could not have accomplished the project by themselves – but working together an amazing result was possible."

This particular project was presented by the mayor and hospital of the municipality as six women had recently died in childbirth because they could not reach the hospital in time.

Solicitation with thumb print signatures from community members



The community described the project as "breaking the barrier" - the barrier to higher education, medical care, and economic prosperity.

Knowledge and skills gained

Engineering knowledge and skills gained by the students:

- **Surveying**
- **Geotechnical**
- **Hydrology and Hydraulics**
- **Formwork Design**
- **Constructability and Construction Engineering**
- **Cost Estimating**
- **Construction Scheduling**
- **Comparing alternatives and selecting a preferred alternative**

How were the knowledge / skills gained important to professional practice?

Risk Analysis
The students learned the value of doing a sensitivity analysis using different materials properties to aid them in making key decisions.

Quality Design
The students learned that accurate quantity estimates are important and can impact the construction schedule when materials are not easily obtained.

Sustainability
As we come to realize that we have limited resources, even in developed countries, the aspect of considering sustainability during the practice of engineering is an important lessons learned.

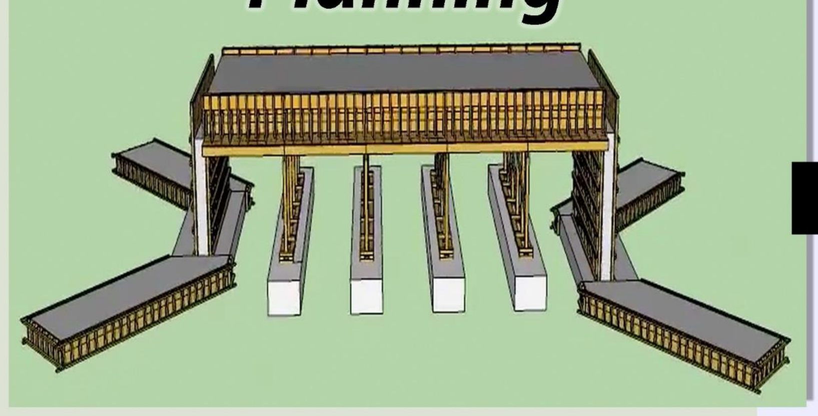
Time Management
The student team logged their time and compared the actual effort to their negotiated budget. Through this process, the team learned how to set project scope for a contract and how to hold themselves accountable for the time spent.

Ethical Use of Engineering Skills
The project team realized their obligation to use their engineering skills to improve the lives of those who are in the most need.

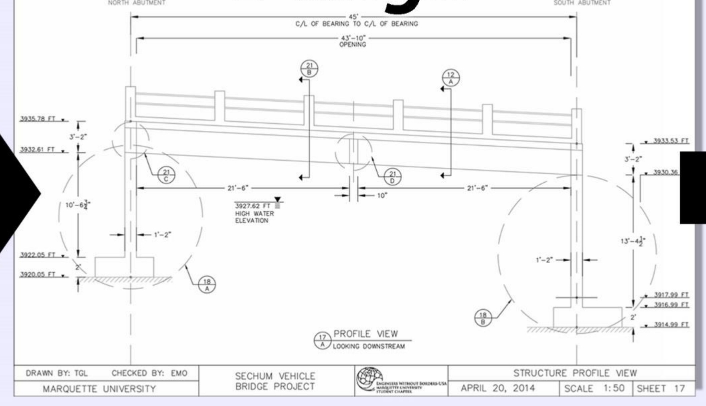
Building Local Construction Capacity
The project was utilized as a classroom for local masons to enhance their understanding of important engineering principles.

Communication
Team members learned to communicate with a variety of stakeholders, including the community and local government.

Planning



Design



Construction

Faculty, students, and professionals

Value of Data Collection and Stakeholder Input
The students learned the value of listening to their stakeholders and using a combination of technical and social data to form a set of possible solutions.

Stakeholder Agreements
The team learned the value of written project agreements.

Development and Execution of a Quality Process
The student team learned the importance of a quality plan and the time required to successfully execute it.

Material Quality
The team learned the variability of materials properties and the importance of adequately accommodating them through the design process.

Construction Process and Requests of Information
The team learned the importance of construction engineering and the need to timely address differing site conditions.

How did the students, faculty and P.E.s interact?

The faculty and professional mentors involved in the project went to great lengths to give the student senior design team a sense of project ownership. As part of the senior design exercise, the team was required to operate as an engineering firm, including submitting teammate CVs and a firm mission statement as part of an interview process to win the work. From there, the team had to negotiate the scope of work and level of effort estimate with professional advisors. To accomplish the technical and managerial challenges posed by this project, the team members collaborated weekly with professional mentors and faculty. The students also met as a team at least once a week to review their progress.

"Through this project, I was able to see first hand the incredible difference engineering projects can make in people's lives."

The Completed Structure

Sechum Vehicle Bridge Abstract

Completed Sechum Bridge

The Sechum Vehicular Bridge is a student-led project encompassing the design and construction of a vehicular bridge over the Rio Pasaguay in Guatemala. Located near the rural, Mayan community of Sechum, the project directly impacts approximately 1,300 people in three (3) rural communities seeking safe, reliable crossing of the Rio Pasaguay to access education, markets, and health care. This particular project was presented by the mayor and hospital of the municipality as a highly critical project as six women had recently died in childbirth because they could not reach the hospital. The project was also heavily advocated for by the primary teachers of the impacted communities as their graduates were unable to further their studies at the junior high and high schools located in the nearby city because they could not cross the river. The community described the project as "breaking the barrier" – the barrier to higher education, medical care and economic prosperity. These passionate stories reinforced to the Team the positive change that engineering projects can have on the health, safety and welfare of the public.

The team consisted of four senior undergraduate students in the civil engineering discipline, with mentorship from eight (8) professional engineers and specific technical backgrounds to support each discipline on the project. The project team met weekly so students could interact with their professional engineering mentors on a regular basis. An additional eleven engineering students, along with over 100 community volunteers, helped with the construction of the bridge which was completed in February 2015.

The project began with a team investigating and collecting information at the proposed site location. Topographical survey points were collected and soil samples brought back for analysis. The design phase consisted of determining the structure type, crossing location, and appropriate bridge dimensions according to standard United States professional engineering practice. Main design concentrations included: hydraulic modeling of the river, structural analysis to select and detail the bridge type, transportation analysis to determine roadway geometry, and construction engineering to schedule and estimate the entire building process. Professional mentors ensured each step was done properly and that design specifications met professional industry standards.

The project provided an excellent real life example to the team and allowed them to gain many important skills. The team learned that considering sustainability during the practice of engineering is important, especially in developing countries where resources are so scarce. Team members also learned how to communicate with a variety of stakeholders, including the end users, government officials, themselves and the general public. This project provided an excellent forum for professional engineers to work with engineering students and demonstrate the value of continuous learning. "It is our obligation as Professional Engineers, to share our knowledge with the next generation of our profession." Lead Professional Engineer.

Finally, the students and professionals alike were reminded by this project on how engineering projects can make a real difference in the world. The project team realized their obligation to use their skills to improve the lives of those who are in most need.

Sechum Vehicle Bridge

I: Project description

The Sechum Vehicle Bridge project is located in the Highlands of Guatemala. It is a 45'-cast in place concrete bridge designed and built by the University Engineers Without Borders (EWB-USA) student chapter.

Completed Sechum Bridge

This region within the highlands of Guatemala is primarily indigenous Mayan due to colonial and post-colonial land issues and related military conflicts. Even by Guatemalan standards, the area is economically depressed. Poverty among indigenous groups, which make up 38% of the population, averages 73% and extreme poverty (less than $1 per day) rises to 27%. Nearly one-half of Guatemala's children under age five are chronically malnourished, one of the highest malnutrition rates in the world.

Located near the rural, Mayan community of Sechum, the project directly impacts approximately 1,300 people in three (3) rural communities seeking a safe, reliable crossing of the Rio Pasaguay to access education, markets, and health care. The bridge provides community members access to Highway 2: a main artery for the region providing access to frequent public transportation and a 15-minute ride to the region's best hospital, the municipal market, and higher education.

Within this context four (4) senior design students, with support of the university EWB student chapter, faculty mentors, and a team of eight (8) professional mentors, set out to identify, design and construct the best solution to meet the needs of the impacted communities.

The project design scope included the roadway, roadway drainage, bridge superstructure, substructure, wingwalls, formwork, construction engineering, scheduling and estimating. The student team were required to submit their final design package for review by their professional mentoring team and the Municipality. The submittal included a verbal presentation of the projects key challenges, risks and solutions.

Team preparation culminated in successful project construction in February 2015. Construction was completed in one month by community members working side by side with the student/ professional project team.

II: Collaboration of faculty, students, and licensed professional engineers

Were licensed professional engineers (P.E.s) involved?

Eight (8) professional engineers were involved. One PE from the disciplines of Hydrology & Hydraulics, Geotechnical, and Transportation; two structural PE's and three PE's representing Construction Engineering.

How did the students, faculty and P.E.s interact?

The faculty and professional mentors involved in the project went to great lengths to give the student senior design team project ownership. As part of the senior design exercise, the team operated as an engineering firm. Submitting teammate CVs and a firm mission statement were part of an interview process to win the work. From there, the team negotiated the scope of work and level of effort estimate with professional advisors.

The team members collaborated weekly with professional mentors and faculty to meet the technical and managerial challenges posed by this project. The students met independently as a team at least once a week to review their progress.

What did the students learn through the collaboration that would not have been learned in the classroom?

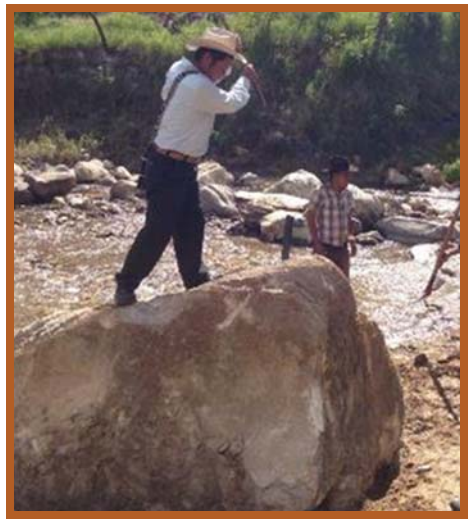
Community Meeting

: : Value of Data Collection & Stakeholder Input. In addition to collaboration between faculty, students, and licensed professional engineers, the project team collaborated extensively with directly impacted communities and the local municipal government throughout the project process. The design team, including two professional engineers, a professional surveyor and two students, visited the site to collect site survey data, geotechnical data, and to conduct interviews with impacted communities. Through interviews with community and municipality members, the team determined that a vehicle bridge would be necessary due to a lack of access to health care facilities, secondary education and markets and the potential for the local public transit system to expand into the impacted communities. The team also identified bridge location alternatives based upon the technical feasibility of the site, community input, and environmental impacts.
Through this process, the students learned the value of listening to their stakeholders and using a combination of technical and social data to form a set of possible solutions.

: : Stakeholder Agreements. The student team wrote and signed a Memorandum of Understanding with municipal and community officials outlining roles and responsibilities of all stakeholders and parties. Project support from the municipality and affected communities was nearly 40% of the total project cost in the form of property right of way, laborers (20 unpaid laborers each day hailing from 6 different area communities), transport of materials and workers to and from site, storage and protection of materials, half of the required cement, sand, aggregates, and electricity from the municipal power lines.
The student team learned the value of written project agreements. That the negotiation process helps to build ownership in the project and clarify the expectations of each stakeholder and their needs.

Stakeholder agreement with signatures and thumbprints

: : Development and execution of a quality process. The student team developed a quality control (QC) process and schedule. The QC plan required that calculations were independently checked by a student teammate and then submitted to their professional mentor for final review.
The student team learned the importance of a quality plan and the time required to successfully execute it.



Rock Excavation

: Material quality. The student team learned that the quality of the materials used is not universal and must be verified to ensure a successful project. University faculty provided support to the student team as it performed materials tests for the project design. The team tested mortar cubes with cement from Guatemala and compared strength results against US cement. Through these tests, the team discovered that Guatemalan cement contains additives to slow cure time, which informed the team's construction scheduling. Test results for rebar, sand, aggregate and wood from previous projects were also used to inform the design.
The student team learned the variability of materials properties and the importance of adequately accommodating them through the design process.

: : Construction Process and Requests for Information. The student team learned that construction does not always go as planned. During the foundation excavation, the rock material was much harder than anticipated and completion required additional time and effort. A very large rock was discovered while excavating one wingwall and the wall geometry was revised to accommodate this differing site condition.
The student team learned the importance of construction engineering and the need to timely address differing site conditions in a disciplined manner.

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

Did the Project include aspects that affect the health, safety and/or welfare of the public? Prior to the project completion, when the river was low community members jumped from rock to rock or drove four-wheel-drive vehicles to cross the river. When the river rose due to rain, community members could not cross safely. Due to Guatemala's rainy season, this meant the community lost reliable access for nearly six months each year.

While the directly impacted communities had access to alternative routes, these routes were circuitous and arduous, adding a difficult two to three (2-3) hours of hiking through the mountains to reach Highway 2. The trip was nearly impossible with a heavy pack of supplies or a sick community member.

This particular project was presented by the mayor and the municipal hospital as a highly critical project because six women recently died in childbirth when they could not reach the hospital in time.

Primary teachers in the impacted communities were strong project advocates. The primary teachers were concerned for their students because when river levels prevented students from reaching school and classes were often canceled. The teachers were concerned for older students seeking secondary education in the nearby city; they had watched former students brave waist-deep rushing water in order to reach their high schools. Alternatively, if students made it to school, they often came back to a swollen river, making it impossible for them to return home. As a result of the dangerous and unpredictable conditions, many parents refused to send their children to secondary schools.

Beyond health and education, access to jobs and markets were of great concern for the well-being of the communities. Community members were unable to hold steady jobs because they were deemed unreliable workers as a result of frequently miss work due to lack of access. Lack of access limited the types of crops grown. For example, few farmers would grow fruits and vegetables because they risked their crops rotting in storage before they could be transported to market.

How was the public projection addressed? Access provided by bridge completion gave community members the ability to control their health, safety, and well-being which were previously at the whim of the rains. Bridge completion provided safe and reliable passage across the river, and was the stimulus for the municipality to improve the roadway to an all season road and establish a bus route to the communities.

The community described the project as "breaking the barrier" – the barrier to higher education, medical care and economic prosperity

Which project features raised student's awareness about the impact of the engineering decisions? The students learned that the absence of a bridge made the communities vulnerable during the rainy season. Many community members shared similar stories of family members suffering because they could not access the hospital located on the other side of the river. The stories of the six young women who died during childbirth because they could not access medical facilities was particularly emotional for the team. The student team felt the impact of this loss on the women's families and the community as a whole. The students were motivated to find a solution.

Did the project highlight how engineering can help solve problems faced by communities nationally or worldwide? The project highlighted how infrastructure is taken for granted in the developed world. The team listened to the community as they described their goals and dreams and how they were restricted by the lack of access. The community described the project as "breaking the barrier" – the barrier to higher education, medical care and economic prosperity. This highlighted how a simple engineering project like a bridge can have comprehensive benefits to the social and economic fabric of a community.

Did the project foster student self-reliance, cooperation or responsibility? The students learned during their site visit that this was no longer an academic exercise, but an opportunity to change people's lives. With that opportunity comes tremendous responsibility which was demonstrated by the look on the student's faces as they signed the MOU committing them to the design and construction of the project and realizing how the community was counting on them.

The students recognized the importance of stakeholder cooperation and how, through those partnerships, amazing change can be accomplished. *As the Mayor stated at the ribbon cutting, "This project required everyone's total dedication and commitment to be realized. The Municipality, student team or community could not have accomplished the project by themselves – but working together an amazing result was possible."*

IV: Multidiscipline and/or allied profession participation

Was more than one engineering discipline involved? Was more than one branch of a particular engineering discipline involved? The scope of the project included site survey, materials testing, hydrologic and hydraulic analysis, geotechnical analysis, roadway realignment geometric analysis and design, bridge sub and superstructure design, retaining wall design, estimating, scheduling, life-cycle cost analysis, and sustainability.

Did the project include other professions? Outside of engineering the team looked to lab technicians, contractors, and masons for technical support. The team relied on interpreters and a Latin American history professor to understand the language and historical context of the communities in which they worked. Additional support and collaboration came from mentors well-versed in contract law and fundraising to ensure the project could become a reality.

V: Knowledge or skills gained

> "Through this project, I was able to see firsthand the incredible difference engineering projects can make in people's lives. I am so proud to be an engineer".
>
> *Student Project Manager*

What knowledge / skills did the students gain?

: : Surveying. The student team learned to do a topographic survey using locally available equipment such as a clinometer, tape and compass. The team learned the value of having a well thought out data gathering plan to ensure that all information was gathered in one site visit and how data was critical to design development.

: : Geotechnical. The student team dug several test pits and collected soil samples for analysis. Rock samples were also collected and brought back to the university lab for testing. The students saw firsthand the critical importance of geotechnical data in identifying acceptable foundation alternatives when a deep pile alternative was deemed unconstructable.

: : Hydrology and Hydraulics. The team completed a hydrological analysis using the program TR-55 and drawing input data from topographical maps and regional rainfall data. With water volumes for 100-year storms identified, the team completed a hydraulic analysis using the program HEC-RAS in conjunction with survey data to model current river conditions and river conditions at the bridge site alternatives. With this analysis, the team identified that a 45-ft deck span was reasonable at all location alternatives and established a high water elevation (HWE) at each of those locations.

: : Bridge Design. The bridge was designed using AASHTO design standards. A key decision was the selection of the design vehicle. The students learned that the design needs to accommodate future loadings that might be realized instead of the lighter loads that currently pass through the river.

: : Formwork Design. Since the team was designing and constructing the bridge, a Design Build delivery was utilized. The formwork needed to construct the project needed to be designed using locally available materials.

: : Constructability and Construction Engineering. No cranes or other heavy machinery were available so the design needed to ensure the project was buildable using locally available equipment and materials. For example, the concrete was mixed using a 1/6 cubic yard mixer resulting in maximum pours available to the team at 20 cubic yards each day.

: : Cost Estimating. The importance of accurate cost and materials estimates was highlighted by the fact that the team needed to raise the funds for the project. The students realized that any significant changes to the materials estimates would impact the agreements with the municipality and community and could jeopardize the project.

: : Construction Scheduling. Since the time that the team was to be on site was limited, the need for a detailed and accurate construction schedule was critical to the project's success. The teams schedule included the breakdown of tasks into carpentry, rebar cutting/bending, and concrete placement. Materials, labor and equipment resources were identified for each task on a daily basis so the construction could be completed in a timely manner.

: : Comparing alternatives and select a preferred alternative. The team considered three (3) different location alternatives and five (5) superstructure alternatives. Each alternative was taken to 30% design. Decision matrices were developed to compare the transportation and superstructure alternatives. The location alternatives were analyzed on a comparative basis in categories of safety, geometry (horizontal and vertical), estimated cost, and sustainability. The superstructure alternatives were analyzed in categories of cost, constructability, durability, maintenance, function & serviceability. Based on these matrices, a location was determined and the concrete T-beam was identified as the preferred superstructure. The project alternatives and recommendations were presented to the community along with the advantages and disadvantages of each alternative. The community concurred with the preferred alternative and the project moved into the final design phase.

How were the knowledge / skills gained important to professional practice?

: : Risk Analysis. The team gained important knowledge on how to weigh risks during the design process. For example, the material properties selected for elements such as wood, steel, cement and aggregates would seriously impact the project's cost and risk of failure. The students learned the value of doing a sensitivity analysis using different materials properties to aid them in making these decisions.

"It is our obligation, as Professional Engineers, to share our knowledge with the next generation of our profession."
Lead Professional Mentor

: : Quality Design. Constructing a project on a remote site with limited access to materials and equipment on a fixed schedule made a quality design critical. The students realized the significant impact on the construction schedule if plans are not clear.
The students learned that accurate quantity estimates are important and can impact the construction schedule when the materials are not easily obtained.

: : Sustainability. The importance of considering sustainability in the project process is highlighted when a team works in a region with so few resources. The design needed to minimize the future maintenance needs and the bridge's exposure to risk elements such as hurricanes and earthquakes.
As we come to realize that we have limited resources, even in developed counties, the aspect of considering

sustainability during the practice of engineering is an important lessons learned.

Did the project include consideration of professional practice concepts such as project management, ethics, contracts or law?

: : Contracts. The project included agreements with the municipality and community and the management of those contracts and any changes needed. Local laws and codes were researched and addressed in the design.

: : Time management was a major lesson learned for the team. Because they set the scope of the project in terms of hours of compensation in a mock contract, each teammate logged hours throughout the life of the project. With these logs, the team was able to calculate actual vs budget levels of effort. Through this process, the team learned a great deal not only about how to set project scope for a contract, but also learned how to hold themselves accountable for time spent. For the project manager, it was a tremendous lesson in management not only of personal time, but also of other individual's time.

: : Continuous Learning. As young engineers entering the working world, team members learned how to seek technical guidance. Team members learned to balance time spent researching a question on their own with asking for help when necessary, always seeking to find answers when possible and ask educated questions when necessary.

: : Ethical Use of Engineering Skills. The students and professionals alike were reminded by this project on how engineering projects can make a real difference in the world. The project team realized their obligation to use their skills to improve the lives of those who are in most need.

: : Building Local Construction Capacity. One of the key goals of the project was to build the construction skills of the local masons. The project was utilized as a classroom for the masons to enhance their understanding of important engineering principles. Key lessons were taught on water-cement ratio and its impact on concrete strength along with rebar detailing to resist seismic loads.

: : Communication. Most critically, team members learned to communicate with a variety of stakeholders. They learned to communicate effectively amongst themselves and with professional mentors to keep the project moving forward. Additionally, they learned how to communicate with end users and government officials to identify project needs, direction, and funding sources. They learned how to present their work in the form of reports and presentations in a professional engineering context as well as for non-engineering audiences in order to secure funding and educate the public.

: : Professional Mentoring. Most professional engineers have benefited from a special mentor during their careers. This project provided an excellent forum for profession engineers to work with engineering students on a diverse and impactful project. "It is our obligation, as Professional Engineers, to share our knowledge with the next generation of our profession." Lead Professional Mentor.