Footbridge in Bolivia

The Socio-Technical Impact of Sustainable Alternatives to Steel and Concrete in Developing Countries: A Case Study of Structural Bamboo in Bolivia

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The thesis presented will discuss topics within structural engineering in civil engineering. The thesis will focus on the technical solution of a footbridge as well as possible sustainable materials and practices that could be utilized.

The capstone project requires a detailed design of a footbridge to be constructed at a later date. The footbridge will be in the rural area of the Pocona municipality in Bolivia, over the K'ellu Mayu River. The problem the technology will address is the ability for the locals of the Pocona region to safely cross the K'ellu Mayu River without the need to traverse 8 kilometers down the river. The river is far too long and during the rainy season, it contains too much water to be able to safely cross. The footbridge will allow pedestrian access to the local village of about 190 residents to access markets across the street and schools for children. Students miss days of school during the rainy season and locals are not able to sell their goods in a traditional economy and the bridge will mitigate said issue. The bridge is to be designed by a team of 5 students each with a specified role.

The STS research will focus on the social and technical implications of using sustainable alternatives to steel and concrete, with a focus on Structural Bamboo in Bolivia. The social impacts will focus on the perception the community has towards the design, development, and usage of structural bamboo and the technological constraints of implementing a sustainable material in a developing country. The research will also focus on the maintainability of sustainable designs in developing countries.

Both the capstone and the STS research will focus on how technology improves the lives of those in developing countries using engineering products. The bridge will solve the technical problem as well as applying cultural solutions to previous barriers. The research will discuss environmental, economic, and cultural sustainable solutions and practices within designed engineered technology.

Rio K'ellu Mayu Pedestrian Bridge Capstone

The Footbridge capstone project is focused on providing a technical solution to the problem at hand in Pocona. The small village is in the rural areas of the Cochabamba Providence in Bolivia. The closest town is 18 kilometers away and that includes markets, hospitals, and schools. A small river, Rio K'ellu Mayu, provides an obstacle for the residents. Accessibility across the river is difficult, especially during the rainy season. The river swells up leaving the river impassable for 150 days. The closest crossing point is 8 kilometers away. Current residents cut down the surrounding trees and place them over the water as a makeshift crosswalk. As a result, the residents of Pocona requested Engineers in Action for a footbridge. The bridge will provide a direct access point for 190 residents and indirectly impact 220 people. The bridge will provide a means to safely cross the river. Locals will indirectly benefit by accessing markets across the river to sell their goods (the community has a traditional economy by having a heavy focus on agriculture/farming). The footbridge will provide 10 children with direct access across the river so now they will not miss school because of the river swelling and being impassable.

Our goal in the project is to design the bridge and each component and create a construction plan. Using our technical skills learned in the past four years, we are tasked with designing the foundation and the walkway of the bridge. Analyzing separate loads, measuring distances, and conforming to the standards of the organization will all provide a practical solution.

Once the structural analysis is complete, the team will organize files and will schedule the timeline of construction for the proposed bridge. By creating the blueprints and the phasing schedule, the team will find the most efficient schedule for the construction of the footbridge. The construction will be done collaboratively by volunteers of university student chapters, residents, and Bridges in Prosperity (the organization spearheading the project with both manpower and materials).

The team will also consider constraints within the community. Local materials will be used when available. Most labor will be handled and coordinated by Bridges in Prosperity but will ask residents to participate so that the community understands the scope and maintenance.

The organization in charge of the design, Engineers in Action, provided the capstone team with background information and a technical analysis. The provided package included modules on designing a footbridge, assumptions required to analyze the structure, soil classification, an AutoCAD file of the elevation and plan view of the site, and corresponding information about the location.

The physical bridge acts as a liaison between the community and their society by providing a year-long solution to the community's problem.

Structural Bamboo: Reliability and Feasibility

The socio-technical addressed will be how engineers can implement economically and environmentally sustainable designs and practices in developing countries using alternatives to steel and concrete in buildings and structures. With the footbridge being in Bolivia and already requiring local resources for the design, the problem addressed will be how to implement structural bamboo as a sustainable alternative to steel and concrete for buildings and structures in Bolivia and focusing on post-construction sustainable practices.

Bamboo is a flexible material that is natural in many parts of the world. Bamboo has historically been used in simple structures for roofs and walls. But what of its application today?

Research has been conducted for years on the material properties of bamboo. Bamboo isn’t a new building material. Bamboo is light but extremely flexible. Due to its flexibility, the bamboo stock has a high tensile strength. Tensile strength means the material can be stretched under stress and return to its original structure without fracture, meaning it is elastic. Another material that is extremely elastic and performs well under tensile strength is steel (with its many iterations). In modern buildings in the United States, most buildings are either reinforced concrete, prestressed concrete, or steel, all of which contain steel. Steel maintains the integrity of the field by allowing flexibility in large loads. Bamboo can be a sustainable alternative to steel as a result, sharing similar material properties with a more lightweight material.

Bamboo also does not have the same carbon footprint. The production of steel requires high energy input and output. The high heat required to melt the steel and constant mining of the ore does not provide a low carbon cost. The acquisition of materials for steel far outweighs the carbon cost when compared to bamboo. Bamboo’s tensile strength, on the other hand, comes naturally from the existing material. While the material can be engineered to yield at a higher capacity, the natural bamboo’s modulus of elasticity is comparable. The yield of steel is far larger though, almost ten times more (Sanchez Vivas et al., 2019). Regardless, having a strong basis with untreated bamboo can provide a larger engineered modulus of elasticity and yield capacity. The numbers indicate potential, but how feasible is the construction of bamboo structures?

Materials can greatly impact the carbon footprint of a project, but construction and maintenance have a longer impact on the carbon footprint. The upfront carbon cost is important, but the life cycle analysis of the structure must be considered. Bamboo construction works by using the stocks tied together to provide a frame and infill is placed between each section. The infill can be mud (like adobe), wood, or bamboo. The construction process does not require sophisticated engineering for simple structures. Engineered bamboo can provide long-term solutions for bamboo structures. GluBam and Lamboo provide that median. GluBam is bamboo stocks glued together in cross sections to form beams and Lamboo is laminated cross sectional bamboo beams. The engineered structures can support higher loads. The bamboo structures must be maintained more often when compared to steel (Xiao, 2022). Maintenance requires more materials to repair, increasing the life cycle cost. The maintenance of steel structures requires extensive treatment that often cannot be provided by developing countries.

The application of bamboo in developing countries provides another. Providing engineered bamboo sounds great as the local material is available in abundance, especially in Bolivia. Yes, simple structures can be built utilizing regular bamboo, but engineered bamboo requires teaching locals about the production, construction, and post-construction. The right engineered tests would be required to ensure the bamboo can sustain heavy loads; serviceability checks as well as other things. Bolivia has building codes but building codes do not exist for bamboo structures even here in the United States. There are international building codes for bamboo structures (Li, 2019), but those emphasize engineered bamboo. Construction is also different in developing countries. Safety requirements, regulations, and laws are in place here in the United States to ensure safe practices. The pre- and post-conditions of construction are also regulated. In developing countries, similar practices apply for construction, but not post-construction. Once the project is delivered, developers and engineers don’t inspect as often as they should, if at all. Teaching communities how to maintain these sustainable designs will create an environment of self-fulfillment and independence (Pocock, 2016). Providing a long-lasting solution and a plan will unsure the sustainable solution isn’t misused.

While the properties and math verify the structure can maintain building loads, how does the general population feel? How do outsiders look at existing sustainable structures? What of bamboo structures? Bamboo structures can be seen in Southeast Asia and Central and South America. They’ve existed for thousands of years. One of the issues is associating natural materials as rudimentary and dated. When thinking of adobe, mud, and wood homes, we think of Pueblo Native Americans and their adobe homes or Vikings with their turf homes. A great solution for their time but technology dated as of today. Why use a mud home when timber, concrete, and steel provide a more structurally stable home? People associate those materials with developing countries because they’re not engineered. Codes and requirements do not exist. Basic tools can be used to build these homes. When compared to other countries, we as Americans look down upon structures that do not use timber, concrete, or steel. The general population in the United States prefers these materials for their quality and safety. This standard created a superior bias we feel towards other countries when we see aluminum sheets as roofs or adobe walls or bamboo frameworks. To change the connotation, serviceability checks must also be emphasized. Serviceability in structural design is when the engineer designs components based on the user's comfortability: A bridge not swaying too much or a building not oscillating or a floor beam not bending too much. With mass timber (an emerging alternative to steel and concrete), fire is a concern. As a result, people are also concerned with bamboo's resistance to fire. Bamboo has been treated to resist abrupt collapse due to fire. The bamboo is charred beforehand on the outside so that the stocks have a longer time to resist the change in temperature and have a more controlled fire (Rockwood, 2015). Emphasizing the engineered serviceability checks in mind can help people trust bamboo structures more. Creating a consensus for international design codes for bamboo structures can provide a structured approach to change the negative perception bamboo structures have.

Bolivia has bamboo and existing bamboo structures. Creating regulations and codes for bamboo structures, providing engineered solutions like GluBam, and practicing maintenance and upkeep of these designs can establish a strong potential for structural bamboo. The footbridge over the Rio K'ellu Mayu will harvest local materials to build the bridge. Using structural bamboo for shear walls or fencing can create a small but impactful establishment of future bamboo structures.

Conclusion

The proper implementation of sustainable designs is just as vital as providing sustainable designs for developing countries. Bamboo has many sustainable benefits that can present a long-term solution for sustainable design. Engineering solutions like bridges is great. Providing the tools so that communities can apply the solutions is better. Designing sustainably is great. Providing the tools so that the communities can apply the solutions is better.

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