RE-CONNECTING BAMBOO

Development And Structural Evaluation Of Connections For Construction Of A Prefabricated Housing Unit Using Engineered Bamboo

Master Thesis for M.Sc. Building Technology

31/10/2019

Delft University of Technology

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Information

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REFLECTION

One of the themes of building technology studio is sustainability. The graduation topic not only aims towards sustainability but also innovation and technology combined for a better and brighter future of the construction industry.

My first encounter with bamboo was back in India, during my Bachelor studies, where I interned with a firm which works in the field of Bamboo architecture. The firm works on a natural form of bamboo. There is always a struggle for durability of the structures that are constructed using these materials. Later here at TU Delft, I learned about advanced forms of the bamboo being researched upon (in Innovation and Sustainability studio), which lead me to work and research further on this material, as it comes across more promising and durable than the natural form.

One of the main intentions of the graduation topic is aiming towards a sustainable future. With growing issues related to the environment and sustainability, Bamboo being one of the answers, is

one such sustainable material which has a lot of potential to be used as a building material. This graduation topic is a little Step towards uplifting the material, improvising and changing the current perception of bamboo in the building construction sector.

A more global approach was to use an advanced form of bamboo structurally, to build a more permanent and durable global standard housing unit as a whole, from here the graduation topic is narrowed down to:

"Is it possible to develop efficient, durable and structural connection system which use engineered form of bamboo for construction for standard housing unit''

How did the research's approach and following the methodology worked?

The research began with understanding the properties and check whether it is possible to use engineered bamboo for structural application, and which form is best suitable for further work. With an abstract of designing a structure using bamboo, the literature review was focused on the research towards a more advanced form of bamboo. One of the primary reasons of bamboo being used less in construction is the lack of research data. With the upcoming boom of sustainability, there has been a lot of research on natural properties of bamboo and now to some extent on engineered bamboo. However, it was difficult to find research on the mechanical properties of Engineered form with absolutely no data on connections using an engineered form.

With these inadequate results of the literature study, it became very important to do experiments on developing and testing the prototypes, to fetch more practical and accurate results, than relying on theory. Thus, further research was more inclined towards experimentation based on which some of the companies and the people working in the field were contacted. In meetings with these companies, some practical aspects of the use and the forms of engineered material in the construction industry were gained, however, it was observed that majority of the material is still used for nonstructural purposes. It was also observed that, there is a lot of research and experimentation going on for use of bamboo for structural purposes making the relevance of research even stronger.

As an outcome of the first literature review, a research methodology was devised. The idea was to **design and alter material properties and develop a** cross-laminated **component which would also** facilitate prefabrication in construction. However, with the above methodology the research was too broad and there would have been lack of availability of tools for prototyping of cross-laminated components, thus it was required to narrow down the topic based on more relevant and feasible options.

In the later phase, the above idea was simplified and reworked upon to develop a design for connections using the existing form of engineered bamboo, based on a prefabricated approach of construction. This phase of the thesis took a lot of time to be reworked on as there were multiple changes in approach until the final methodology.

With research's in the advanced engineered form of bamboo, the ultimate structural limits were considered based on assumptions for further work. A lot of assumptions are made in the research process due to unavailabilitly of the basic standard data of the material. The majority of References and Design inspirations are adapted from Timber construction technology. This part was important because these references added a lot more accuracy to research before the prototype results were achieved.

Based on the data available for bamboo and timber a standard structural system was proposed for construction of a basic G+1 structure. The proposed structural system gave an understanding of the important joineries required to build the house.

Multiple iterations of designs were made to connect the structural framing elements. The designing was done through sketching and prototyping study models using foam. The finalized design was supposed to be prototyped for further optimization, but a lot of issues were faced in this phase of the thesis, from sourcing the material to prototyping using the material. The material is very hard and heavy, and the current woodworking tools available are not the most efficient equipment to work with. With the help of one my Mentor it was possible to Prototype one on joinery configuration. Howoever it was realized during this process that it is very difficult to cut the material using the basic woodworking tools, which also tells us the strength and workability of the material compared to wood.

Thus, with no option of prototyping, eventually, the structural analysis was done using ANSYS software, static structural analysis. This analysis was combined with intuitive analysis based on the test results of one physical prototype and from the research done in efficient designing with material. Timber research combined with Bamboo research, played an important role, as this learning allowed us to Intuitively predict the outcomes of final results. *(Also,* it was *very important to refer from timber yet keep all the research aspects of implementing it in bamboo in mind)*.

It was challenging to follow the research plan and it kept changing and improving continuously, the reserch being first of its kind, the entire process depends a lot on the results of research and the experimentation done, continually redirecting the outcome of the project. Eventually, I learned and accepted that it would not be possible to adequately cover and research all aspects, to propose a design, as the related potential research topics could expand exponentially. Instead, It was important to narrow the scope in order to produce a more substantial and reliable first draft.

It was understood that Bamboo is a very unstable material that needs to be analyzed in multiple ways and thus multiple ways of structural analysis needs to be done and final results were a comparative evaluation of all these test methods adopted above. At the end of the thesis with a very limited time frame, it was possible to lay basic design rules for efficient connections and design using the engineered bamboo material – Bamboo Scrimber and propose the most workable connection design configuration and also to some extent with right inputs of properties and validate it structurally using ANSYS static structural analysis. It would have been helpful to do experimental testing as well as to validate the entire structural system globally using FEM analysis software.

In conclusion, Bamboo was a bit of a difficult material to work with, including a lot of issues faced in finding the right structural properties, the delay in sourcing the material for prototyping and finally prototyping the material using normal woodworking Machinery was also a challenge. The support from the Mentors through all these difficult times and different challenges was overwhelming. The research intends to provide the best with all these limitations and boundary factors and ease up the further process of research and development, by being a guiding light based on these above processes for future researchers.

To what extent are the results applicable in practice?

People have been researching and building with bamboo for many years, yet even today not many buildings are built with bamboo. The designers and engineers lack research on standardized

components and design guidelines. This research and design of the connections (which are analyzed based on strength, feasibility) would give an insight to any designer, implementing them in practice.

Scientific and professional Relevance:

China is doing a lot of research on the engineered form of bamboo. These materials are majorly produced there and shipped across the world. However, even with the potential (for use in structural purposes), the use is limited to Non-structural purposes. With more availability of technical research on the feasibility of these materials for structural use, it will be an addition to the existing research database and a big step towards bamboo's usability in global construction sectors.

Wider social context:

In developing countries, one of the reasons for the low use of bamboo in society is its association with the term - poor man's timber. The reason being, mostly the natural form of material used has durability and aesthetics issues. This research addresses most of the above aspects of construction including durability, form of bamboo which looks like wood (aesthetical) and its standardized use in construction. Additionally, foreseeing the capital investment in such a system, it is for the middle class and richer part of the society which would help in removing the tag of poor timber. Following the richer trends it will also help gain more acceptance amongst poor towards the material. Today, the use of Bamboo as Construction material is also the need of an hour, considering all the sustainability crisis.

RELEVANCE:

I view this project as a first-step towards re-thinking the use of bamboo for construction applications, in architecture. While the solution proposed as a system was used as a case study to develop connections, giving hope to many more design possibilities of using Bamboo in construction. In Practice, until the material is used in mainstream architecture and construction, the research would still help in building temporary structures. Offering a more permanent, aesthetically pleasing, durable, cheap and most importantly would improve the quality of life of people without being heavy on their economic budget. Additionally, using bamboo instead of wood would save a lot of deforestation. For example: In India, there is no ban on cutting bamboo. It is treated like a cultivation crop that can yield business and income for farmers like any other agricultural crop. The more material is used the more it will contribute to the society (sustainable, degradable, embodied energy and availability) in the form of circularity with very little disturbance to natural habitat.