Research Plan for aE Studio Students

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Introduction

Personal fascination
I have a personal fascination for using technological solutions to solve problems in the built environment. In the past, I have done a lot of research into passive climate buildings, in which much progress can be made. However, more recently I have also started to take great interest in the types of materials used as this contributes to a large part of the sustainability of architecture. It surprises me how traditionalist the construction world is with regards to this, especially when realizing how much is already possible with sustainable materials. The use of materials like wood therefore fascinate me, but this already has a very large knowledge base.
Recently, I remembered my father telling me about bamboo when I was younger. I remembered him mentioning that it was the fastest growing plant on earth. This thought got me interested in the potential of using bamboo in architecture. Upon further research, it became clear to me that there was much unused potential in the material and as such, I wanted to do my graduation project about it.

Problem Statement
Construction materials that are both non-renewable and CO2 intensive are currently used extensively in the built environment. This is primarily down to cost and ease of use (Chau et al., 2012).
However, continuing to use these materials has severe consequences on CO2, NOx and NH3 emissions (Chau et al., 2012). Emissions of these gasses have been shown to increase the greenhouse effect (Baumert et. al., 2005) and lead to eutrophication of soil (Kros et al., 2008). These effects have led to European and Dutch legislation to limit these emissions. This legislation severely hinders construction speed (CoBouw, 2019), negatively affecting the housing crisis in the Netherlands.

Tower blocks have been shown to account for a large part of non-renewable and CO2 intensive material use (Chau et al., 2012) due to their relatively challenging structural properties and financial backing (Lentz, 2020). There are exceptions, as engineered wood such as glulam and CLT are increasingly used (Van der Lugt, 2017).
Problems arise, however, when considering the scale of its application, as the current production of pinewood is not able to keep up with projected larger demands (Van der Lugt, 2017), possibly leading to material shortage or over-exploitation (Arets et al., 2011; Van der Lugt, 2017). Additionally, pinewood construction is mechanically not ideal, due to the large volume of material needed to achieve a certain load bearing capacity. It is therefore of importance to look for additional, fully renewable and CO2 negative building materials to combat these challenges.

A material that shows great potential for use in architecture and structural engineering is Moso Bamboo (Phyllostachys Edulis/Pubescens).This material has been considered in the past, but problems associated with its production location and transport lead to it often being discarded as not sustainable. However, the more recent possibility of using Europe grown Moso bamboo (Bamboologic, n.d.; Onlymoso, n.d.) should force us to reconsider using this material in our built environment. As of yet, the main problem hindering the use of this material on a larger scale is a severe lack of industrialization and standardization (van der Lugt et al., 2006). This has led to the notion that the application of bamboo building elements is not yet properly established and as such it is not used to its full potential in larger scale projects. Further research, therefore, is necessary.

Relevance

Recently, initiatives have been taken to farm bamboo in Europe. Bamboologic (www.bamboologic.eu) and Onlymoso (www.onlymoso.com) are examples of companies that do this. European Moso bamboo has similar properties to the bamboo grown in China, making it applicable in the same use-cases. (BambooLogic, n.d.; Onlymoso, n.d.) Additionally, there are a number of positive local side-effects from the farming of bamboos, such as absorption of CO2 and NOx, desalinization of soil as well as economic opportunities (Van der Lugt & Vogtländer, 2014). This shines a new light on the use of bamboo in Europe, as it could be a sustainable large-scale solution and a viable addition to engineered pinewood construction in many cases.

However, as of yet, the main problem hindering the use of Moso Bamboo on a large scale is severe lack of industrialization and standardization (van der Lugt et al., 2006; Van der Lugt, 2017). Numerous studies have been done on the use of raw bamboo in load bearing structures or as supporting structures, especially in China (Chung & Yu, 2002; Widyowijatnoko & Harries, 2020; Xiao et. al., 2008). The knowledge in this field is established well enough to have practical implications. This becomes clear through the numerous case studies using raw bamboo (Xiao et. al., 2008; Van der Lugt, 2017). On the other hand, very few case studies use engineered forms of bamboo to their full potential. This is not due to a lack of knowledge: there is plenty of information about the possibilities of engineering bamboo (Mahdavi, 2011a; Mahdavi, 2011b; Sinha et. al., 2013; Sharma et. al., 2015). However, the step from theory to practical application, as has already been done with raw bamboo, has not yet been taken with engineered bamboo. Therefore, in order to make the use of engineered Moso bamboo more standardized and accessible as a building material, the existing knowledge base about engineered bamboo needs to be extended to the applied context.

The transition from engineered bamboo as a material, which is already thoroughly researched, to the practical application possibilities into architecture and the implications this has on a design is a gap that needs to be bridged, which is what I want to achieve with my thematic research.

Thematic Research Question

Umbrella question:

Can Europe-produced Moso bamboo be optimally engineered into industrialized building elements for use within common typologies and is it a viable alternative to other renewable building materials?

Sub questions:

1. *What are the mechanical properties of Moso bamboo and how can the raw material be processed into engineered forms of bamboo?*

2. *What are the advantages and disadvantages of Moso bamboo building elements when compared to other commonly used building materials?*

3. *What is the optimal form of bamboo to use for each building element type, with regards to the mechanical properties, sustainability, production cost, safety and building codes?*

4. *What is a suitable design strategy for the optimal use of said bamboo building elements for architectural applications within Europe? (Design tool)*

Relation to Design Question

Through my design project I would like to test the results from the research paper and use it to quantify the implications of using bamboo building elements on design aspects like the load bearing structure and sustainability.

The reason a high-rise project was chosen was because of the relevance it has on the housing crisis in the Netherlands. It was mentioned earlier that high-rise accounts for a large part of unsustainable and unrenewable material use. At the same time, it is expected that density in urban areas will steadily increase. It is therefore especially relevant to experiment with sustainable and renewable materials during this development to have a serious impact on the sustainability of construction on a large scale. Additionally, due to the potential of Bamboo in mechanically challenging conditions, high-rise presents a perfect opportunity to test this.

Research framework

Key terms, concepts, theories, methodology
There are a number of different aspects that are researched. Firstly, a theoretical framework is made and available information is coherently compiled to move forward. This research is quite qualitative and involves many different fields of knowledge, such as biology, forest management, life-cycle-analysis and structural/civil engineering. The second part of the study consists of a quantitative comparison of different materials. The fields of knowledge that relate to this part are mostly to structural/civil engineering and building technology.
The thematic research overall is a mix of qualitative and quantitative research, although the emphasis is more on the quantitative. This is the case because the result of the thematic research is a design tool, in which the results from the quantitative comparison study is implemented. As such, quantifying differences is the goal.
The way the quantitative comparison study is conducted falls within the realms of simulation research, because equally performing building elements are compared. The basis for this comparison is essentially simulation of a certain performance and then quantifying the dimensional differences between materials.
The design tool is essentially an applied conclusion of the quantitative comparison study and contains data from all three research-by-design domains, but related more strongly to flow and stock. The design project, however, adds strong emphasis to the make domain due to the added spatial and building engineering components.

Methods
In ATTACHMENT 1, a diagram is shown with a full explanation of the methods used per research question as formulated in Tanya Tsui's workshop series and refined afterwards.

Preliminary conclusions, choices and design strategies

Europe produced Moso bamboo can be engineered into a number of forms, all of which possess a unique quality that makes it well-suited for a particular application. These exact forms of engineered bamboos are currently already being mass produced in Asia and, provided European bamboo growth steadily increases, there is great potential for production of bamboo-based building elements on an industrial scale in Europe.
In general it can be concluded that for an equally performing building element, bamboo requires less volume, is more cost-effective and far more renewable than common wood-based equivalents. Provided Europe produced Moso bamboo is used, the ECO-cost performance is also on par or better.
The unrivaled renewability, relatively low cost and excellent mechanical performance of Moso bamboo building elements give it a significant advantage over other renewable and non-renewable building materials. As such, large-scale application within European typologies appears viable. It must be noted, however, that the growth of Moso bamboo cannot take place in cold and dry conditions. In terms of land-use, therefore, it rarely competes with Larch or Beech. In Europe it should therefore not be seen as a replacement or competitor, but rather as an alternative, especially in high-performance use-cases, such as high-rise applications.

This conclusion, in addition to the very specific sub conclusions implemented, influence the design. The Moso bamboo building elements that were studied can be implemented into the design in the most efficient manner and this is backed up by quantitative data. Additionally, the design enables further development of the design tool. By testing it in a practical application other aspects like aesthetics and use can be better implemented.
The use of Moso bamboo building elements also has consequences for the *make* aspect of the building. For example, a modular, largely prefabricated structure that can be assembled very quickly and using demountable connections can be made using bamboo.

However, the thematic research, being highly technically-focused, has little to no implications for aspects like function, or public/private relation. These are therefore linked to an additional concept that is separate from the bamboo. It is because of this, that the preliminary design products currently contain no additional information with regards to the implementation of research conclusion and as such are not implemented in this research plan.

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APPENDIX 1 – Methods Elaboration

Research Question	What data do you need?	How can this data be collected?	How will this data be analyzed?	What will be the expected results?
1. What are the mechanical properties of Moso bamboo and how can the raw material be processed into engineered forms of bamboo?	- Anatomy of harvested bamboo stems - Data of types of processing raw bamboo can undergo - Physical properties of bamboo in different processed or non-processed states	- Literature	Summarizing and linking information from different literature sources to acquire a clear theoretical framework	Overview of processing possibilities and mechanical properties
2. What are the advantages and disadvantages of Moso bamboo building elements when compared to other commonly used building materials?	- Quantitative data on strength, stiffness, ECO-cost, renewability of different common building materials - Information on qualitative properties of certain materials	- Literature - Reference studies - Manufacturer data	Raw data will be implemented into a comparative study method that sets a baseline performance and scales physical properties accordingly. (Unifying data if you will)	Raw datasheet of a number of different materials in a unified format, so that they are ready for comparison
3. What is the optimal form of bamboo to use for each building element type, with regards to the mechanical properties, sustainability, production cost, safety and building codes?	- Qualitative data on what is asked from a building element in different applications - Comparative data on strength, stiffness, ECO-cost and renewability of different common building materials	- Literature - Comparative study - Research by design	Data from question 2 will be used to draw conclusions about general performance. These conclusions will then be combined with qualitative requirements of a design tool to create a practical conclusion.	Quantitative comparison study with conclusions about the performance of bamboo building elements
4. What is a suitable design strategy for the optimal use of said bamboo building elements for architectural applications within Europe? (Design tool)	- All of the above	- Not applicable	Not applicable	A user-friendly design tool that presents designers with relevant comparative information about using sustainable building materials and quantifies their design choices

APPENDIX 2 – Research Plan Diagram