Graduation Plan for aE Studio Students

Personal Information

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Studio Information

Architectural Engineering Graduation Studio
AR3AE100
Mo Smit (1st tutor)
Gilbert Koskamp (2nd tutor)
Pierre Jennen (3rd tutor)

Argumentation of choice of the studio
Personal interest in the engineering side of Architecture and using innovative technological solutions to solve problems with regards to the built environment and sustainability. Fascination for heavily integrated design strategies in which a concept is applied on all scales of the building.

Graduation Project Information

Title
Rise of Bamboo (Graduation Project Title) / Phyllostachys (Building Title)

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.

Objectives

General:
To research the potential and limitations of using European Moso bamboo (Phyllostachys Edulis) based building elements in large scale construction.

Thematic research objective:
To research the feasibility of using Moso bamboo building elements in different typologies and to formulate a practical design strategy for optimal application of engineered Moso bamboo building elements.

Design objective:
To design a high density housing project that uses engineered Moso bamboo building elements, applying and testing the afore mentioned design strategy. Additionally, quantifying what effects the use of Moso bamboo building elements has on the sustainability of the project

Overall design question
How does the application of Europe-produced Moso Bamboo building elements affect the design and sustainability of a large scale housing block in the Netherlands?

Thematic Research Question
Main 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)*

Process

Methodology
Design:
The design process is split up into multiple phases, as seen in the planning scheme (Attachment 2):
1. <u>Context research</u>: In this phase, the societal and physical context of the design project will be researched and documented in the project elaboration booklet.
2. <u>Program definition:</u> In this phase, the program will be partially defined in order to get an idea of the scale and functionality of the building. This will be based on an own vision, the aspirations of the municipality as well as the needs according to the context research.
3. <u>Sketch design:</u> In this phase, the bulk of the design work will be done. The program will be further established and experimentation with different layouts, aesthetics and most of all structures will be conducted.
4. <u>Preliminary design</u>: In this phase, a good basis from the sketch design will be developed further and more attention will be payed to the structural and engineering aspects of the building.
5. <u>Final design:</u> In this phase, the design will be refined and finished. Additionally, the final presentation material will be made.

Thematic Research:
[SEE APPENDIX 1]: *The methodology for the thematic research was developed according to the Research plan meetings in a separate formatting.*

Literature to consult for thematic research

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Reflection

Relevance in the larger social, professional and scientific framework
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 the gap my thematic research aims to bridge.
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.

Relation between graduation topic, studio topic, master track and master programme
The studio topic is Architectural Engineering and as the term implies, it emphasizes the engineering side of architecture. My topic strongly relates to this by posing a technical question about the possibilities of engineering a raw material into building elements that are usable in European architecture.

However, because this engineering topic gives little handhold with regards to functionality of a building, extra architectural emphasis is found in the 1 Million Homes assignment, organized by the studio. In this assignment, you respond to the current housing crisis in the Netherlands with a design project. I decided to combine the need for sustainable materials in high-rise architecture with the ever-increasing demand for housing in urban areas into the design of a skyscraper in Rotterdam Central District.

The relation between Architectural Engineering and Architecture as a master track is mostly that of specialization. As mentioned, Architectural Engineering emphasizes the engineering aspect of architecture and looks to innovative technical solutions to solve architectural problems.

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