Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
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Studio	
Name / Theme	Building Technology
Teachers / tutors	First mentor: Ir. J.E.P. Smits Second mentor: Prof.dr.ir. A.A.J.F. van den Dobbelsteen External mentor: Mark Lepelaar, NPSP
Argumentation of choice of the studio	Not applicable in building technology master track. My graduation is mainly focussed on structural design, with the focus on new and more sustainable building materials.

Graduation project	
Title of the graduation project	The effects of UV radiation, humidity and temperature on the mechanical properties of flax and bamboo fibre reinforced bio composites.
Goal	
Location:	No location needed
The posed problem,	Through an increasing environmental concern and a growing interest in environmentally friendly materials, the bio composite market is growing rapidly (Yan, Chouw, & Jayaraman, 2015). Replacing petro/fossil based composite with bio based composites is already done within the field of automotive engineering and product design, but, within the civil and building engineering, bio composites are still a rarity. However, the mechanical properties of certain natural fibre reinforced composites is comparable with glass fibre reinforced composites, which is used for structural purposes. The limited use of natural fibre reinforced bio composites for structural engineering is meanly because there is a lack of data concerning the long term durability of natural fibre reinforced bio based composites. To find acceptance in structural engineering, it is needed to understand the effects of the outdoor environment, resulting in the degradation of the bio composite and therefore raising safety concerns (Yan et al., 2015).

research questions and	Main research question: What are the effects of UV radiation, humidity and temperature on the mechanical properties of flax and bamboo fibre reinforced bio composites? Sub questions: - What are the possible effects of UV radiation, humidity and temperature on natural fibre reinforced bio composites? - What is the best suitable bio based resin for flax and bamboo fibre composites? Taking into account bio based content, cost of product and mechanical properties. - How does the LCA of flax and bamboo fibre reinforced bio composites compare to petro/fossil based fibre reinforced composites? For example, glass fibre reinforced composite.
design assignment in which these result.	The main goal of this graduation is research into flax and bamboo fibre reinforced bio composites, but depending on the results of the research there will be a manual made on how to use these materials for structural design, including examples of small construction principles and possibilities.

Process

Method description

The research has a quantitative approach. This means that the focus is on gathering scientific data, facts, and to study relationships between the data using existing theories and findings found literature (Fellows & Liu, 2008). Within the quantitative approach it is important to define what data needs to be collected, how the data will be collected and how to use the data. A thorough study of the underlying literature and theory of the subject needs to be done to make sure no important factors are missed, making sure that there is no reduction of the validity of the results and to prevent problems while executing the research (Fellows & Liu, 2008).

1.1. Data collection methods:

Within the quantitative approach there are three ways of gathering data: using questionnaires filled in by respondents of interviewing respondents, conducting experiments and literature study using previous generated data from others (Fellows & Liu, 2008). This research relies mainly on literature study and conducting experiments, although it might prove to be useful to contact professionals and use their expertise as well.

A good understanding of the subject is the reason for conducting a literature study. The literature study is divided into three different parts. The first part is creating a general idea on what is meant by bio composites and exploring the flax and bamboo based bio composites, collecting data on production of the fibres, types of polymers used, production methods and also environmental impact. The next part is focused on the mechanical properties of the flax and bamboo based bio composites and the testing methods to find them. While the last part of the literature study is about the (possible) effects of UV radiation and humidity on bio composites and how to test these.

Besides a literature study, an experiment needs to be designed to acquire data which helps investigate how UV radiation and humidity conditions effect the mechanical properties of flax and bamboo based

bio composites. For better control of variables and results throughout the experiment, assumptions and limitations should be noted and justified (Fellows & Liu, 2008). In section 1.1.2. the design of the experiment will be explained.

1.1.1. Limitations and assumptions

A bio composite is composed of fibres and resin, combined through a production process. In this research the focus is on bio based composites, which means a focus on natural fibres and bio based resins. The selection of natural fibres and bio based resins is based on 3 things: commercial availability, costs and mechanical performance. For bio based resins the amount of the bio based content is also important and therefore needs to be considered.

Another limitation to the research is the timeframe. The research takes place from April 2016 until December 2016, 9 months in total. Therefore, there is a limitation to the amount of test we can do and the amount of samples we can make. This influences the amount of bio composites which can be tested and that needs to be considered during selection of the fibres and resins.

Furthermore, the simulation used to expose the samples to UV radiation, humidity and temperature variations is designed to approach the reality. However, this approach is never 100 percent accurate. But there is no time to just put the samples outside, this is simply too time consuming.

The last assumption to be made is that all samples are coated with a clear UV-blocking coating, because this would happen in reality as well. There is also a possibility to use a coloured coating/paint, but for esthetical reasons there is decided to use clear coating to keep the bio based composite visible.

1.1.2. Experimental design

The experiment will consist out of two parts. The first part is to find the right bio based resin to use with bamboo and flax fibres. The second is to find mechanical properties of some selected flax and bamboo based bio composites and to apply UV radiation, humidity and temperature variations to samples. This includes testing the mechanical properties of the samples at specific points throughout the weathering simulation.

Resin selection

The resin selection for this research partially depends on the production methods used to make the flax and bamboo composites. The curing properties and the viscosity of the resin used makes it only suitable for certain production processes. For this research we use two different production methods: VARTM and a compression moulding. The flax fibres will be combined with a resin through the VARTM production process, while the bamboo fibres will be combined with a resin through compression moulding. The resins selected for flax and bamboo fibres are showed in table 1.

Flax fibers – VARTM process	Bamboo fibres – Compression moulding
Greenpoxy 56 (Sicomin)	Enviroguard M 98054 (CCP)
Enviroguard I 93271 A (CCP)	BioRez (TFC)
	Bio based Epoxy

Table 1: Resins possibilities for flax and bamboo fibres

To find the best resin fibre combination, samples will be made in cooperation with NPSP, who provides the fibres and resins. These samples are tested through a tensile test, which will be conducted conform ISO 527-5. The tensile test will be performed at the TU Delft.

Through the tensile tests, mechanical properties of the samples can be compared. Together with the selection criteria: percentage bio based and costs, a suitable resin can be chosen for flax and for bamboo fibres.

Weathering test
With the selected flax and bamboo bio composite a weathering test will be conducted to find the effects of UV radiation, humidity and temperature. The goal is to test the mechanical properties throughout the simulation. There will be a moment to test at the start of the simulation, two weeks into the simulation, four weeks into the simulation and six weeks into the simulation.

First, samples have to be made to conduct tests and simulation. All the samples of each material, flax bio composite and bamboo bio composite, will be made from one batch. This eliminates the changes of deviations in results due to production differences. There need to be samples for tensile tests, four point bending tests, compression tests, samples to place into the weathering simulation and samples which will not undergo simulation. The samples which will not undergo simulation will work like a reference to eliminate changes in mechanical properties due to deterioration by time. The measurements of the samples are shown in figure 1.

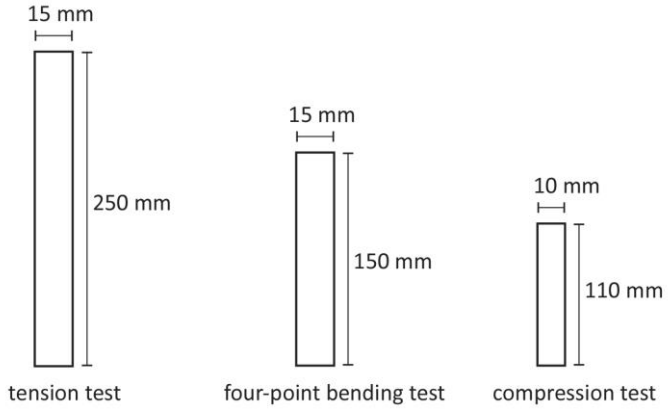

Figure 1: Sample measurements for testing. Note: all samples are 4 mm thick.

At the start of the simulation, week zero, each bio composite will be thoroughly tested for their mechanical properties. There will be a tensile test, conform ISO 527-5, a four point bending test, conform ISO 14125, and a compression test, conform ISO 14126. These three tests together will give an almost complete overview of the mechanical properties of the material, which can be used as a baseline for the whole simulation.

Then the simulation starts. The simulation will be conducted with a QUV machine, which exposes the samples to cycles with UV radiation, temperature and humidity. This test will be conducted conform ISO 4892-1.

However, the amount of samples which can be placed in the simulation is limited, therefore we chose to place only samples suitable for tensile test, these will be representable for the effects on the mechanical properties. The first batch of samples are taken out of the simulation after two weeks and will be tested to find the mechanical properties. At the same time the controller samples, which are two weeks old, but have not undergone the simulation, are tested. This is repeated after four and six

weeks. The proposed moments of two, four and six weeks of simulation represent eight, 16 and 24 months in real time in the Netherlands.

In the end the experiment should provide raw datasets for each material (flax and bamboo composite), containing data of mechanical properties of samples without and with exposure to UV radiation, humidity and temperature variations. In the data analysis these datasets will be studied to find the effect of the simulation on the mechanical properties of the bio composite.

1.2. Data analysis

The goal of the data analysis is to find the relationship between the mechanical properties of the samples and the weathering simulation. However, the first data analysis to be done is about finding the best suitable natural fibre and bio based resin combination. With each combination of fibre, bamboo and flax, and resin there will be three tension test done, which each have a different testing speed. These three test all give five results. These five results per test can be used to find the mean of the mechanical properties and the standard deviation per test. For both flax fibres as bamboo fibres there will be a comparison taking into account the found mechanical properties, product costs and percentage bio based. Through a discussion with mentors and NPSP This should result in one flax and one bamboo fibre bio composite which will be used for the weathering simulation.

It is important to have a good database of the material properties of the bio composites before tested in the weathering simulation, because a good baseline is needed to compare it to data deriving from the simulation. This database is composed through data from tensile, compression and four-point-bending tests. Each test using five samples, which give a mean and standard deviation for each mechanical property. The data collected this moment will be used as the “0-weeks” point in the weathering simulation.

Samples are placed in the weathering simulation machine for two, four and six weeks. Each of those three moments some samples are taken out of the machine and will be tested with a tensile test. At the same time samples will be tested from the controller group, which is kept in a dark box and had not any exposure to the weathering simulation, except time. This produces two times five raw testing results for both bamboo and flax fibre based composite. These five results give a mean and a standard deviation for each mechanical property.

After the six weeks there will be data for flax and bamboo fibre composites from four points in time, zero, two, four and six weeks to be exact. For both the flax and bamboo composites this data will be plotted in a graph, each graph representing a mechanical property. Compared with the data form the controller group, these graphs are used to find a relationship between the weathering simulation and the mechanical properties.

Literature and general practical preference

Assarar, M., Scida, D., Mahi, A. E., Poilâne, C., & Ayad, R. (2010). Influence of water ageing on mechanical properties and damage events of two reinforced composite materials: Flax–fibres and glass–fibres. *Materials & Design, 32*.

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Yan, L., Chouw, N., & Jayaraman, K. (2015). Effect of UV and water spraying on the mechanical properties of flax fabric reinforced polymer composites used for civil engineering applications. *Materials & Design, 71*.

Reflection

Relevance

For 2020 it is expected that the amount of natural fibres used in composite materials in Europe will grow to 28 percent of the total reinforcement materials used in composites, compared 13 percent in 2010. This growth in the bio composites market can be explained by the increasing environmental concern and a growing interest in environmentally friendly materials which are able to replace the fossil/petro based composites (Yan, Chouw, & Jayaraman, 2015). This leads to the ultimate goal of creating high quality composites based on 100 percent renewable resources (Tambyrajah, 2015).

Despite that this process is still in development, the application of bio composites is already widely applied within the automotive and boat engineering, but also within product design bio composites are used. But, within civil and building engineering natural fibres and bio composites are still a rarity. However, replacing glass fibre with a natural fibre, like for example flax, does show potential. Comparing E-glass fibre to flax fibre shows that E-glass fibre has a tensile strength up to 2050 MPa and a density of 2600 kg per m^3, while flax fibre has a tensile strength up to 1500 MPa and a density of 1500 kg per m^3 ("CES Edupack 2015," 2015). Although flax fibres have a lower tensile strength, they are also lighter, proving to be a possible replacement for the fossil based glass fibre. In contrast to the natural

fibre industry, the polymer industry is still developing towards a fully bio based polymers. Nowadays most of the of the bio based polymers used, are still partially fossil/petro based. While others, like furan resin, are made out of 100% renewable resources (Eseyin & Steele, 2015).

Next to the benefits of natural fibres used as reinforcement in bio composites, like renewability, bio-degradable, high technical qualities, more health friendly, there are also some challenges. One main concern regarding natural fibre reinforced bio composites is the long term durability and the lack of data about it. To find acceptance in structural engineering, it is needed to understand the effects of the outdoor environment, resulting in the degradation of the bio composite and therefore raising safety concerns (Yan et al., 2015).

The goal of this research is to investigate the long term effects of UV radiation and changing humidity and temperature conditions on the mechanical properties of a flax and a bamboo based bio composite for structural engineering purposes.

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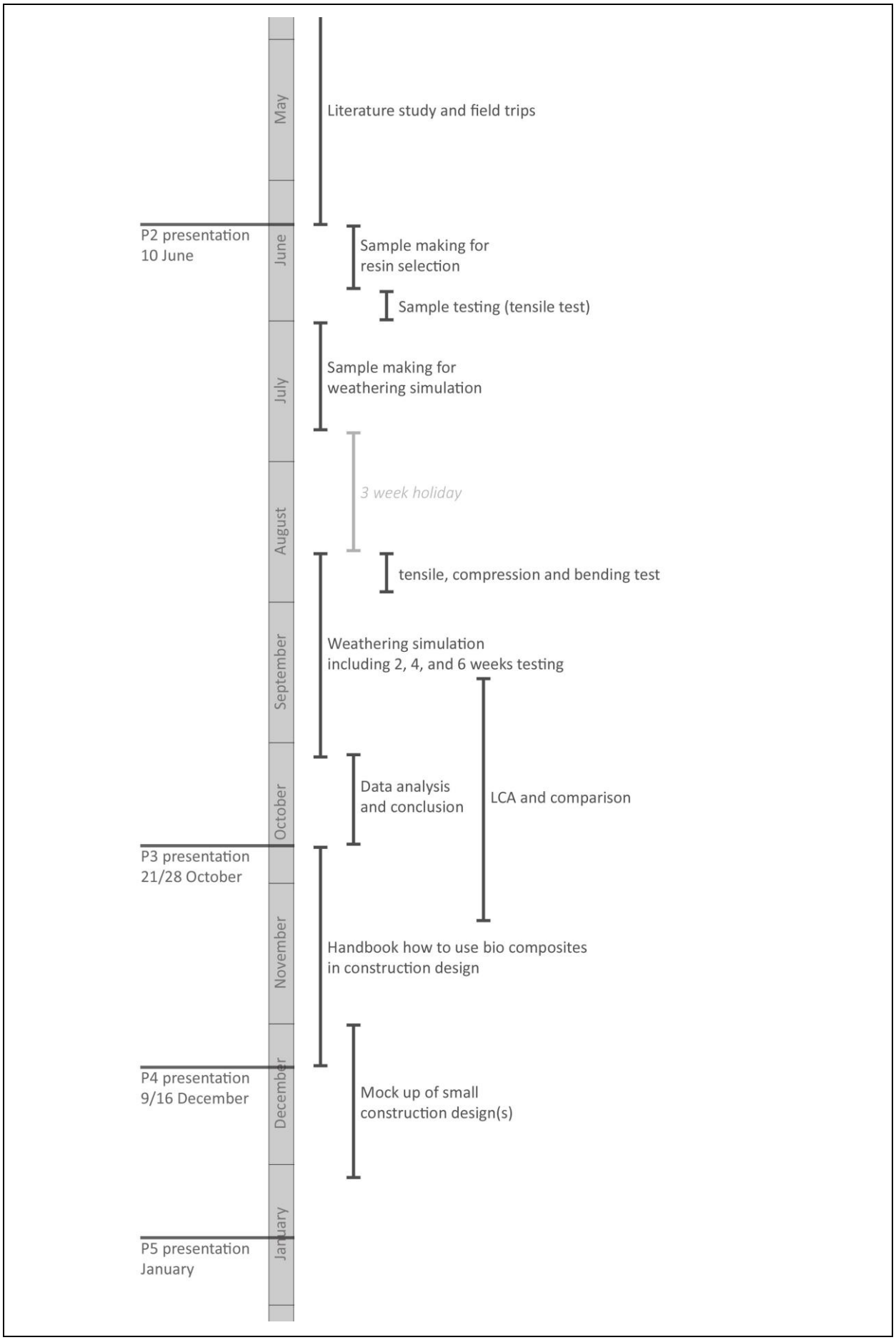
Yan, L., Chouw, N., & Jayaraman, K. (2015). Effect of UV and water spraying on the mechanical properties of flax fabric reinforced polymer composites used for civil engineering applications. *Materials & Design, 71*.

Time planning

The time planning is shown on the next page.


May
June
July
August
September
October
November
December
January
Literature study and field trips
P2 presentation
10 June
Sample making for
resin selection
Sample testing (tensile test)
Sample making for
weathering simulation
3 week holiday
tensile, compression and bending test
Weathering simulation
including 2, 4, and 6 weeks testing
Data analysis
and conclusion
LCA and comparison
P3 presentation
21/28 October
Handbook how to use bio composites
in construction design
P4 presentation
9/16 December
Mock up of small
construction design(s)
P5 presentation
January