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	
Name	Nader Merhi
Student number	5190487

Studio		
Name / Theme	Building Technology: Façade Application of Non-Wood Bio-Based Composites	
Main mentor	Mauro Overend	Structural Design
Second mentor	Arie Bergsma	Façade Design
Argumentation of choice of the studio	The motive of the studio choice is related to the increasing environmental awareness and the growing interest in Non-Wood Bio-composites as a new sustainable construction material, with the outcome of developing knowledge about new sustainable materials and their application procedure facing the new environmental challenges in the building environment.	

Graduation project	
Title of the graduation project	The effects of humidity, temperature, and UV radiation on the mechanical properties of natural fiber reinforced composites and their possible façade applications.
Goal	
Location:	No location is needed

The posed problem,	
Research questions	How does natural fiber reinforced composites perform when subjected to humidity, temperature, and UV radiations, and how can it be applied on the building envelop? Sub-questions: 1- What are the best suitable natural fibers and bio-based resins in terms of mechanical properties and reaction to weathering conditions? 2- How does natural fiber reinforced composites compare to petroleum/fossil-based fiber reinforced composites such as glass fiber reinforced composites and carbon fiber reinforced composites? 3- What are the corresponding manufacturing processes to the chosen fibers and resins? 4- What is the effect of coating on natural fiber reinforced composites? 5- What are the design limitations of the manufacturing processes? 6- What is the design, structural, climate, and safety components to be considered when designing a façade element using natural fiber reinforced composites?

Design assignment in which this result.	In the end of this thesis, it is expected to achieve the following objectives: 1- An overview of the Natural Fibers and Bio-Polymers including their mechanical properties and embodied energy. 2- A comparison between the mechanical properties of natural fibers reinforced bio-composites and petroleum/fossil-based fibers reinforced composites before and after subjection to weathering conditions. 3- Assessment of composite manufacturing techniques and their design limitations. 4- A detailed design of a facade component using natural fiber reinforced composites and its manufacturing process and cost

Process

Method description

The methodology to conduct my research is divided into 2 parts:

- **Part 1:** Research by Experimentation
  - A) Testing on mechanical properties
  - B) Experimentation on Shaping and Flexibility
- **Part 2:** Research by Design

The 2 parts are interrelated and will be conducted simultaneously after finishing the literature review part.

The literature review is the initial part of the research in which background information will be gathered to be used as a base for the experimentation part. The literature will define the materials to be experimented and the techniques that will be used. At the end of the literature review, it is valid to start with the first part of the methodology.

Part 1 (A) (*Testing on Mechanical Properties)* is essential to test several mechanical properties of natural fiber reinforced composites that will help in defining how and where could it be applied on the building skin.

<u>The mechanical properties that will be tested are:</u>

a) Tension (using Universal Testing Machine)
b) Bending (three-point flex test)
c) Water Absorption (using drying and weighing)

These tests will be conducted before and after subjection of the samples to accelerated weathering conditions using QUV Accelerated Weathering Tester which will expose the samples to cycles of UV light and moisture at controlled temperatures. This is to stimulate the outdoor weathering conditions and note how these materials react to simulated outdoor conditions.

The size of the sample is still to be defined. Several samples will be created and tested.

The samples are a combination of Natural Fibers and Bio-based Epoxy:

Natural Fibers:

1- Jute (ETSY Supplier)
2- Flax (Easy Composites)
3- Hemp (Easy Composites)

Fibers (to conduct comparison):

1- Carbon Fiber (Easy Composites)
2- Glass Fiber (Easy Composites)

Bio-based Epoxy:

1- Sicomin Greenpoxy 56

Each fiber will be combined with the Epoxy through 2 production techniques

1- Hand Lay-Up Molding
2- Vacuum Bagging

The decision on the Fibers, Epoxy, and production technique was achieved through the literature review, in which information on 22 Natural Fibers was conducted including their composition and mechanical properties, and then properties were compared in a table with glass fiber and carbon fiber.

In what concerns the Epoxy, the literature covered 13 polymers (11 Thermosets and 2 Thermoplastics). Decision was made on a comparison done on the polymer's mechanical properties, color, transparency, time of reaction, suitable production technique (since some production techniques are not accessible without access to composite factories). The decision was made on the Epoxy. And then the research on a bio-based epoxy started which was also covered in the literature.

Finally, the production technique was limited to the available equipment's and the ones that I can use myself:

1- Hand Lay-Up
2- Vacuum Bagging

Part 1 (B) *(Experimentation on Shaping & Flexibility)* is designated to experiment with the molding of the composites and see to what extent can these composites be deformed and customized to specific envelope designs.

It will also cover the mixtures (fibers + matrix) to explore if there is a possibility to achieve a flexible, transparent material.

Part 2 is the research by design. This part is basically the part in which a façade component will be designed in detail.

Following the findings of the literature and the progress of the experimentation, a façade component will be designed accordingly. Research by design will start first by a brainstorming phase, in which several options of façade applications will be explored.

It is crucial to define the objective of the application (protection from environmental factors, decorative, visibility regulation, …)

Defining the objective of the application will help in setting the boundaries of the design, since a big number of options could be considered which can make it difficult to decide.

After defining the objective, it is important to take into consideration the experimentation progress to start detailing the system accordingly.

With that being done, the work on the final objective becomes valid. A clear complete façade system using natural fiber reinforced composites could be designed and detailed. At that stage,

several possibilities will be explored in terms of detailing, and several modifications will occur before agreeing on a final outcome. The final stage of research by design is to decide if a complete prototype of the element could be fabricated, however at this stage of the research it is not valid to confirm this decision.

Literature and general practical preference

1. Ali, E., Hasan, M., & Islam, N. (2012). Chemical treatment of coir fiber reinforced polypropylene composites. *Industrial & Engineering Chemistry Research, 51(10): 3958-3965.* https://doi.org/10.1021/ie200693v

2. Arrakhiz, F.Z., El Achaby, M., Malha, M., Bensalah, M.O., Fassi-Fehri, O., Bouhfid, R., Benmoussa, K., & Qaiss, A. (2013). Mechanical and thermal properties of natural fibers reinforced polymer composites: Doum/low density polyethylene. *Materials & Design, 43:200-205*. https://doi.org/10.1016/j.matdes.2012.06.056.

3. Bernard, M., Khalina, A., Ali, A., Janius, R., Faizal, M., Hasnah, K. S., & Sanuddin, A. B. (2010). *Materials and Design, 32(2):1039-1043.* DOI:10.1016/j.matdes.2010.07.014

4. Drobny, J. G. (2014). Handbook of thermoplastic elastomers. (2nd ed.). *Elsevier Inc*. https://doi.org/10.1016/C2013-0-00140-5

5. El Messiry, M. (2017). Natural fiber textile composite engineering. *Taylor & Francis Group.* https://doi.org/10.1201/9781315207513

6. Fan, M., & Fu, F. (2017). Advanced high Strength natural fiber composites in construction. *Wood Publishing Series in Composites Science and Engineering (74).* https://doi.org/10.1016/C2014-0-03942-1

7. Kaewkuk, S., Sutapun, W., & Jarukumjorn, K. (2012). Effects of interfacial modification and fiber content on physical properties of sisal fiber/polypropylene

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8. Kandola, B. K., Pornwannachai, W., & Ebdon, J.R. (2020). Flax/PP and flax/PLA thermoplastic composites: influence of fire retardants on the individual components. *Polymers, 12(11), 2452.* https://doi.org/10.3390/polym12112452

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Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

The graduation project Bio-based composites and façade applications, combines 2 main fields 1- Structural Design 2- Façade Design. These 2 fields are crucial parts of the building technology track. The focus of the project lies on the experimentation of new sustainable materials that will replace petroleum/fossil-based materials used on the building envelop. The building envelop is considered the threshold between the built environment and the urban conditions and, as such, the research is in relation with the Master of Science in Architecture, Urbanism and Building Sciences.

The findings of this research, basically, the overview on non-wood bio-based fibre reinforced composites, the experiments on the composites, and the design of the façade system will be relevant for the progress in building technology progress.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework?

Social Framework:

With the increasing environmental awareness in the building sector, and the challenge of the building industry to adapt to the European Union's development strategies and environmental challenges, it is relevant to investigate new non-wood bio-based materials, and find a way to use it as a replacement of petroleum/fossil-based materials. Investigating in that area could have a positive impact in response to today's environmental challenges on a social level and on a scientific level.

On a social level, the research aims to find a product with reduced embodied energy, environmental-friendly, yet with comparable properties as conventional materials, which is considered a positive step in response to the environmental challenges facing today's society.

Scientific framework:

Creating an overview of the natural fibres, bio-resins, production methods, and sharing the results of the experimentation that will take place at TU Delft, will contribute to the generation of new ideas and concepts to proceed in using non-wood bio-based fibre reinforced composites in the building environment. It will allow for further scientific development in both the material itself and its application on the building skin. Conducting this research could be considered as an opening way in exploring the applicability of non-wood bio-based fibre reinforced composites in the field of architecture, which is for the moment, at the very early stages of application, and requires investigation.

Time Schedule