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	Lara Neuhaus
Student number	561896

Studio		
Name / Theme	Building Technology Graduation Studio AR3B025 / Engineered circular bio-composites	
Main mentor	Mauro Overend	Structural Design
Second mentor	Olga Ioannou	Façade and Product Design
Argumentation of choice of the studio	Building materials highly affect the degree of sustainability a building can achieve, both in its carbon balance and end-of-life prospects. There are many fields left to explore in this sector and I find it exiting to explore a novel material like polymer-based composites by investigating possible ways to make them circular. Looking at waste-flows as material source could be a key action to react to growing demands of non-fossil-based resources for building products.	

Graduation project	
Title of the graduation project	Exploring the Impact of waste-sourced Bio-fillers on the functional and mechanical Characteristics of Hybrid Filler Bio-Composites in a Façade Application.
Goal	
Location:	None
The posed Problem	The sustainability of buildings is highly dependent on material and design choices, impacting carbon footprint and end-of-life prospects. With the construction sector responsible for 39% of global carbon emissions (Crawford, 2022) the need for more circular building products is pressing. Fossil-based composites, used in aviation, automotion, and construction (Oliveux et al., 2015), have a high functionality but pose sustainability challenges due to non-renewable sources, high production emissions, and limited recycling potential. Exploring bio-based polymers with plant-based reinforcements might be a solution. As the demand for natural resources in construction rises (Singh, 2020), exploring alternatives to virgin-grade materials is needed.

	Utilising waste streams, especially from the agri-food industry, which is significant in the Netherlands, holds potential for sustainable and local solutions. Currently, a significant amount of waste from these industries remains underutilized. In the development of façade panel, which is a well-suited application for bio-based composites, this project aims at significantly reducing embodied carbon in the non-structural built environment. Façades also provide design freedom for architects to showcase bio-based materials, addressing both aesthetic and functional requirements. To summarise, a knowledge gap exists in using waste-material sources to engineer bio-composites for façade applications aligned with circular economy principles. Incorporating bio-fillers in composite façade panels could contribute significantly to a reduced environmental impact and influence the materials performance uniquely.
Research Questions	- What is the relevance of bio-based composites façade panels in the bigger context of a circular economy? - How does the use of various biobased waste materials (coffee ground, cocoa shells, stone fruit pits, nut shells (to be finalised)) influence the material properties of a polymer-based bio-composite when used as a filler? - Which proportions between the waste-based filler, a second fibrous filler and matrix results in the best outcome in material qualities regarding the mechanical properties? - Which size and mixture of grainsizes of the filler results in the best outcome in material qualities regarding the mechanical properties? - How does the moulding process and product design factor into the materials performance and circular valorisation of a façade panel? - What limitations for the design process are imposed by the material choices? - What are the implications of each filler for usability and aesthetics in a façade cladding application? - How does the resulting facade product compare to established products regarding the performance and circularity (bio-degradability, prospects of reuse and recycling)?
Design Assignment	This thesis aims to explore local sources for waste material that can be used in the creation of bio-composite façade panels as a

	filler and that, by being used in such a way, have and overall positive impact on the circular environment. After allocation and evaluation of the material sources the project aim to explore the best way to use these waste materials in the composite material as a filler, which includes the exploration of mechanical and functional properties with different waste types, compositions, grain sizes and amount of filler added to the mixture. Furthermore, this project aims to explore experimentally the impacts of material and composition choices in bio-fillers, as well as available manufacturing techniques, on the design process of a composite façade panel. Retroactively the implications of design options on the process of creating the material composition are to be considered as well. Finally, the goal is to put the resulting product into relation with the bigger context of socio-economic trends and circularity efforts.

Process

Method description

Literature Research

The process starts with an investigating the general definition and relevance of bio-composites and research application types. Then bio-composites role in a circular environment are studied, including life-cycle analysis, end-of-life-options for composites, studies on recycling options, and the overall environmental and economic impact.

The second part of the investigation consists of defining the relevance of utilizing waste-material as secondary material in bio-composites. By identifying mayor sources of organic waste in the Dutch context, the structures of industrial waste production and a priority scheme for use cases of organic waste, waste sources and their potentials for the planned application are defined and selected for further investigation.

The next part of the literature review focuses on the composite material development. Topics of interest are studies on bio-based fillers regarding their performance with varying size, volume and in relation to the composition with matrix and fibrous fillers. Also, the methods of manufacturing and testing are researched and how they could influence the resulting product.

Another section of research is to be dedicated to the product design of facade panels with bio-composites, how the material composition and manufacturing method influences the design and which limitations and possibilities are imposed by the material, how a façade panel from bio-based material could be implemented as a competitive marketable product and how the product would fit into a circular economy.

Research By Design

After identifying potentially useful waste flows, experimental material testing is to be performed in three stages.

1. The creation of a bio-composite samples from Polyethylene Furanoate (PEF) as matrix, reed as a fibrous filler and one of the waste-sourced materials from the prior selection respectively.
   Testing: Indicial visual inspection for haptic, bonding success, colour and bending strength; mechanical testing for bending strength and absorption
   Result: Reasoned elimination of unsuccessful probes and allocation of promising material candidates

2. Production of samples from promising materials with same matrix and fibre materials but with variation of filler sizes and volumes in proportion to matrix and fibre.
   Testing: Mechanical and functional testing including for tensile strength, three-point bending, impact resistance, water absorption, frost resistance and weathering (UV, temperature and moisture, possibly for a selection of the most promising compositions)
   Result: Evaluation of different Filler materials for their usability in this bio-composite application in different composition variation and identification of the highest performing material, filler sizing and composition with matrix and fibres.

3. Design exploration of façade panel design with the implications and limitations imposed by the material outcome from phase 2 and creation of small samples and a full-sized prototype from the highest performing material composition with debated design choices.
   Testing: As needed for the design exploration, possibly bending or impact tests for samples of differing thicknesses or shape.
   Result: Façade Panel Prototype and identified dependencies between design and material choices.

The production of composite samples and prototypes will most likely employ the compression moulding technique, in which a “dough” is created from the three ingrediencies (filler/polymer resin/fibre), which is then pressed with high pressure. Still, other methods of production are up for consideration.

Assessment

During and after the experimental design phases, the choices are evaluated on their impact on the products life-cycle and end-of-life prospects. This includes the usability, functional and mechanical performance in respect to the desired application of a façade panel, optical effect and attractiveness, and on the larger scale the durability, impact on reusability and recycling option, bio-degradability and environmental impact.

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Reflection

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

This thesis project focuses on material research and building product design with emphasis on circularity and carbon reduction. This falls into the scope of the Building Technology master tracks main teachings and research fields. It also aligns with the overall orientation of the architecture faculty towards a circular and environmentally friendly building sector.

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

Fossil based plastics like polymers and polyesters in combination with a fibre reinforcement have proven to lead to high performance composites used in aviation, the automotive industry and the building sector. Since the limitation of fossil resources urges us to engage with renewable materials and climate change demands a more holistic view on production, construction, service life and end-of-life scenarios of buildings, new composites made from natural fibres, fillers and bio-based plastics have a great potential to replace established but non circular products. Only few composite building products in this category from partially or fully renewable sources exist and the rapid developments in the research on new bio-plastics leaves a research gap with a lot of possibilities for new products that could replace conventional building products.
Waste as a local and cheap source for secondary material has a great potential to not only reduce the reliance on virgin resources in building products but also improve the reuse material with previously little or no value from waste-streams and extend the materials useful lift. In this I aim to advance the effort to find more sustainable and fully circular options for building products and thereby to improve the chances for a carbon neutral building industry in the future.