Graduation Reflection

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POTENTIAL & LIMITATION TO 3D PRINT A WINDOW FRAME WITH PURE CELLULOSE & LIGNIN

Building Technology Track

First Mentor: Dr. Serdar Asut | Design Informatics
Second Mentor: Prof. Dr.-Ing. Ulrich Knaack | Façade & Product Design
Consultant Dr. Michela Turrin | Design Informatics
External Supervisor: Dr. Richard J.A. Gosselink
Examiner: Willemijn Wilms Floet

Graduation Process

Position of the graduation topic in the studio

This master thesis aimed to promote wood waste as an ecological contributor to the building industry through the use of additive manufacturing. Within the Building Technology track, the master thesis combines the discipline of design informatics and facade design. Both topics were selected for research and design on a sustainable and circular innovative facade component. In a time of environmental distress, the profession has the responsibility to act with new ideas and solutions to be handed to future generations. Therefore, my graduation topic integrated a 3D-printed custom-built window frame to marry the relationship between the graduation thesis, master 's track, and master 's program.

Looking back at the research methodology

The research strategy was based on "Research by design". Phase 1 was dedicated to the contextual background of my research topic based on literature papers and conducting multiple interviews with experts in the field of 3D printing with bio-based materials. Phase 2 was dedicated to the writing of the contextual background. Phase 3 was based on "practice" to experiment and evaluate different material recipes. Phase 4 was also based on "practice" to produce and prototype 3D printed components. Therefore, the "Research by design" approach was the correct methodology to follow as different mechanical tests and printed elements were successfully demonstrated. However, due to the limited time of a graduation thesis and many unexpected challenges that came along, phase 3 and phase 4 could have been implemented at an earlier stage of the thesis to ease the design process and scientific evaluation.

Research and design-related

After the state-of-the-art research manifested by Thomas Liebrand in 2018 by extruding pure lignin and cellulose with acetone, the aim of this research was based on changing the binding agent into a bio-based one. Therefore, the initial research was based on literature reviews and interviews to test different natural binding agents with cellulose and lignin. Once the exploratory phase of the findings was conclusive, the design of a final product was only achievable by understanding the limitations and advantages of 3D printing them. Therefore, a series of printing tests were conducted to further guide the final shape of a 3D printed window frame.

Dilemma during the process & how it was dealt with

As the initial phase of the graduation topic relates to the explorations of bio-based recipes, a regular collaboration between the faculty of civil engineering & geosciences with the faculty of architecture and the built environment should be implemented. It would ease the fabrication and testing of the explored recipes to collect additional information to further produce a product that could potentially enter the building industry. Fortunately, thanks to our mentors and Prof.dr.ir. P.C. Christian Louter, we were able to find a collaboration between both faculties to further test the final recipes. Lastly, it was hard to foresee the time it would take to install and equip the 3D printers. With the help of Serdar Asut, Paul de Ruiter, and full access to the LAMA lab, the process to purchase the necessary tools and installing the equipment was achievable between P3 and P4.

Societal Impact

Applicability of results

Thanks to the collaboration made with Alexsander Alberts Coelho who chose the same research topic, two types of results were achievable. After exploring a material research phase together, Alexsander Alberts Coelho conducted the mechanical testing of our findings with the focus to design a structural node and I conducted the printability of our findings to design a window frame. Given the current results of the mechanical properties and printability of our final recipe, it is possible to 3D print building components in a cold extrusion process (liquid deposit modeling) with lignin and cellulose in combination with water and methylcellulose.

Further improvements

More research is necessary to improve the printing workflow and material properties of the recipe to become a fully integrated facade component. The final recipe and fabrication process need further study in regard to the printing process and scientific testing to improve the reliability of our recipe and offer a larger range of geometrical freedom. Thus, scaling up the process and improving the material's viscosity, shrinkage, and reduction of its water content should be further studied. Lastly, the structural properties of the final recipe should be improved by adding different lengths and types of fibers while 3D printing.

Sustainability & Social Relevance

The possibility of 3D printing with a wholly bio-based material coming from waste is a great accomplishment. Also, the final paste could potentially become circular if crushed into a powder that can be reprinted. By implementing a fully sustainable and possibly circular recipe with the implementation of sustainable technology, the impact of such harmless and natural innovation will reduce the construction industry ‘s carbon footprint and lead to a healthier environment. I am a true believer that the use of robotic manufacturing processes in combination with bio-based and waste materials will lead to a fully sustainable, circular, and the unique built environment.

Professional Relevance

3D printing window frames can be utilized in different areas of the construction industry such as in the heritage field by replacing or enhancing existing window frames. It can also be beneficial to large-scale 3D printing companies. During my interview with Marijn Bruurs, Witteveen+Bos, he has elaborated his interest in my graduation topic. Marijn Bruurs described that the interface between window frames and 3D printed concrete buildings is still traditional. Therefore, the freedom to 3D print complex elements such as window frames can be utilized to enhance the uniqueness of custom habitats.
Also, the connection between window frames and 3D printed habitats leaves room for improvement, as they are not completely flush with each other. As both materials utilize a different manufacturing process, a perfect fit could only be established by 3D printing a window frame as well as the surrounding structure.