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	Swornava Guha
Student number	5961815

Studio		
Name / Theme	Building Technology Graduation Studio/ SD, DI, MIT	
Main mentor	Dr. Faidra Oikonomopoulou	Glass Structures Cast Glass, Glass Recycling
Second mentor	Dr. Charalampos Andriotis	Decision Making, Optimization, Artificial Intelligence
Argumentation of choice of the studio	Building Technology takes an interdisciplinary approach to design and innovation, bridging the divide between architecture and engineering. Through the courses I've undertaken, I've been inspired to explore areas where research and innovation are needed most. Unlike many other fields, architecture has lagged in technological advancements. I strongly believe it is essential to drive architecture toward more technology-focused construction systems to stay aligned with the rapid developments in material science and engineering. My passion for construction and structural mechanics, coupled with hands-on experience in architecture, fabrication, and construction, has naturally led me to this studio. I aspire to contribute by developing innovative design solutions and engaging in research that advances the engineering of efficient, high-performance structures. At the same time, I am committed to addressing the challenges of (contextual) sustainability, working toward creating structures that are both innovative and responsible.	

Graduation project	
Title of the graduation project	A novel Workflow for Circular Assembly using 3D-Printed Glass Masonry units with a Kirigami-inspired Interlayer
Goal	
Location:	No Specific location

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<tr><td>The posed problem,</td><td>3D printing is emerging as a promising technology due to its ability to produce complex geometries, minimize material waste, and enable structurally optimized designs. While advancements like G3DP2(a glass 3D printer developed by the Mediated matter group at MIT) demonstrate its potential in glass additive manufacturing, its application remains limited at larger scales due to the size constraints of 3D-printed products, necessitating segmented construction. Masonry construction with glass also necessitates the requirement of an interlayer to avoid glass-to-glass contact. However, there has been limited research on developing a fully circular assembly system to address these challenges.</td></tr>
<tr><td>research questions and</td><td>Can a Kirigami-inspired interlayer be the solution for a reversible dry-assembly system with 3D-printed glass bricks in the built environment? What are its potential benefits and key considerations?</td></tr>
<tr><td>design assignment in which these result.</td><td>A. Develop a novel interlayer solution for the dry assembly of 3D printed glass masonry units by inventing (i.) an effective (kirigami inspired) geometry for the required interlayer stiffness in a designed pure-compressive shell structure (ii.) the ‘architecture’ of the interlayer and (iii.) Appropriate production and assembly
B. Develop strategies for tessellations for interlocking 3D printed glass units based on production limitations of current 3D printing technology
C. IF possible, generalize the solution for other 3D printed glass dry-assemblies</td></tr>
<tr><td colspan="2">[My thesis is an attempt to establish a solution for developing an assembly system for masonry structures out of 3D printed glass units that are completely circular. Although the thesis is directed towards finding interlayer geometry and material, it</td></tr>
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would also investigate aspects of constructability and limitations of the dry- assembly of a compression-only shell. Ideally, we would like to derive a generalized solution, addressing the drawbacks and challenges relating to geometric complexity, ease of fabrication and end of life prognosis]

Process

Method description

The method of the thesis follows research through design methods earlier explored in design assignments of the course. Broadly speaking, it has been divided into three parallel phases in terms of literature study and exploring tools for design.

A. **Phase 1: Designing a compression only form-** This will entail research by exploring various tools for designing a particular chosen compression only form for the assignment. Here, the research is categorized as:
   Theories: The quest to find a suitable method to design a pure compression shell for our dry assembly- through case studies that are applicable and thereby exploring openly available tools to do so.
   Tools for design: Explore the different computational tools to achieve a particular shape chosen as per literature, develop a comparison and research on the most effective way to move forward.

B. **Phase 2: Discretization and Detailing-** This phase would involve research in two directions-
   Tessellation and Brick geometry- Derive the most promising tessellation and brick geometry from literature and prototyping. Validation of structural performance and required stiffness for the interlayer would be derived here. We will also select a particular section of the geometry which is critical for further analysis of discrete elements.
   Interlayer geometry- The interlayer geometry and material will be parallelly researched to arrive at feasible options- of a composite sandwich interlayer system with kirigami as the stiff yet flexible core. To arrive at the kirigami architecture, initial prototyping of different forms would be done. At this stage, research findings from the MIT team would be utilized to arrive at a particular kirigami architecture for the interlayer to be worked on. Finally, the idea is to arrive at a parametric tool to select the geometric properties for the interlayer application in any given load conditions of a dry-interlocking structure that replaces the requirement of discrete modelling and finite element analysis on the interlayer geometry.

C. **Phase 3 Prototype and Validation**- This phase, parallel with phase 2, will involve several prototyping and testing both overall form dry assembly, and interlayer geometry. Final prototypes for testing and production technique will be derived during the process.
   Currently the idea is to apply the promising interlayer solution and interlocking brick geometry to create a straight masonry wall assembly before applying the same to the designed geometry.
   Scaled Prototyping will be carried out with different materials initially.

Literature and general practical references

For the literature and design research, various research papers are being looked into, which would be outlined in the Report. Some of the key references that also frame the problem statement and research question are hereunder:

- Papers on current 3D printing technology for glass and its limitations

Inamura, C. (2017). *Towards a New Transparency: High Fidelity Additive Manufacturing of Transparent Glass Structures across Scales*.

Inamura, C., Stern, M., Lizardo, D., Houk, P., & Oxman, N. (2018). Additive Manufacturing of Transparent Glass Structures. *3D Printing and Additive Manufacturing*, *5*(4), 269–283. https://doi.org/10.1089/3dp.2018.0157

Zhang, D., Liu, X., & Qiu, J. (2021). 3D printing of glass by additive manufacturing techniques: A review. *Frontiers of Optoelectronics*, *14*(3), 263–277. https://doi.org/10.1007/s12200-020-1009-z

Massimino, D., Townsend, E., Folinus, C., Stern, M., & Becker, K. (2024). Additive manufacturing of interlocking glass masonry units. *Glass Structures & Engineering*. https://doi.org/10.1007/s40940-024-00279-8

Stern, M., Townsend, E., Massimino, D., & Becker, K. (n.d.). *Advancing Sustainable 3D Printing: The Feasibility of Recycled Glass as a Building Material With Additive Manufacturing*.

- Robotic Glass vault- its form study and interlayer study

Parascho, S., Han, I. X., Beghini, A., & Miki, M. (n.d.). *LightVault: A Design and Robotic Fabrication Method for Complex Masonry Structures*.

Parascho, S., Han, I. X., Walker, S., Beghini, A., Bruun, E. P. G., & Adriaenssens, S. (2020). Robotic vault: A cooperative robotic assembly method for brick vault construction. *Construction Robotics*, *4*(3–4), 117–126. https://doi.org/10.1007/s41693-020-00041-w

Beghini, A., Miki, M., Walker, S., Han, I. X., & Parascho, S. (2020/21). *Robotic construction of a self-balancing glass masonry vault: Design and tessellation*.

- Interlocking masonry structures with cast glass

Oikonomopoulou, F., Bristogianni, T., Barou, L., Jacobs, E., Veer, F. A., & Nijsse, R. (n.d.). *Interlocking cast glass components, Exploring a demountable dry-assembly structural glass system*.

- Selection of Interlayer properties for glass masonry

Oikonomopoulou, F., & Bristogianni, T. (2022). Adhesive solutions for cast glass assemblies: Ground rules emerging from built case studies on adhesive selection and experimental validation. *Glass Structures & Engineering*, *7*(2), 293–317. https://doi.org/10.1007/s40940-022-00178-w

Oikonomopoulou, F. (2019). Unveiling the third dimension of glass: Solid cast glass components and assemblies for structural applications. *A+ BE| Architecture and the Built Environment*, (9), 1-352.

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)?

   This graduation topic is a clear intersection of multiple disciplines, including Structural Design, Design Informatics, and also certain aspects of Product development, Innovation, Material Science, and Circularity. These areas align seamlessly with the focus and ethos of the Building Technology Program within the MSc AUBS. Alongside my prior interests and experience in architecture, fabrication, and design, this choice has been strongly influenced by some of my most inspiring courses in the program—Technoledge Glass Structures, Computational Intelligence for Integrated Design, Sustainable Architectural Materials and Structures (SAMS)—as well as the hands-on, innovative spirit of Bucky Lab. Together, these experiences have shaped my decision to pursue this multifaceted topic.

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

   In the domain of Architecture and Engineering, there has always been a search to innovate new and sustainable ways of building. Its relevance within the larger social, professional, and scientific framework could be outlined as below-

   Social Relevance: With growing awareness of environmental issues, the work aims to address the need for circular construction systems by focusing on reversible assembly techniques and additive manufacturing technology. Thereby also promoting deconstruction, recyclability and waste reduction. It also aims to innovate with ancient techniques like kirigami and combine them with cutting edge 3D printing technology.

   Professional Relevance: The project aims to showcase how 3D-printed glass can transform construction with scalable, reusable methods. Modular interlocking systems offer practical solutions, addressing current glass assembly challenges. The thesis also aims to expand on professional tools by integrating material science, computational design, and structural mechanics.

   Scientific Relevance:
   The topic addresses scale and assembly challenges, advancing the potential of 3D-printed glass in architecture. It also adds to interdisciplinary research by merging architecture, engineering, material science and computation. Exploring kirigami-based interlayers, the work would advance architected materials/ metamaterials with applications in multiple fields.

Much of this remains uncertain and will depend on the outcome of the project. However, the ideas outlined above form the core vision of this thesis, guiding the research directions and decisions. If the results prove promising, there will be significant potential to refine both the product and the technology, while also adapting solutions to fit diverse applications- like cast glass masonry structures.