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	Andreas Mananas
Student number	5917530

Studio		
Name / Theme	AR3B025 Building Technology Graduation Studio	
Main mentor	Faidra Oikonomopoulou	Structures & Materials
Second mentor	Charalampos Andriotis	Structures & Materials
Argumentation of choice of the studio	n/a	

Graduation project	
Title of the graduation project	Topology Optimization for Process-Induced Anisotropy in Glass Structures. Leveraging Topology Optimization Algorithms to Address Anisotropic Behavior Introduced by Additive Manufacturing Methods in glass structures
Goal	
Location:	Delft, The Netherlands
The posed problem,	[Problem Statement]
research questions and	**Research Question**: How can process induced anisotropy be integrated into topology optimization of additively manufactured glass structural components to ensure manufacturability and structural integrity? **Secondary Questions:** • What are the existing additive manufacturing techniques, and which are most suitable for fabricating glass components? • How does additive manufacturing introduce process-induced anisotropy in materials, and what are its implications for mechanical performance? • What are the operational capabilities and constraints of topology optimization algorithms?

	• How can topology optimization algorithms incorporate process-induced anisotropy to ensure alignment between design intent and fabricated properties?
design assignment in which these result.	This research aims to integrate process-induced anisotropy into topology optimization (TO) workflows for the design of additively manufactured glass structural components. The study focuses on aligning design intent with fabricated properties by accounting for anisotropic effects introduced during the manufacturing process. The design assignment revolves around the creation of optimized glass components that are not only structurally efficient but also manufacturable using additive techniques. The project targets a framework where anisotropy, resulting from the layer-by-layer deposition of molten glass, is incorporated into TO algorithms to ensure structural integrity and performance predictability. The investigation involves analyzing the operational parameters of existing AM techniques suitable for glass, identifying how these techniques introduce anisotropy, and exploring their implications for structural design. Simultaneously, the research evaluates the capabilities and limitations of TO algorithms, developing strategies to embed anisotropy considerations into the optimization process. The outcomes will be validated through experimental and computational testing of additively manufactured glass prototypes. Ultimately, this project aims to establish a comprehensive methodology for designing "anisotropy-aware" TO glass components, bridging the gap between computational optimization and manufacturing constraints, and setting the foundation for sustainable, high-

	performance architectural and structural applications of additively manufactured glass.

Process

Method description

The methods and techniques utilized in this research follow a structured, iterative approach that builds upon a detailed theoretical foundation and progresses through practical experimentation and validation. The project is divided into two primary phases: a comprehensive literature review and a practical phase. These phases intersect dynamically, ensuring a continuous refinement of insights and approaches.

The literature review serves as the cornerstone for developing a robust understanding of three critical areas: the material properties of glass, the processes involved in its additive manufacturing (AM), and the application of topology optimization (TO) algorithms. For the study of glass as a material, the research leverages existing knowledge and expertise, notably the work of my mentor, Faidra Oikonomopoulou, as well as the contributions of Koniari and others. The goal here is not to examine every facet of glass properties exhaustively but to gain a focused understanding of how these properties influence the research outcomes.

Additive manufacturing is integral to this project, especially in conjunction with TO. The exploration of AM focuses on its history, primary processes, and state-of-the-art developments, particularly in glass additive manufacturing, with a focus on the G3DP2 process. While AM is crucial, its role in this research is foundational, providing context for how layer-by-layer manufacturing techniques impact material behavior and manufacturability. This examination lays the groundwork for integrating process-induced anisotropy into TO workflows.

Topology optimization forms the central pillar of the research. Significant effort is devoted to understanding its principles, algorithmic operations, and potential for addressing challenges specific to glass AM, such as overhang constraints and path continuity. This rigorous investigation ensures that TO methods are appropriately adapted to account for the unique characteristics of glass and AM processes.

Following the establishment of the theoretical framework in P2, the practical phase begins, marked by experimentation. This phase will involve mechanical testing of 3D-printed glass components to assess their strength and compare the findings with existing data. These experimental results will provide essential insights into how process-induced anisotropy affects the mechanical performance of glass components. The data gathered will be integrated into the TO algorithm, enhancing its ability to account for anisotropic behavior and ensuring alignment between design intent and fabricated properties.

Simultaneously, computational experimentation will commence using the 169-line MATLAB code as a foundation building upon the advancements of Brueren.

Mathematical modeling will be used to develop the logic needed to adjust the stiffness matrix, which is essential for incorporating anisotropy into the TO algorithm. By P3 (maybe also a bit after P3), this work will progress toward the development of a comprehensive framework that integrates previous research and new advancements.

As the project moves into P4, the focus will shift to validating the TO algorithm and refining the framework. Validation will involve applying the framework in a smaller scale and using tools like ANSYS or real life experiments (depends on certain factors that are not yet known) to evaluate structural integrity. The aim is to ensure the framework's ability to produce manufacturable and structurally sound results that account for the intricacies of glass AM processes.

Finally, during P5, the framework will be refined and optimized to maximize its potential. The culmination of this work will be a fully validated framework that incorporates process-induced anisotropy into topology optimization, providing a practical and theoretical foundation for future applications of glass in structural and architectural contexts.

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Reflection

This research focuses on integrating process-induced anisotropy into topology optimization (TO) for the design of additively manufactured glass. This topic directly relates to the Building Technology (BT) track within the MSc Architecture, Urbanism, and Building Sciences (AUBS) program, as it merges computational design, material science, advanced manufacturing technologies and structural design, to develop innovative solutions for sustainable construction.

In the broader scope of the MSc AUBS program, the project embodies its emphasis on interdisciplinary approaches by exploring the intersection of architecture, engineering, and material innovation. By bridging computational design tools and manufacturing processes, my project showcases how technology can redefine material usage and structural efficiency.

This research addresses critical challenges at the intersection of sustainability, material efficiency, and advanced manufacturing. As topology optimization and additive manufacturing technologies become more popular, understanding and integrating process-induced anisotropy into topology optimization is crucial for creating manufacturable, structurally sound designs. This contributes to a growing demand for resource-efficient solutions in construction, particularly with high-performance materials like glass.

Scientific Relevance

On a scientific level, the research advances the field of computational design and material science by exploring how topology optimization can incorporate anisotropy resulting from manufacturing processes. It contributes to the body of knowledge on the integration of manufacturing constraints into design optimization and paves the way for further innovations in the use of glass in structural and architectural applications.