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Relevance

Though fully glass structures have become increasingly accepted within the built environment, it is still regarded as a two-dimensional material, based on float glass construction. Cast glass allows the creation of complex, solid objects, transforming glass to a fully three-dimensional material. Most research into structural cast glass, however, has been limited to relatively simple, repetitive geometries of stacked components; copying the design language of brick or stone blocks.

This research proposes a different design language for cast glass. Glass design using Topology Optimisation can be used to make structurally viable elements with only little material. These geometries can be annealed much faster than conventional solid glass elements, due to their low mass, organic shapes and thin material sections. The short annealing times eliminate one of the major challenges of cast glass fabrication, and can significantly help in making cast glass a competitive alternative to conventional glass structures.

Additive manufacturing has been used to simplify the mould-making process required for fabricating cast glass components. Conventional mould making is a complex, labour intensive process, which limits the casting of customised complex geometries. It has been shown that additive manufacturing of moulds can be used to streamline this process. Together with the reduced annealing times achieved with topology optimisation, this shows that cast glass has great potential to be used as a structurally sound and economically feasible construction material in the built environment.

This project is a merger of technology and aesthetics. Using new tools, innovative fabrication techniques and a unique material, a type of transparent structures is explored that has not been possible to make so far. Different fields of expertise, Structural Design and Design Informatics are used together to achieve this goal. This interdisciplinary approach to architectural innovation is what I think makes this a true Building technology project.

Process reflection

In this thesis, a methodology of *Research through Design* was used. Here, the research question is linked to a design assignment. As the design progresses, problems and challenges are encountered. By solving tangible problems like these, the different aspects of the research question can be answered. In this project, a case study structure was chosen, and redesigned using a different type of loadbearing structure. The idea behind this was that it should save time, as a lot of design work was already done in the pavilion. This would allow me to focus more on the part of the design that is relevant for investigating the research question.

This had mixed results. On the one hand the case study provided a clearly defined design assignment, and provided a practical set of limitations to keep the project grounded in reality. However, during the project it became more and more noticeable that the selected case-study was being modified to be something it was not originally designed for, structurally. Many challenges of the design process (such as the peak stresses in the shell, or the vulnerability to wind loads) were direct consequences of this; a lot of time was used on trying to solve these issues. This time might have been better spent designing a structure from the ground up, fully taking into account the possibilities and limitations of cast glass and topology optimisation. The challenges encountered did help to find the limitations of the proposed design process.

The design methodology proposed a clear workflow of research, tool development, design and testing, with some chance for feedback iterations between steps. Though the broad strokes of this process were followed, in practice tool development and design were merged fully in a back-and-forth process, with a lot time spent on trial-and-error designing. Some more reflection on the results would have saved time, which also could have been spent better elsewhere.

This entire process taught me to be more critical about what I am spending my time on during my work. Especially at the beginning, a lot of time was wasted on elaborate parametric grasshopper scripts and optimisations that were not used in the end. Formulating a clear goal, and critically considering whether what is done is useful to reach this goal is important in cases such as these, as it will reduce time lost on side projects that are of less importance.

To illustrate: In this thesis, a lot of time was spent on finding ways to make topology optimisation work for a grid shell, as the results found so far proved structurally unreliable. This raised the question of what I was trying to achieve. Solving Topology Optimisation was not the goal of the project, it was merely a tool to test whether this kind of geometries could be made in glass, and how that would perform. Making this clear helped me to continue with my project on a point where I felt stuck.

What also proved more challenging than expected was the actual application of Topology Optimisation on glass. Glass is a unique material, with properties that are quite different from most other building materials. This meant that some assumptions that are normally used for TO are no longer viable. I am very grateful for Dimitris Vitalis from ARUP and our own Fred Veer as their feedback helped me continue when the whole project seemed unfeasible. Jackson Jewett from MIT should also be mentioned here, as he elaborated further on the technical side of the challenge, and made some suggestions that might prove to be promising follow-up research projects.

The sand moulds that were initially an important part of this research also proved problematic. The TU Delft does not have the tools to produce these, which meant we had to rely on an external manufacturer. Unexpected delays on their side meant that these moulds were not ready before P4, meant that wax printing had to be researched as an alternative. This took some weeks, and meant that some elements of the node design did not receive the attention they should have. Clearly, not enough time was scheduled to account for this.