Just Glass.

Development of a Topology Optimization Algorithm for a Mass-Optimized Cast Glass Component.

Reflection
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Point 1: Graduation Process

A. How are research and design related?

The project is related to the use of Topology Optimization techniques for the mass customization of structures made from cast glass. Research is an integral part of the process, since the project aspires to create a new tool for the design of these components and experiments with different trajectories in order to see how this can be done more efficiently. During this process, new criteria and limitations derive through the evaluation of the algorithm results and feed back to the optimization process.

Overall, this thesis serves as a continuation of the research already been done in TU Delft regarding structural glass as a novel material for constructions and particularly casting as a manufacturing process - which currently is only been used for the creation of small components. In this regard, it integrates limitations and remarks from previous theses and research experiments in order to further explore the potential of these designs and see how these can be combined effectively in one feasible form.

Specifically, this thesis aspires to create a new tool through coding that will fill the research gaps highlighted in the previous years. Given that glass, as a brittle material, has considerably different allowable limits regarding its tensile and compressive strength, it cannot be efficiently optimized using the existing commercial software, since it only evaluates one of the two constraints through the optimization process. This thesis aims to create a new tool that addresses this problem while at the same time integrates in the design the annealing and manufacturing criteria related to cast glass structures in order to ensure that the optimization will conclude to a form feasible to be manufactured.

B. How is the graduation topic positioned in the studio? What is the relationship between the methodical line of approach of the graduation studio (related research program of the department) and your chosen method?

Sustainable Structures Graduation Studio focuses its research in the creation of novel structures which, at the same time, will be resilient and efficient in terms of material use. The overall aim of the studio is to be able to respond to the future growing construction demand in a sustainable way. In this regard, use of structural glass as a building material is strongly beneficial, since it combines properties, such as durability and recyclability, with good structural performance.

Regarding the methodical line, the graduation studio seeks to deploy the advantages of using Topology Optimization and Artificial Intelligence tools for the exploration of forms that result to resource-efficient and resilient architectural structures. At the same time, the boundaries of glass designs regarding performance and form are being explored with prototypes and practical experiments. In this regard, it is evident that the methodology of the project is aligned with the general methodical line of the studio, since, firstly, it takes into consideration the feedback from the practical research related to cast glass as well as uses computational optimization methods in order to explore the forms that can be created and, based on that, extract the final design.

C. How did the research approach work out & did it lead to the results you aimed for?

During this thesis, the main principle was to divide the research trajectory into different parts in order to be able to compare the results obtained in each step with the results extracted from existing structural software or with outcome from literature studies using similar approaches. The aim was to be able to apply an efficient troubleshooting in each step and have a sound base for the next steps.

However, given that creating a design tool through coding was a completely new approach to the research that has already been done, it goes without saying that this was not a straightforward process. Drawbacks and limitations in the method derived through the process and new approaches were adopted at times. In this regard, it is evident that the thesis contributed to the existing research both with tangible and non-tangible results, since it managed to create a workable design tool which can be the base for further exploration and development, but also added to the existing knowledge with experimenting and comparing different methods and glass types and concluding to which ones are more efficient for this process.

D. Did you encounter moral/ethical issues or dilemmas during the process & how did you deal with these?

Overall, structural design serves a very important societal role since it seeks to provide safe and durable constructions for people, contributing to their sense of comfort with providing the necessary structural, thermal and visual qualities. In this regard, it goes without saying that exploring the potential of designing structures with a unique aesthetic result, such as glass transparency, while at the same time saving in terms of material and energy resources is a logical step in this direction.

It should be highlighted, though, that, given that this research trajectory is still at an early phase, these structures require a high level of customization in order to be achieved, rendering them more costly than the conventional building methods and therefore not directly applicable to the needs of mass production. However, It is strongly believed that, with further research in this direction, the material and energy cost can further be reduced whereas, the recent developments on the digital fabrication techniques ensure that creating the customized moulds needed for these applications will be easy and fast, enabling for time and cost efficient production of these components.

Point 2: Societal impact

A. To what extent are the results applicable in practice?

The algorithm takes into account a wide range of structural, manufacturing and annealing criteria in order to approximate at most the physical conditions and ensure as much as possible the feasibility of the final design. Additionally, small prototypes that have been developed during recent theses in TU Delft showcase that these complex forms can indeed be created in a considerably shorter time period.

However, before applying these forms into practice, more testing should be held in order to evaluate their structural integrity through prototyping and validate the results deriving from the simulation. Moreover, the way of connecting the components between them but also fixing them to the rest of the building volume should be explored in order to minimize the effect of the connectors to the overall transparency of the components.

B. To what extent has the projected innovation been achieved?

The innovation which was aspired to be achieved through the project is fulfilled to some extent. A workable version of the tool has been created and a result that has integrated efficiently a sufficient number of constraints has been successfully extracted. However, this tool can serve as a solid base for the development of even more complex structures by applying different load cases or integrating more manufacturing constraints in the algorithm. In this regard, it is evident that, although there is a successful outcome, there is a broad field for further exploration which is only restricted by the limit of the available time corresponding to the duration of this Master thesis.

C. What is the impact of the project on sustainability (people, planet, prosperity) & sustainable development?

The project refers to sustainable constructions in the sense that it occupies with the design of a mass-customized form that will save in terms of resources and energy used for its fabrication. Moreover - taking into consideration that glass is a material which can be fully recycled - these applications could also offer a nice alternative for using the glass waste which is increasing nowadays improving the sustainability of the application. However, it should be underlined that this exploration is out of the scope of this paper and requires further exploration.

D. What is the socio-cultural & ethical impact of the project (relation between the project and the wider social context)?

The benefits of this research follow the overall societal needs for the creation of adaptive and sustainable structures. The fast enlargement of the urban population as well as the ageing of the existing infrastructure in the upcoming years will contribute to an increase in the demands regarding the construction industry. Having this said, it is significantly important to be able to make efficient use of the material sources and enhance recycling and reuse in order to have environmentally sustainable solutions.

Moreover, if these forms are achieved, they could be applied in a wide range of different building envelopes, both new constructions but also existing ones. Particularly, this project, besides its novel character, aspires to show that these solutions can easily be integrated into existing building shells, offering different spatial qualities in existing constructions in order to enrich the potential of how these buildings can be reused and further attracting the people's attention to them.

E. How does the project affect architecture/the built environment?

It goes without saying that exploring this potential can create a new architectural language and enforce the change in mindset towards glass as a building material. It will showcase that different spatial qualities can be achieved while, at the same time, pushing the limits of engineering to a new level by encouraging its use in the form of cast self-standing components instead of float glass sheets. Glass could therefore compete with the conventional building materials, such as concrete or stainless steel, since it offers a relatively high compressive strength in combination with durability and recyclability and could possibly replace them in construction industry applications.