SECTION ACTIVE EXTRUDED GLASS STRUCTURAL ELEMENTS

AN EXPLORATIVE STUDY ON THEIR POTENTIAL FOR ARCHITECTURE

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REFLECTION

General

This thesis aims to design a meaningful addition to the toolkit of architectural glass by exploring the potential of section active extruded glass structural elements for architectural design.

In a wider perspective this project relates to Delft University of Technology's Glass & Transparency Research Group and the chairs of Structural Design & Mechanics and Architectural Glass. A number of structural glass projects have already been executed and many others are being worked on, each increasing in complexity. Examples of this are the glass bridge and glass swing. This thesis positions itself as an extension of this line. Where all previous projects were using vector active structural glass elements, this project complements those and tries to broaden the horizon by exploring the possibilities for section active structural glass elements.

This thesis also positions itself alongside the graduation thesis of Steven Engels. His thesis expands upon the knowledge of vector active tubular glass structures. Some research data and general thoughts could be shared and exchanged.

This thesis is generally conducted through researching by design. Methodically different design alternatives are compared and in such a way conclusions for the research are drawn. An example is the systems comparison. Design facilitates my research here. However also some input/starting parameters are needed for the designs and here you could argue it's designing by research. An example of this is the compressive strength test. Here research facilitates my design.

This thesis was partly made possible by our collaboration with glass manufacturing company SCHOTT. SCHOTT is interested in expanding their market and looking into new applications for their products. This has been beneficial for this thesis as they could support us with samples for testing, giving us a tour through the factory, and kindly answering our questions about the production process and possibilities. I would say the partnership with SCHOTT does have a small ethical issue attached to it. SCHOTT does not make the products that would be ideal for the final design of this thesis since they don't truly extrude their glass tubing. Their production process differs slightly, resulting in different advantages and possibilities. This is why with their current equipment they wouldn't be able to produce the final design, which is probably not what they were hoping for. However the partnership with them was still beneficial for us as we got to test extruded glass products and also still beneficial for them as their samples got tested for material properties not known by them yet.

Process

What I especially like in methodologies is a clear structure and the necessity of every part of the process. It should all fit together perfectly and cooperating towards answering the main question. I tried to achieve this in my thesis and I think I succeeded quite well in creating a solid story-line. My methodology kept me from sidewinding or forgetting aspects and also kept my eyes on the prize during this project with many different aspects: an answer to the research question. The workflow graphic I designed helped clarifying the relation between all parts.

I particularly like that I got to do so many different things: working from nothing to formulating the question, to compelling the current toolkit, to setting up a design vocabulary and decision making framework, to making a draft design from qualifying forces, to dimensioning the design from quantifying forces, to analysing the design, to designing and executing physical experiments, to visiting the factory, to selling the concept through renders, to comparing it to other systems, and to critically reflect upon it. I went through all phases of a design, from designing the question to questioning the design with all its small details. This is what especially appealed to me when I started and what kept my energy high throughout. It was incredibly educational in many different aspects. I chose this approach on purpose since I very much enjoy this wide perspective and I want to again thank Ate Snijder especially for giving me the space to do this.

Overview of most important tools per phase:

- Background study: literature review, finding reference projects
- Analytical: sketching, physical models
- Numerical: computer modelling, Python, Microsoft Excel, Rhino/Grasshopper, DIANA
- Experimental: experiments, visiting factory
- Presentation: InDesign, Lumion, AutoCAD

Also I feel like my assessment criteria helped me a lot in the methodology. They kept me taking into account all things part of the wide perspective I'd chosen through all aspects and scales: sustainability as well as structural performance, aesthetics as well as building sequence.

In general I think my planning was realistic and I was able to keep to it for most of the time. Obviously some things took longer than expected

and others a little less long, but as I came to understand: a planning is wrong already when it's only just drawn up and they are there to constantly adjust in decreasing amount of degrees throughout the process. What I could have done better is being more pro-active in organising the tests as early as possible. I underestimated the time it takes to design, schedule and prepare physical tests.

Looking back at my graduation plan I was able to do what I set out to except for some of this physical testing. A factor that did impact the planning for this majorly is the covid-19 crisis that emerged right before I finished the draft design. Although being disappointed in missing out on the learning experience of most of the physical tests, I translated the plans to research proposals in order to, despite the tests being cancelled, continue the line of thought and the overall structure of the thesis. This solution worked well for me and I could deepen some other aspects with the time gained.

I'd like to discuss one other hiccup in the project: to master the finite element analysis software DIANA was harder then expected. Arguably the interface of this software is not very friendly and only very few tutorials can be found. Performing the simulations took longer than expected. This time was partially made up by not having to simulate multiple rounds as I originally intended. The plan was to give the design first dimensions, than do a round of physical testing and simulate improvements to the design. As the physical tests couldn't be performed on the design anymore, I had more time to get a grip of the software. What helped me in this situation was Ate's availability and experience with the software. He was there to answer my questions when I would get stuck.

Continuing to other things that could have gone better on a personal level: sometimes I tend to get too far carried away in my own ideas, not taking into account an important feature/aspect that I didn't think of yet. What helped me here is talking to my mentors. They would hover over the project and ask the important questions before diving into detail when I sometimes was stuck in a particular scale. This has been very insightful for me at times and I hope to successfully apply this more in future projects.

One of my other pitfalls is getting stuck in computer-aided design. My mentors were also especially helpful in this too. After the first meeting I had with Ate about my graduation topic, he handed me a one of SHOTT's glass elliptical tubes. With the large box under my arms going back to the studio, I remember thinking that having a physical example would help greatly remembering the scale and getting a feel for the material and product. With Ate I also visited the SCHOTT factory which gave me a great insight into the production of their elements and an understanding of their possibilities. Another thing I did to get out of the computer is making analytical models to understand the structural behaviour of certain elements. This was as fun as it was insightful. Looking back I could have made use of this more.

Now that I'm talking about it I want to stress the crucial role of each of my mentors. They helped me not only with their great expertise regarding the contents of this thesis but also besides that I learned a lot from them. What struck me most about each of them is: James' critical attitude and experience in the field, Ate's curious attitude and open mind, Marcel's wide knowledge and down-to-earth perspective. Thank you. There are far more well-deserved thank-yous in the acknowledgements.

Societal impact

The results are to a reasonable extent applicable in practice. However the result of the thesis is not a market-ready product. It's rather a set of ideas valued on potential. This research will serve as a possible inspiration for further research and product development for others as well as myself.

The projected innovation has been achieved to a great extent I believe. The final rubric assessed the designed system as having high potential for architectural implementation, meeting expectations.

The project does contribute to sustainable development as the design is a modular and demountable façade system. Regardless of whether the designed system will be implemented in whatever shape or size, the design-thinking could still contribute to more sustainable designs of any kind in the future. Looking at if this design would be widely architecturally implemented it would still not directly have a huge impact sustainability-wise. This is because if you look at the building practice in general only a small percentage of buildings will use the designed elements. However, since the type of buildings this system would be used in is public and often exemplary, the sustainable approach could then stimulate other designers of the built environment to more sustainable designs.

When splitting the project in people, planet, and profit/prosperity, it aims to do the following:

- People: it aims to add positive experience value for users of buildings where the designed element would be used.
- Planet: glass is a very sustainable material and it aims for the system to be modular and re-usable.
- Profit/prosperity: It aims to inspire good products which can then be produced for actual designs.

The aim for the socio-cultural and ethical impact of this thesis is to further develop a contemporary and 'upcoming' architectural language which is enjoyed world-wide as it's featured in one-of-a-kind designs of mostly public buildings which are for everyone to experience.

In a wider social context glass buildings are perceived as barer/representation of the digital age. It's an ultramodern aesthetical language. This language needs to be updated and variety needs to be added to keep the experience special and keep improving. It helps society portray the zeitgeist if you will.

Conclusion

The thesis generally has turned out as I had expected. I am happy with the many different aspects that are involved in this explorative research. Up front I knew that this explorative research would likely not be conclusive on certain aspects of the answer, but I think I managed to answer the research question satisfactory. The thesis achieved what it set out to do. However despite that it feels a little unfulfilling stopping with this research now. Conducting the experiments set out as research proposals would make the final answer much clearer.

Looking back on my process it was exciting, very educational and a lot of work. In some regards I would want this project to continue for much longer as I still think there is so much to learn and like I mentioned this project doesn't feel completely finished yet. In other regards I will be thankful that it's over and I can then start a new project as I'm always full of energy to start new projects.

A huge thank you goes to everyone involved and making this process such a treat overall by adding new ideas, good advice, honest feedback, lasting positivity, and humour.