Product development of Hybrid Glass Blocks

Rethinking shape, manufacturing process and assembly system

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REFLECTIONS

The overall thesis research and design phase are reflected in this chapter. The following points are considered and elaborated briefly

- Relationship between research & design
- Relationship between graduation topic, studio topic, master track and master programme
- Research Method & approach
- Relationship between graduation project & wider social, professional & scientific rframework
- Ethical dilemmas faced during research

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RELATIONSHIP BETWEEN RESEARCH AND DESIGN

The current thesis aims at the product development of hybrid glass blocks by rethinking shape, manufacturing process, and assembly system. The design philosophy followed is based on the ‘Materials as design tool’ developed by Hanaa Dahy which suggests that the choice of the material can be used as the main driver for product development. The aspects of the study are Material selection, efficient production technology, design and validation. The initial two aspects need thorough research that generates guidelines for the design development.

The research first explores the potential of glass as a high-performance material in the building industry. This enables us to look at the glass on a microscopic level by researching its classifications, material compositions, applications, properties, and essentially limitations. Furthermore, the current 3D glass blocks (hollow, solid, and hybrid) were thoroughly examined in terms of manufacturing, assembly system, application, and performance. Various design solutions for improving structural and thermal performance were investigated, which assisted concept development. The conclusions derived from the existing research aid to formulate the design guidelines for the development of hybrid glass blocks. For practicality in the design process, a case study was selected on which the final design output was implemented. Based on current research material, various methodologies were investigated for numerical validation of structural and thermal performance. The product development approach, which was defined during the research phase, was used to evaluate the developed design concepts. Thus, the research and design were two interconnected parts of this thesis.

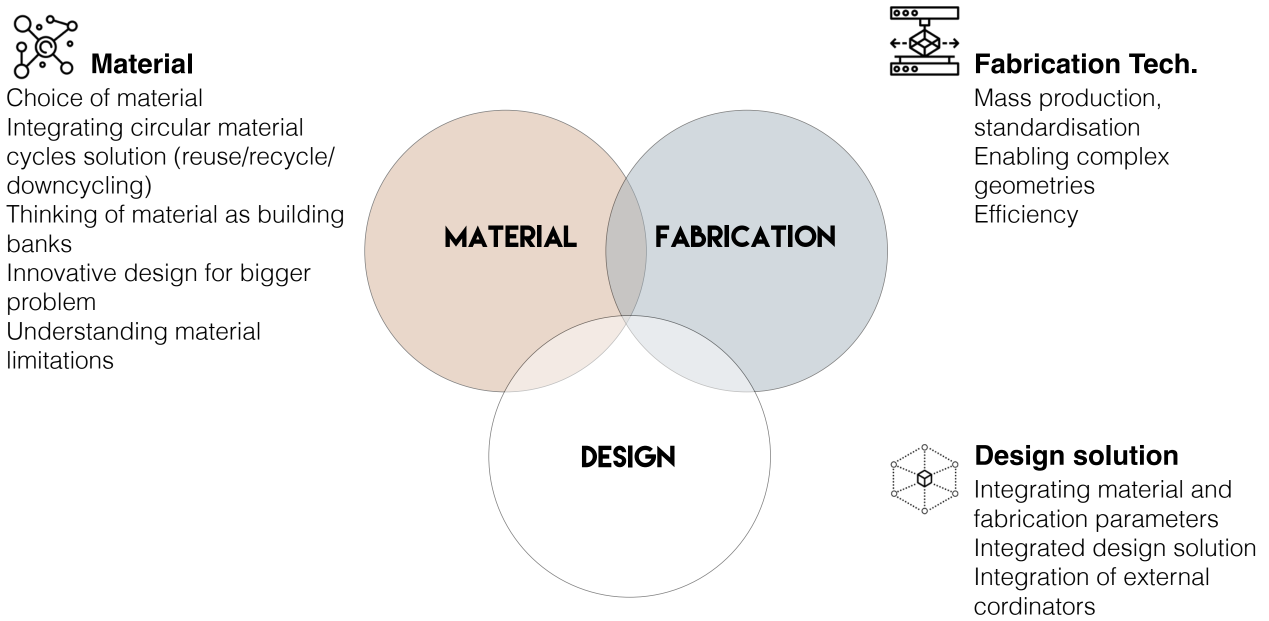

Figure 1.1: Materials as design tools adapted from (Dahy. H 2020)

2

RELATIONSHIP BETWEEN GRADUATION TOPIC, THE STUDIO TOPIC, MASTER TRACK, AND MASTER PROGRAMME

The Sustainable design graduation studio focuses on the development of innovative design technologies within the built environment. The material ‘Glass’ is widely used in the building industry due to its distinctive optical, thermal, and structural properties in various forms, for example, partitions, glazing panels, glass blocks, etc. The existing glass block systems offer either optimal thermal performance or structural stability but neither a combination of both. ‘Hybrid glass block’ is an innovative concept that endeavours to bridge the gap between the solid glass blocks’ thermal performance and hollow glass blocks’ load-bearing capacity.

Since this is a recently emerged concept, the research focuses on defining design guidelines, manufacturing methodology, assembly system, and numerical validation along with the freedom of exploration of various design concepts in a realistic case study. This research resulted in an energy-compliant sustainable glass product for application in the building industry. On a broader level, the focus is on structural design and climate design, which are two branches of the Building Technology track. The output of this thesis is the design of a hybrid glass block with its potential application and integration on a facade system with goals of sustainability and circularity. Overall it is a perfect integration of architecture and engineering streams that has an emphasis on the design of innovative and sustainable building components. The research topic is also related to the ongoing research on Sustainable structures in TU Delft.

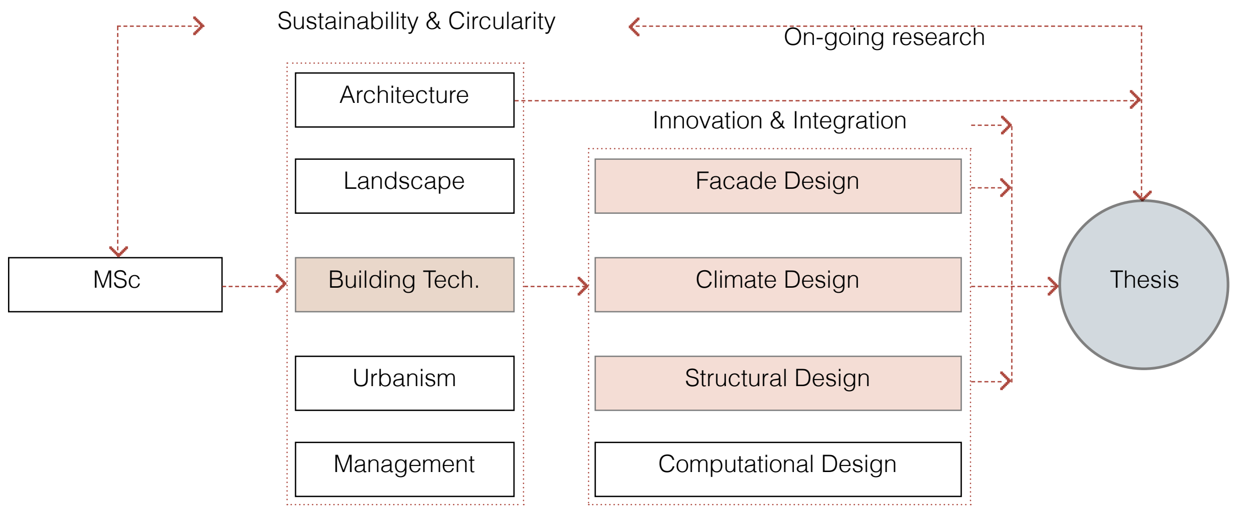

Figure 1.2: Interrelation between MSc course, track and graduation studio

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RESEARCH METHOD AND APPROACH CHOSEN IN RELATION TO THE GRADUATION STUDIO METHODICAL LINE OF INQUIRY

The product development of Hybrid glass block is categorised into five phases;

Phase 1: Literature study and theoretical framework
The first section of the thesis relied on evaluating current literature, notably on glass and glass block technology. Material qualities, compositions, manufacturing procedures, geometries, assembly systems, configurations, and challenges were thoroughly investigated. Various design approaches were also investigated to improve the structural and thermal performance of the current glass blocks. A case study from the Maastricht Academy of Arts (1993) was identified and studied to offer a realistic scenario for developing structural, thermal, and assembly parameters. To develop the design guidelines, the European building codes were reviewed. This phase concluded with a clear set of design goals, guidelines, and concept development methodologies.

Phase 2: Design Development
During this phase, different design approaches based on form, assembly mechanism, and optical quality were investigated. To improve structural performance, a comprehensive investigation of alternative geometries and cross-section thicknesses was carried out and assessed using first-hand calculations. A product development methodology was implemented for the evaluation of these concepts. Every design component was reviewed based on its specified criteria, and the selected alternatives were further appraised based on the design goals and standards. This phase concluded with a final design concept.

(My ear and jaw difficulties were an interesting factor that helped me come up with the final design concept. I noticed that the disc between the jaw and the ear bone is becoming thinner as a result of poor teeth alignment owing to inappropriate jaw movement. This led me to create the dry-stacked interlocking assembly concept. The two glass blocks cannot be kept in direct contact as there is a considerable risk of stress development along the contact surface and when the load is applied they will slide due to friction. To transmit the stresses and decrease friction, an interlayer similar to the ear disc is necessary, as is an interlocking element to position the blocks together. The final cross-section is inspired by human anatomy and mimics the shape of a human bone.)

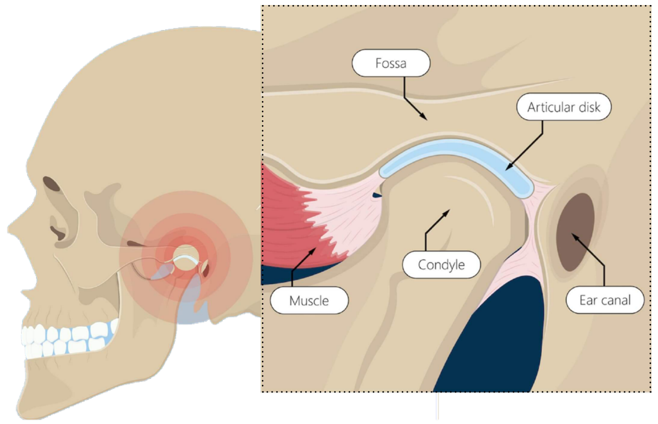
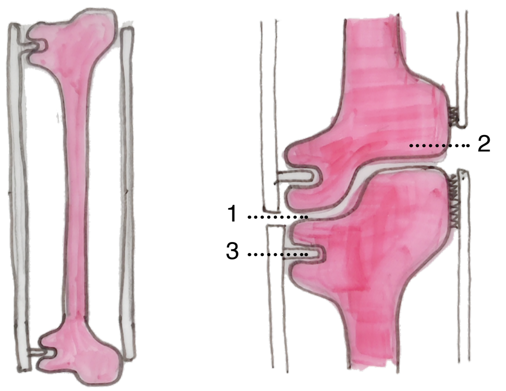


Figure 1.3: TMJ Dysfunction (Eric Davis Dental)



1. Interlayer similar to articular disc
2. Alignment detail
3. Condyle detail

Figure 1.4: First Concept Sketch

Phase 3: Design Refinement
The final design concept was refined in terms of manufacturing and constructability. Based on the results of the research phase, a step-by-step manufacturing methodology was investigated. The inter-relationship and impact of the manufacturing process on the design were addressed, resulting in design improvement. Furthermore, a dry-stacked interlocking assembly system was investigated in terms of its connection to the unit as well as system level, with the definite direction of reversibility and ease of assembly being evaluated. This phase is completed with the final design being refined depending on the manufacturing process and constructability. At this stage, many risk scenarios were explored to include them in the design. The initial plan was to prototype the chosen designs and further assess them, however, because of time and material constraints, it was decided to detail just one final design (and if time permits can prototype it in the glass lab)

Phase 4: Design Evaluation
This phase concentrated on a thorough examination of the final design using the numerical approach of validation. Hand calculations were used to assess the glass block's thermal and structural performance. Several strategies are proposed for validating the design through experimentation.

Phase 5: Design Application & Conclusion
In this phase, the final design is detailed, and the design output is delivered in the form of facade drawings, installation procedures, and risk scenarios.

A systematic approach for design development is followed throughout the whole thesis which was built on the conclusive research study. The research output is the design of a hybrid glass block, its design and engineering guidelines, and its manufacturing process and assembly system with numerical validation and improvement recommendations.

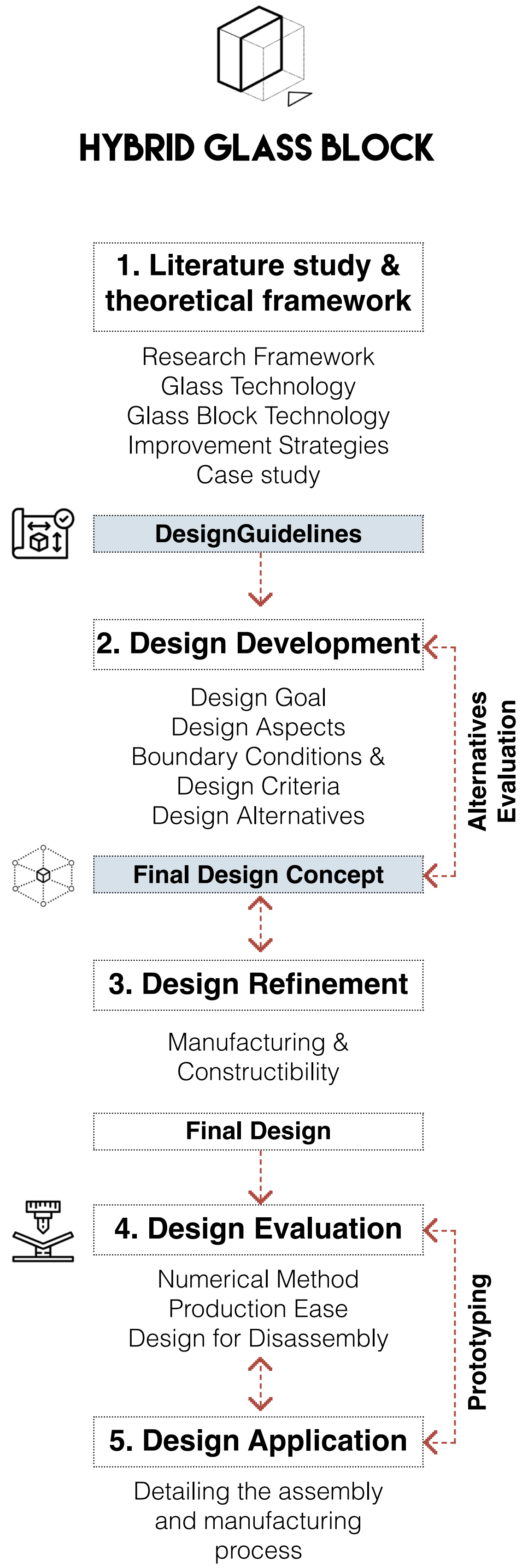


Figure 1.5: Reseacrh Method & Approach

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RELATIONSHIP BETWEEN THE GRADUATION PROJECT AND THE WIDER SOCIAL, PROFESSIONAL AND SCIENTIFIC FRAMEWORK

In the last two decades, the building industry is slowly evolving and transitioning toward designing and creating sustainable environments to meet the global challenges of climate change and scarcity of natural resources. The focus is aligned toward adaptable building systems that are energy efficient and have a low carbon footprint. This simply means that every product that goes into the making of the building environment should be energy-efficient, sustainable, and have less carbon footprint. The focus is not only limited to a system level but also a unit level.

“The use of glass in architecture has never been more popular, but the global drive to increase the energy efficiency and sustainability of buildings is posing a challenge to architects, engineers, and manufacturers alike” (James O’ Callaghan, 2020) To ensure the future of architectural glass it is important to push the boundaries of products that provide innovative solutions to meet these global challenges. A lot of architectural projects are increasingly using glass in many innovative ways and this will significantly increase in the future since it is sustainable.

The current research aims at developing a glass block that adheres to energy efficiency and sustainability goals by unveiling its true potential.

The design focuses on two main aspects,
(i) increasing the thermal and structural potential of 3-dimensional glass components
(ii) a dry-stacked interlocking assembly system that is modular and circular. To increase the thermal performance of the glass additional e-coatings are applied on the surface which makes them undesirable for recycling at the end of the life cycle.

An attempt is made in this research to focus on designing a maximum recyclable glass component by eliminating the application of e-coatings and incorporating air cavities within the design. Furthermore, an interesting approach to the dry-stacked interlocking assembly system is explored by eliminating the use of adhesives and designing the system for disassembly. This allows the ease of replaceability and reusability of the glass components. This will completely change the way how glass is perceived in society. The methodology in which the potential of the glass has been explored relates to the scientific curiosity of developing innovative glass structures that are energy giants and sustainable.

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ETHICAL ISSUES AND DILEMMAS WHILE DOING THE RESEARCH, ELABORATING THE DESIGN AND POTENTIAL APPLICATIONS OF THE RESULTS IN PRACTICE

The application of glass in architecture is presumably owing to its great optical characteristics; however, structural glass has lately become increasingly widespread, which may or may not have equivalent optical quality. It was established during the research phase that increasing cross-section thickness and cavity width improves structural and thermal performance. However, the application of these strategies has a significant impact on transparency. As an architect, I like the transparency that glass offers to the design; nevertheless, as a young building technologist, it is my moral obligation to prioritise the performance of the glass block. When developing the design assessment criteria, it was determined to prioritise performance above transparency. As a result, the developed product is significantly better suited to achieving high building performance while overlooking optical quality.

The design evaluation process is particular to the initial guidelines and criteria developed. Based on this, many potential concepts were designed, however, only one was selected based on its suitability to the selected case study and design goals. Other design approaches offer room for improvement if the design and assessment criteria are altered. As a result, the final design solution is specific to the case study and is applicable in practice when performance and sustainability criteria must be satisfied.

The purpose of this research is to validate the structural and thermal performance of the developed hybrid glass block. A numerical method of validation is being investigated for this. The design focuses on the dry-stacked assembly system for cast glass blocks, which is still under development and has yet to be thoroughly verified. Thus, structural calculations are performed only based on the current research and safety assumptions. The preceding thesis on enhancing the thermal performance of the cast glass block presents values for various cavity widths and glass thicknesses. These numbers, however, are specific on a unit level and are determined by software simulation. These thermal performance data serve as the foundation for the current design. For a dry-stacked glass assembly system, it is rather essential to generate values on a system level. The initial intent was to validate various design concepts through prototyping and experimentation. However, a novel system that is yet to be completely developed, requires a lot of time and resources for experimental validation.

Lastly, it would be beneficial to involve the production and assembly system specialists in the design process to get a more practical approach to design development.

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