Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: Building Technology

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	Twinkle Nathani
Student number	5069041

Studio		
Name / Theme	Building Technology Sustainable Design Graduation Studio	
Main mentor	Faidra Oikonomopoulou	Researcher, Structural Design and Mechanics
Second mentor	Martin Tenpierik	Associate Professor, Building Physics
Argumentation of choice of the studio	N/A	

Graduation project	
Title of the graduation project	Hybrid Glass Block; Load bearing and thermally sound glass block
Goal	
Location:	Amsterdam, The Netherlands
The posed problem,	Glass's use as a building material dates to ancient times, one of the first appearances in Roman bath-houses, where it was used in windows to trap the heat inside. Since then, it has been extensively used in various forms in the built environment. The reason behind its wide application is its innate transparency, which allows for unhindered light in a space and visual connectivity between the inside and outside. This quality led to the development of hollow glass blocks during the industrial revolution. These blocks are durable, fire-resistant, exhibit heat resistance, and sound deadening properties. Since then, technologies in glass have constantly been developing to adapt to the changing trends. In recent years, new explorations have begun to uncover the structural potential of glass. It is no longer just a cladding material but is also being used for load-bearing applications due to its high compressive strength. One such fine example is cast glass bricks in Crystal House, Amsterdam. The volumetric cast glass components minimize the risk of failure due to buckling (and thus due to the introduction of peak tensile stresses). Thus, they are highly stable as they take full advantage of the high compressive strength of glass.

	One of the most significant drawbacks of cast glass bricks' current systems is the unsatisfactory thermal performance due to the absence of a cavity and the thick cross-section, which acts as one thick single glazed unit. On the other hand, Hollow glass blocks are non-load-bearing due to their thin cross-section which results in internal buckling under a compressive load and thus, the system is susceptible to failure. Therefore, this research aims to develop a Hybrid block that can exhibit structural strength and meet modern energy criteria. The objective is to bridge the gap between solid glass brick's stability and the hollow block's efficiency.
research questions	The main objective of the research is to contribute towards the innovation of Glass Structures by developing a new hybrid block that bears advantages of both hollow and solid glass blocks, namely a satisfactory insulating and load-bearing performance and can meet the challenges of the modern time. Thus, the main research question formulated is: **"In what ways can we develop a Hybrid glass block that exhibits a combination of structural and thermal properties and can be efficiently manufactured?"** The sub-research questions formulated are: 1. What are the main engineering criteria and challenges involved in the development of a Hybrid block? 2. Which are the main factors influencing the thermal performance of the system? What methods can be employed to increase the efficiency and what are the advantages and limitations of these methods? 3. Which are the main factors affecting the manufacturing process of these blocks? What methods can be employed and what are the advantages and limitations of these methods? 4. What are the main factors affecting the build-ability of Hybrid blocks in a structure?
design assignment in which these result.	The research will lead to designing, experimenting and validating different hybrid blocks and engineering its fabrication and assembly in accordance with the design criteria.

Process

Method description

The process of development of the novel hybrid glass block is divided into four phases:

-Phase 1: literature research and data review,
-Phase 2: design and analysis
-Phase 3: manufacturing and constructability
-Phase 4: conclusions and reflections.

Phase 1
The first phase primarily focuses on studying various books, research papers, journals, and websites relevant to the chosen topic and developing a thorough understanding of the problem in question. This phase serves as the base for the next steps in the research framework. Therefore, an in-depth study will be conducted on hollow and solid glass blocks, their distinguished properties, manufacturing and installation processes. A case study of Ports 1961, Shanghai building was selected and analyzed to provide a realistic scenario in defining structural, thermal properties, and assembly criteria. These helped in defining preliminary design guidelines. Upon referring to building codes from the region of selected case-study and Eurocodes, the guidelines were refined into final design criteria. Based on the said criteria, concepts for improving structural and thermal performances were also explored and evaluated to suggest the most probable ideas to be taken forward in the next phases.

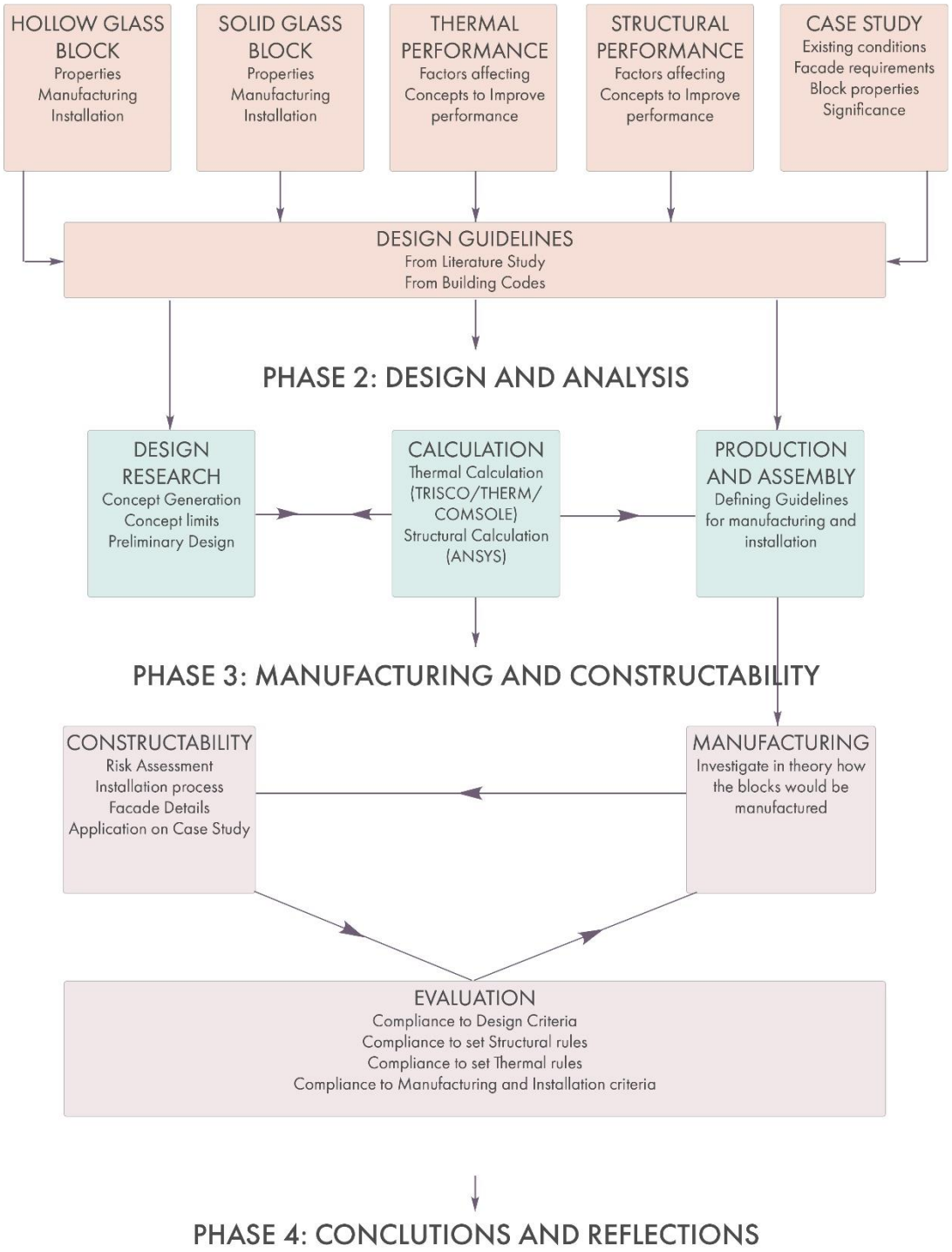
Phase 2
In the second phase of design and analysis, design solutions for the hybrid block were investigated in detail. The first design ideas were evaluated on the criteria mentioned in the design guidelines. The design was then developed from the chosen ones by exploring methods to make the block resistant to heat. This was verified using the software TRISCO. Various alternatives of different sizes, cavity widths, and insulative material were developed and analyzed for their thermal transmittance values. These options were then evaluated on their ease of manufacture, optical properties, and recyclability to shortlist the best ones. A risk analysis was carried out to inform the design of the structural process. The analysis identified scenarios that can impact the performance of the system and the measures for those were considered in the design process. The chosen options at the end of thermal analysis were then optimized to carry the loads based on the materials' parameters and constraints. Various connection options were studied and evaluated to design the final connection system for the block. This phase was a continuous back and forth process, which ended in two designs that meet the set rules. Further, the manufacturing and installation process was investigated for the new block, and the designs were evaluated based on the parameters set for this procedure.

Phase 3
The third phase largely focuses on feasibility study of the developed prototypes by it's application in the case study building Ports 1961, Shanghai. Initially, this phase was set out for verifying the final designs through prototyping but due to the current unprecedented circumstances with no access to the faculty labs, it was not possible to develop, experiment, and test prototypes. Therefore, the manufacturing and assembly of the blocks were investigated in theory. A set of guidelines were developed for the preparation and procedures required for the manufacturing and assembly of these units on site.

Phase 4
The fourth phase finally focuses on summarizing details about the hybrid block; its properties, engineering, and installation. The research is concluded with the evaluation of the method, and recommendations are provided to develop the technology further.

METHODOLOGY

PHASE 1: LITERATURE STUDY AND DATA REVIEW



Literature and general practical preference

The following documents, journals, papers and websites will be referred:

Beall, C. (1988). How does glass block perform? The Aberdeen Group

Beccali, M., Corrao, R., Ciulla, G., & Lo Brano, V. (2012). Improving the thermal performance of the transparent building envelope: finite element analysis of possible techniques to reduce the U-value of the glassblocks

Binarti, F., D. Istiadji, A., Satwiko, P., & T. Iswanto, P. (2014). Raising High Energy Performance Glass Block from Waste Glasses with Cavity and Interlayer In: Hakansson A., Höjer M., Howlett R., Jain L. (eds) Sustainability in Energy and Buildings. Smart Innovation, Systems and Technologies, vol 22. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-36645-1_15

Carlen Glass Merchants Ltd. 2021. Clear Float Glass | Extra Strength, Highest Quality, Stylish - Carlen Glass. [online] Available at: <http://www.carlenglass.ie/services/clear-float-glass/>

De Vis, K., Jacobs, P., Caen, J., & Janssens, K. (2010). The Use of Glass Bricks in Architecture in the 19th and 20th Centuries: A Case Study

Fagan, E. (2015). BBuilding Walls of Light: The development of glass block and its influence on American architecture in the 1930s (Master of Science). Columbia University.

Haldimann,, M., Luible, A. and Overend, M., 2008. Structural Use of Glass. Zurich: International Association for Bridge and Structural Engineering IABSE, pp.143-150.

Kuznik, F., Catalina, T., Virgone, J., & Johannes, K. (2014). Study on the melting and solidification in a glass block containing a phase change material. Mathematical Modeling in Civil Engineering, 2010, pp.37. <hal-01016436>

Liu, M. (2019). Suitable Façade Systems for different climate of China. Presentation, Delft, Netherlands

Manz, H., Egolf, P., Suter, P., & Goetzberger, A. (1997). TIM-PCM External wall system for solar space heating and daylighting. Solar Energy, 61(6). doi: https://doi.org/10.1016/S0038-092X(97)00086-8
Neumann, D., G. Stockbridge, J., & S. Kaskel, B. (2000). Glass Block.

MaterialDistrict. 2021. Conturax - MaterialDistrict. [online] Available at: <https://materialdistrict.com/material/conturax/>

Mills, G., n.d. Understanding Glass - Types of Glass and Glass Fabrication Processes. [online] Thomasnet.com. Available at: <https://www.thomasnet.com/articles/plant-facility-equipment/types-of-glass/>

Oikonomopolou, Faidra. Unveiling the third dimension of glass. A+BE | Architecture and the Built Environment, [S.l.], n. 9, p. 1-352, nov. 2019. ISSN 2214-7233. Available at: https://journals.open.tudelft.nl/abe/article/view/4088. Date accessed: 2 dec. 2020. doi: https://doi.org/10.7480/abe.2019.9.4088.

Oikonomopoulou, F., Veer, F., Nijsse, R., & Baardolf, K. (2014). A completely transparent, adhesively bonded soda-lime glass block masonry system. Journal Of Facade Design And Engineering. doi: 10.3233/FDE-150021
Oikonomopoulou, F., Bristogianni, T., Veer, F., & Nijsse, R. (2017). The construction of the Crystal Houses façade: challenges and innovations

Optical Glass House / Hiroshi Nakamura & NAP" 13 Sep 2020. ArchDaily <https://www.archdaily.com/885674/optical-glass-house-hiroshi-nakamura-and-nap> ISSN 0719-8884

Overend, M., 2012. ICE Manual of Structural Design. ICE Publishing, pp.399 - 412.

Pittsburgh Corning Corporation. (2007). Designing with Glass Block: Abundant Applications Provide Practical, Aesthetic and Green Solutions. Architectural Record. Retrieved from https://continuingeducation.bnpmedia.com/article_print.php?L=99&C=361
Pittsburgh Corning Corporation. (2010). Architectural Glass Block Products

Seves. Installation Guide. Retrieved from http://www.sevesglassblock.com
1919/16HTI WAVE. Retrieved from https://www.sevesglassblock.com/product/191916-hti-wave/

Cao, L. (2020). Glamorous Glass Bricks Are Booming – Again. Retrieved from https://www.archdaily.com/941686/glamorous-glass-bricks-are-booming-nil-again

Castro, F. (2015). Ports 1961 Shanghai Façade / UUfie. Retrieved 4 January 2021, from https://www.archdaily.com/769961/ports-1961-shanghai-facade-uufie

GRIDLOCK. Retrieved 4 January 2021, from https://extechinc.com/gridlock-mortarless-glass-block/

HUGHES, D. (2021). BRICKS DECODED: THE RETURN OF GLASS BLOCKS. Retrieved 4 January 2021, from https://www.yellowtrace.com.au/return-of-glass-blocks-glass-bricks/
Ports 1961. (2015). Retrieved 4 January 2021, from https://www.tess.fr/en/projet/ports-1961

Solid Glass: Vistabrik & Vetropieno. Retrieved 4 January 2021, from https://www.sevesglassblock.com/vistabrik-and-vetropieno/

Sterling-studios.com. 2021. Cast Glass, Sample 27472-B, Sterling Studios. [online] Available at: <https://www.sterling-studios.com/finishes/glass/cast-glass/27472-B>

Wanda, L., 2015. MIT's Neri Oxman on the True Beauty of 3D Printed Glass. [online] Architect. Available at: <https://www.architectmagazine.com/technology/mits-neri-oxman-on-the-true-beauty-of-3d-printed-glass_o>

Reflection

Relevance

Relevance between Graduation topic and Master Studio

The sustainable design graduation studio aims for innovative design technologies in the built environment. The material glass is widely used in the building industry for its unique optical properties in various forms, for example, glazing units, glass blocks, etc. The present glass block systems used in building facades have limited potential as they offer either structural stability or optimal thermal performance. With the increasing demand for energy-efficient constructions, it is important to explore the possibilities of making glass blocks energy compliant. Therefore, this research focuses on developing a novel glass block system that responds well mechanically and adheres to the new energy criteria. This system in an examination is new, and not many experiments have been done in this area. This makes studying and experimenting with this technique challenging but gives a great amount of freedom in exploring new ideas. A thorough understanding of the system in a realistic environment is possible in combination with a case study. The topic is related to the ongoing research at TU Delft on sustainable structures. The focus is on Structural and Climate design, two sub-directions of the Building Technology track. The hybrid glass assembly under consideration is self-bearing; therefore, it will significantly affect the structural system of the applied building. The thermal performance of the entire system will also serve as valuable inputs to evolve this technology further.

Scientific and Social Relevance

In recent years, the world is slowly transitioning towards creating robust environments due to rapid climate change, scarcity of natural resources, and depletion of fossil fuels. The infrastructure needs to be adaptive more than ever, have less carbon footprint, and be compliant with the energy regulations. While we have developed many building systems (smart façade's, EWF for ventilation, etc.) that can help, it is also important to investigate the unit level (the size of a brick) for overall impact. Glass and energy efficiency has been an oxymoron for a long. A lot of research has been conducted to make glass buildings use less energy, and we have achieved it by applying coatings, making them non-recyclable. Thus, this thesis aims at developing a block of glass that adheres to the energy regulations by changing the design and alternating the way we perceive glass.

The current research can function as a basis on how 3-dimensional structural glass components can be made more energy-efficient. This study provides fundamental insight into various methods explored in developing the novel technique, which can further lead to more energy-compliant glass structures. Hence, this research provides a scientific relevance as it illustrates possibilities of glass in structural configuration and is also socially relevant as it will improve the portrayal of glass structures in being energy giants.

Time Planning

The time planning for the research has been tactically spread between the five presentations.

The first phase lies between P1 and P2 focuses on literature study and data collection. A case study will also be selected for a more realistic approach and this will end into the development of final design criteria. The second phase lies between P2 and P3 is the design and analysis phase. This will be directed towards developing the block and testing it computationally on software for thermal verification. The third phase between P3 and P4 will focus on fabrication and assembly of the design in real world conditions. The fourth and final phase between P4 and P5 is marked for refinement of the research and final report will be produced at the end.