Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

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	**Nils Wulfsen**
Student number	4561090

Studio		
Name / Theme	Building Technology, Transparent structures / Glass Design	
Main mentor	Dr. Ir. Faidra Oikonomopoulou	Chair Structural Design & Mechanics
Second mentor	Dr. Ing. Marcel Bilow	Chair Building Product Innovation: Product Development, Production Technologies, Façade Design
Argumentation of choice of the studio	New innovations continually unlock possibilities in both structural and architectural applications. This studio stands out as a leader in pioneering these advancements, challenging norms by creating building components considered implausible with glass. I am drawn to the prospect of contributing to tomorrow's glass designs, envisioning a unique application or method that seamlessly blends structural integrity with aesthetic appeal.	

Graduation project	
Title of the graduation project	Free-form transparency in a self-supporting hybrid facade panel, a design assessment between concrete and cast glass.
Goal	
Location:	The case study is a self-supporting facade of a retail store from Bulgari and designed by MVRDV, located in Kuala Lumpur (Malaysia).
The posed problem,	**Main Problem** The complete transparency of facades can have drawbacks. Occupants may experience issues such as glare, heat gain, and the need for extensive sun shading systems due to the size of the glass facades. Furthermore, fully glass buildings often lack aesthetic tension and architectural innovation due there monotony. The potential innovation in hybrid elements, blending transparency with opacity, faces challenges due to the current restrictions on design freedom for transparent facades. A critical gap exists in research focusing on connections for hybrid systems, hindering the realization of versatile and aesthetically pleasing building components.

	Sub Problem Structural: Due the silica-alkalis reaction (ASR) between glass and concrete, causing internal pressure, can lead to cracking, deterioration and reduced structural durability. Manufacturing: The complex 3D geometries for glass elements occurring in the design phase, which gives the architects its design freedom, are limited by the manufacturing and production of cast glass. Sustainable: There is a lack in design for disassembly for hybrid elements with embedded connections due no provision in recycling the two materials separately.
research questions and	**Mainquestion** In what way can we design a self-supporting hybrid facade panel, consisting of a transparent and opaque material? An experimantal study for a design approach towards a hybrid connection between cast glass and concrete. **Subquestions** An comparetive study in terms of Composition, Fabrication, Sustainabiliy and Design limits for the materials glass and concrete: • What is the best Glass and Concrete composition for a hybrid connection? • What is the most suitable fabrication and manufacturing method to make a glass-concrete facade panel according the best usable composition? • What are the design limits for a hybrid facade panel looking into connection, curvature and freeform geometry? • What are the main considerations design for disassembly possible for a casted hyrbid connection?
design assignment in which these result.	The aim is create design boundaries for a self-supporting facade allowing transparency in a free-form, especially in concrete and cast glass hybrid element. This is done by making experimental prototypes and eliminating design options by research through design.

Process

Method description

The method of the thesis is divided into 5 parts:

1) Literature review

Two investigations are conducted. Firstly, the focus is on understanding the fundamental principles of a hybrid components and choosing a transparent and opaque material (by making a matrix of all various materials possible) to pick the most suitable materials for my research. The second investigations is about the general information of both selected materials and to make a comparison and selection in composition, fabrication method and production processes for the second part of this thesis.
Besides the more literature research of the two investigations in this part also references projects will be investigated to gain insights in real-life applications with one of them as a casestudy project. For the casestudy multiple external meetings will take place to gain more insight and know every detail of this project. This helps understanding the way of thinking and designing principles for my own facade panel.

2) Design & Experiment framework

The comparative study serves as design and experiment guidelines for this phase. The two hybrid materials are chosen with there associated fabrication and production method. Now the set up needs to be made for the research & design phase. The design criteria are formulated as guidelines for the research, determining what will be tested. A framework is established for the experimental research on the prototypes, defining both the design boundaries and the setup for structural testing.

3) Research through design

This part consists of making the different designs and prototypes. By making prototypes, which also assess the manufacturability, research can be done by looking into the various designs and their possibilities and limitations. Different hybrid connections will be experimentally tested in the lab to assess structural performance.

4) Desing refinement

All the tests and design research is done and qualitative results are calculated or tested. To arrive at a final design concept, considerations are made regarding the advantages and limitations. The ultimate design is thoroughly developed and detailed into a cohesive whole. This process also involves a close examination of the manufacturing and assembly steps. Once the entire concept is finalized, the final prototype is created. This prototype is intended to depict how the design should appear in real-life applications.

5) Evaluation & Conclusion

After making the final prototypes and all the testing results are done, a full evaluation will be made. There will be an comparison assessment with the casestudy.
In the conclusion, all aspects are summarized and the feasibility and potential real-life applications are examined. Recommendations are provided to support further research in hybrid panels, all limitations are discussed, and the research demonstrates the potential of the study.

Literature and general practical references

The literature research consists of 4 parts. For each part different references are consulted. The four parts consists of 1) Hybrid panel information 2) General glass information 3) General Concrete information and 4) Case study. The references and sources you see below are the most important references which I already used.

1) Hybrid panel information.

The references off the reference projects are excluded in this list.

[1] Gilabert, F., Van Tittelboom, K., Tsangouri, E., Van Hemelrijck, D., De Belie, N., & Van Paepegem, W. (2017). Determination of strength and debonding energy of a glass-concrete interface for encapsulation-based self-healing concrete. Cement and Concrete Composites, 79, 76–93. https://doi.org/10.1016/j.cemconcomp.2017.01.011

[2] Cao, H., & Evans, A. (1989). An experimental study of the fracture resistance of bimaterial interfaces. Mechanics of Materials, 7(4), 295–304. https://doi.org/10.1016/0167-6636(89)90020-3

[3] Zhou, J., Huang, M., Sagnang, F., & Soboyejo, W. O. (2006). Interfacial failure of a dental cement composite bonded to glass substrates. Dental Materials, 22(6), 585–591. https://doi.org/10.1016/j.dental.2005.06.007

[4] Barou, L., Oikonomopoulou, F., Bristogianni, T., Veer, F. A., & Nijsse, R. (2021). Fill-In-Glass Restoration: Exploring Issues Of Compatibility For The Case Of Schaesberg Castle . In P. Roca, L. Pelà , & C. Molins (Eds.), 12th International Conference on Structural Analysis of Historical Constructions : SAHC 2021, Online event, 29 Sep - 1 Oct, 2021 (pp. 1571-1582). International Centre for Numerical Methods in Engineering, CIMNE. http://congress.cimne.com/SAHC2020/frontal/doc/Ebook_SAHC2020.pdf

[5] Mohammadi, A., Ghiasvand, E., & Nili, M. (2020). Relation between mechanical properties of concrete and alkali-silica reaction (ASR); a review. Construction and Building Materials, 258, 119567. https://doi.org/10.1016/j.conbuildmat.2020.119567

2) General glass information

[1] Oikonomopoulou, F. (2019). Unveiling the third dimension of glass: solid cast glass components and assemblies for structural applications. A+BE: Architecture and the Built Environment, 9, 1–352. https://doi.org/10.7480/abe.2019.9.4088

[2] Oikonomopoulou, F., Bristogianni, T., Barou, L., Veer, F., & Nijsse, R. (2018). The potential of cast glass in structural applications. Lessons learned from large-scale castings and state-of-the art load-bearing cast glass in architecture. Journal of Building Engineering, 20, 213–234. https://doi.org/10.1016/j.jobe.2018.07.014

[3] Giesecke, R., & Dillenburger, B. (2022). Three-dimensionally (3D) printed sand molds for custom glass parts. Glass Structures & Engineering, 7(2), 231–251. https://doi.org/10.1007/s40940-022-00176-y

[4] Oikonomopoulou, F., Bhatia, I. S., Damen, W., Van Der Weijst, F., & Bristogianni, T. (2020). Rethinking the cast glass mould. DOAJ (DOAJ: Directory of Open Access Journals). https://doi.org/10.7480/cgc.7.4662

[5] Bristogianni, T. (2022). Anatomy of cast glass: The effect of casting parameters on the meso-level structure and macro-level structural performance of cast glass components [Delft University of Technology]. https://doi.org/10.4233/UUID:8A12D0B1FEE2-47F1-9FA9-FF56AB2E84C1

[6] Bristogianni, T., Veer, F. A., Snijder, A., Nijsse, R., Delft, T., & Delft, T. (2017). Production and Testing of Kiln-cast Glass Components for an Interlocking, Dry-assembled Transparent Bridge. 7.

[7] Nijsse, R. (2003). Glass in structures: Elements, concepts, designs. Birkhauser-Publishers for Architecture.

3) General concrete information

[1] Xu, Y., & Jin, R. (2022). Multi-functional concrete with recycled aggregates, 267-288. Woodhead Publishing.

[2] CQ_254_Winter2015 (zie bronnen)

[3] Guzlena, S.; Sakale, G. (2020). Self-healing of glass fibre reinforced concrete (GRC) and polymer glass fibre reinforced concrete (PGRC) using crystalline admixtures. Construction and Building Materials, (), 120963–. doi:10.1016/j.conbuildmat.2020.120963

[4] Bartoš, P. (2017). Glassfibre Reinforced Concrete: a review. IOP Conference Series: Materials Science and Engineering, 246, 012002. https://doi.org/10.1088/1757-899x/246/1/012002

[1] Akhnoukh, A., & Buckhalter, C. (2021). Ultra-high-performance concrete: constituents, mechanical properties, applications and current challenges. Case Studies in Construction Materials, 15, e00559. https://doi.org/10.1016/j.cscm.2021.e00559

[6] Constantinescu, H., Gherman, O., Negruțiu, C., & Ioan, S. P. (2016). Mechanical properties of hardened high strength concrete. Procedia Technology, 22, 219–226. https://doi.org/10.1016/j.protcy.2016.01.047

[7] Ravitheja, A., Kumar, G. P., & Anjaneyulu, C. M. (2021). Impact on cementitious materials on high strength concrete– A review. Materials Today: Proceedings, 46, 21–23. https://doi.org/10.1016/j.matpr.2020.03.659

[8] Daczko, J. (2012). Self-Consolidating concrete: Applying what we know. CRC Press.

[9] Krivenko, P. (2020). Compressive strength of concrete. BoD – Books on Demand.

[10] Zhou, J., Lu, D., Yang, Y., Gong, Y., Ma, X., Yu, B., & Yan, B. (2020). Physical and mechanical properties of High-Strength concrete modified with supplementary cementitious materials after exposure to elevated temperature up to 1000 °C. Materials, 13(3), 532. https://doi.org/10.3390/ma13030532

[11] Knaack, U., Hickert, S., & Hildebrand, L. (2015a). CONCRETABLE. In TU Delft Bouwkunde eBooks. https://doi.org/10.47982/bookrxiv.19

4) Case study

Information about the case study is divided into two parts. The first one is general information which can be found online. The second part of the case study research is done through external communication and with TU Delft. Different people and companies are contacted to gain knowledge about the insights of this project. The meetings are:

TU Delft – Faidra Oikonomopoulou (Material research) n.v.t.
MVRDV – Aser Gimenez Cortega (Associate director) 20/12/23
Tensoforma – Laura Finazzi (Engineering & construction) 18/01/24
Bulgari – Thor Krisofersson (Architect) 19/01/24
Bulgari – Agnese Mazzi (Sustainability) t.b.a.
ABT – Erwin ten Brincke (Structural research) 31/01/24

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

The "Glass Design and Transparent Structures" studio strives to redefine innovation in glass structures, exploring novel applications. This research focuses on a hybrid facade panel, bridging concrete and glass, concurrently addressing the objectives of the 'Building Product Innovation' and 'Structural Design & Mechanics' chairs in Building Technology. By assessing the manufacturability, structural performance, design criteria, production methods and sustainability this research is pushing the boundaries of glass innovation. Beyond contributing to Building Technology, the research introduces a new design language with implications for architectural design worldwide. The relevance of this work extends to the Master Architecture, Urbanism, and Building Sciences program, promoting a close and mutually beneficial connection between advanced research and the dynamic fields of building and architectural sciences.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

SOCIAL & SCIENTIFIC RELEVANCE

The objective of this research is to create a new design language with no distinct zones of transparency and opaqueness. This study explores the challenge of creating a self-supporting panel with a hybrid connection between concrete and glass, a combination with minimal existing research. By casting solid glass elements, it becomes possible to achieve free forms with high transparency and high compressive strength, enclosed within a concrete framework. Despite the shared material property of brittleness and different expansion coefficients, the collaboration between the two materials, considered unrealistic, introduces this hybrid partnership as a novel building material composite.

This research goal serves as one of the first introductions to this hybrid collaboration. Until now, experimental work has been conducted separately for each material. The data, encompassing performance and structural development of both materials, can serve as a guideline and aid in the research.

The outcome of this experimental study provides new insights into the collaboration between concrete and glass on various fronts. Beyond structural benefits, the final product offers architectural opportunities. It provides architects with the choice and possibility to select transparency in a free form way as a facade material. The interplay between light and dark, open and closed, transparent and opaque, brings significant aesthetic value to the field of architecture.

SUSTAINABILITY RELEVANCE

Technological advacements and material innovations has been a growing trend in the build environment. More and more hybrid (embedded) elements have been created to achieve enhanced properties or functionalities. Despite the growing prevalence of hybrid materials, there is a notable absence of provisions for recycling these elements.
In addition to the soctial en scientific relevance, this thesis intension is also to achieve a reversible connection that allows recovery of the two materials and their eventual recyclability. Hence, the experimental process will be guided by the design for assembly approach.

If, ultimately, an interlocking embedded connection between glass and concrete can be established through the research, it could also be applied as a solution for other products utilizing hybrid materials (without the use an interlayer).