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	Véronique van Minkelen
Student number	4552156

Studio		
Name / Theme	Building Technology	
Main mentor	Dr. Faidra Oikonomopoulou	Chair Structural Design & Mechanics
Second mentor	Dipl.-Ing Marcel Bilow	Chair Building Product Innovation: Product Development, Production Technologies, Façade Design
Argumentation of choice of the studio	In my decision to integrate Structural Design with Façade and Product Design, a significant motivation lies in the increasing use of glass in the building industry. Despite its growing popularity, there remains a limited understanding of its recyclability potential, a gap that is particularly pressing in the context of the global imperative to reduce raw material use and aim for zero waste. While TU Delft has conducted various studies exploring the possibilities of incorporating glass waste into new panels, a major challenge persists: these recycled materials often exhibit diminished structural performance. There is a notable deficiency in knowledge regarding the optimisation of glass waste in new glass systems without compromising on structural integrity. This interdisciplinary approach seeks to address these critical issues, contributing to the development of more sustainable glass usage in construction.	

Graduation project	
Title of the graduation project	Re^3 Façade Glass Panels Assessing the structural performance
Goal	
Location:	Delft, The Netherlands
The posed problem,	*In this graduation plan, it is crucial to comprehend certain key terms: 'float glass' refers to a distinct process of making flat, uniform glass, and 'cast glass' denotes the production of volumetric glass with specific dimensions.* • There is a growing need for more sustainable construction practices. • The European Union has established ambitious targets to realize a zero-waste paradigm in the construction

	sector. This initiative is closely aligned with the EU's guidelines that emphasize the reduction of CO2 and other greenhouse gas emissions. These efforts are part of a broader strategy to promote a circular economy, ensuring sustainable development and environmental protection. • There is a growing need for sustainable materials in construction that can be recycled or repurposed into their original form. Several construction materials are already being successfully recycled, serving as prime examples of this trend. For instance, concrete is often crushed and reused in new construction projects, while steel from demolished structures is frequently melted down and reformed for new uses. Additionally, recycled glass (pre-consumer glass) is increasingly being incorporated into building materials, showcasing the industry's commitment to sustainable practices. • Despite glass is 100% recyclability, it often ends up being downgraded to products like bottles and glass wool at the end of its lifecycle in float glass applications, such as in architectural glass. Recycling glass can minimize the use of raw materials as glass cullets can replace them, leading to zero waste. Additionally, recycling requires less energy for the production of new glass panels, thereby reducing overall energy consumption. • However, currently due to both technical and supply-chain barriers, glass recycling in construction follows an open-loop system, leading to a gradual degradation in material quality. Float glass eventually transforms into products like bottles and glass wool, or even worse, it may end up in landfills. Recent studies highlight that post-consumer glass waste, particularly from float glass, remains a largely unresolved issue. In the Netherlands, only 7.5% of collected float glass is recycled back into the same product. • To tackle this problem of post-consumer waste (float) glass, TU Delft has conducted extensive research on the circularity of glass, examining the present challenges in float glass recycling and its potential reuse in new volumetric glass components made 100% of waste (float) glass using kiln-casting. • Recycling through kiln casting of various glass components back into glass products has been successfully demonstrated by Magna Glaskeramik, which produces cast glass panels using 100% recycled glass from industrial production plants. • A promising new direction explored by TU Delft is the creation of composite cast glass panels, with a lower-degree glass cullet in the bulk, encapsulated by a higher-quality degree of glass waste at the surface.

<table>
<tr><td></td><td>However, there is limited knowledge regarding the impact of different geometric and compositional parameters on the final structural performance of such volumetric kiln-cast panels.</td></tr>
<tr><td>research questions and</td><td>Main research question:
What is the effect of the different parameters in respect to the geometry and glass composition of composite cast glass panels to their overall structural performance made out of Construction and Demolition (C&D) (float) glass waste?

Sub questions:
What are the main practical implications and limitations of recycling C&D glass elements?
How can casting be utilized in the manufacturing of glass panels for built environment applications, specifically in transforming C&D glass waste into reusable cast glass products for facade envelopes, and what are the advantages and limitations of this method?
Which glass composition family group is the most promising in the creation of recycled glass beams?
How does a composite C&D beam compare with a homogeneous C&D beam of similar external glass quality in terms of structural performance?
How do variations in geometrical parameters, specifically the face-core thickness and the position or geometry of the bulk material, affect the structural performance of recycled composite C&D cast beams?
How does temperature impact the homogeneity and structure of the composite panel?
How do different flaws/defects in glass, such as bubbles, colds, nickel sulphide, etc. manifest in the beams created from recycled glass ,and how do they impact the structural performance?
What information does the crack pattern provide about the properties of the glass beam?
How can recycled C&D waste beams be optimised using finite element models?
Is there an optimum balance between class B and C waste for achieving structural performance while maximizing material recyclability?
The meanings of Class B and C waste will be detailed in the report.
How should a created panel be reintegrated into the building market after its production from recycled materials?</td></tr>
<tr><td>design assignment in which these result.</td><td>Boundary Conditions:
The scope of this thesis revolves around assessing the structural performance of a novel recycled cast glass panel, specifically engineered from 100% C&D (float) glass waste, intended for application in loadbearing façades with the primary focus on enabling closed-loop recycling. The research will be conducted at the glass lab facilities at Stevin Lab II, where multiple C&D</td></tr>
</table>

<table>
<tr>
<td></td>
<td>
(float) glass waste beams will be manufactured and subjected to various tests to analyse structural performance parameters.

Design Objectives:

Creation of Recycled Glass Panel:
Develop and manufacture recycled cast glass panels using C&D (float) glass waste, emphasizing its potential for closed-loop recycling.

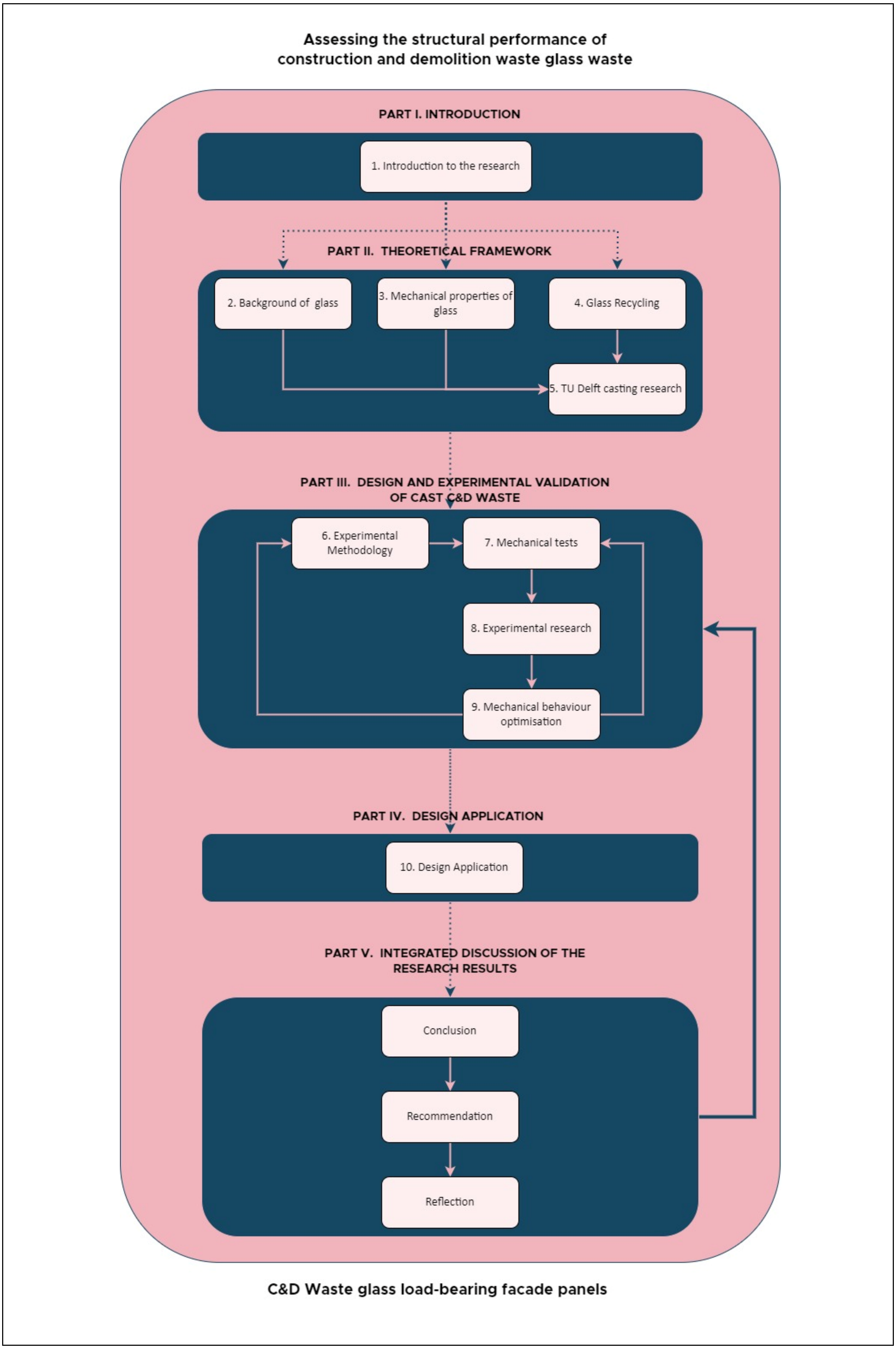
Testing Parameters:
Conduct comprehensive 4-point bending tests on the manufactured C&D glass cast beams to:

Assess the structural balance between performance and minimizing material downgrading to landfills.
Analyse the impact of a composite cast waste panel versus a homogeneous cast panel on structural performance.
Investigate the influence of varying geometrical parameters (e.g. core-face ratio, position/geometry of the bulk) between different glass grades (B and C) in the composite panel.
Evaluate the effects of inherent faults in the recycled glass material on structural integrity.
Examine the influence of temperature on the structural performance.
Investigate the feasibility of optimising the shape of lower-grade glass using finite element models.

Integration of Class C Glass Cullet:
Determine the viability and benefits of integrating Class C glass cullets more extensively into new cast glass panels, contributing to a more circular economy in glass recycling practices.

Microscopic and Mechanical Evaluation:
Analyse structural differences at a microscopic level and after subjecting the cast panels to a four-point bending machine to comprehend the variances in structural performance between composite and homogeneous cast glass panels.

Overall Goal:
The overarching objective of this study is to comprehensively evaluate the influence of composite cast glass panels on structural performance and ascertain the microscopic and mechanical disparities in structural behaviour. This research aims to contribute insights into enhancing recycled cast glass panels' suitability for loadbearing façade applications while fostering a more sustainable and circular economy in (float) glass recycling practices.
</td>
</tr>
</table>


Assessing the structural performance of
construction and demolition waste glass waste
PART I. INTRODUCTION
1. Introduction to the research
PART II. THEORETICAL FRAMEWORK
2. Background of glass
3. Mechanical properties of glass
4. Glass Recycling
5. TU Delft casting research
PART III. DESIGN AND EXPERIMENTAL VALIDATION OF CAST C&D WASTE
6. Experimental Methodology
7. Mechanical tests
8. Experimental research
9. Mechanical behaviour optimisation
PART IV. DESIGN APPLICATION
10. Design Application
PART V. INTEGRATED DISCUSSION OF THE RESEARCH RESULTS
Conclusion
Recommendation
Reflection
C&D Waste glass load-bearing facade panels

Process

Method description

This thesis employs a mixed-methods approach to address its primary objectives and answer the research questions posed. The methodology is structured into five distinct phases, each playing a crucial role in guiding the research process. These phases are detailed in the following sections. Additionally, the figure above illustrates the overarching research framework.

Part 1: Introduction:
This section provides a comprehensive overview of the research, beginning with the context of glass recycling. It outlines the problem statement, highlighting the current challenges in achieving complete recyclability of glass. From this, the research gap is identified, leading to the formulation of the primary research question and its associated sub-questions. The objectives and boundary conditions of the study are then delineated. This is followed by a detailed explanation of the methodology, outlining the sequential steps required for the research. The planning of the research is subsequently discussed, along with its connection to building technology. Finally, the societal and scientific relevance of the study is addressed.

Part 2: Theoretical framework:
This section provides a comprehensive understanding of glass, encompassing its behaviour, common types, and manufacturing processes. It then transitions to a discussion of glass's mechanical properties. The focus shifts to the service life and end-of-life considerations of glass units, followed by an exploration of the potential for glass recycling. The current state of glass recycling is then highlighted, leading into an examination of the treatment processes for C&D glass waste. The capabilities and applications of glass cullet are also detailed.

In the final chapter of this section, the potential of casting methods in enhancing the recyclability of glass is explored. This includes an overview of the casting projects undertaken by TU Delft so far. The discussion then moves to the advantages of using casting for the recycling of C&D glass waste. Lastly, the potential of composite cast glass is emphasized, highlighting its significance in the context of glass recycling.

Part 3: Design and Experimental validation of cast C&D waste:
This section presents the experimental methodology, which includes a detailed account of the variables involved in the research, the preparation of moulds and cullets, firing schedules, and the procedures employed in the glass lab facilities at Stevin Lab II. The research utilizes both class B and C cullets, each containing certain contaminants. The report will later elaborate on the differences between these classes.

The methodology involves designing necessary prototypes and evaluating the beams based on aesthetic qualities such as translucency, the absence of significant cracks, mixing quality, and homogeneity. It should be noted that the outcomes of the beams are unpredictable, and as such, the aesthetic criteria may need adjustment based on the results obtained from the oven. Subsequently, the study includes mechanical tests on the beams, employing a four-point bending machine and analysing the data obtained. Additionally, the research encompasses microscopic examination of beam fractures to determine causative factors, including oven faults, cullet grade and size, firing schedule, and material impurities.

The section concludes with an exploration of optimising the mechanical behaviour of glass waste beams using a finite element model. This optimisation focuses on the shape and positioning of various C&D waste glass classes, specifically class B and C.

Part 4: Design Application:
This section explores the potential applications of glazed panels made from C&D glass cullet. It includes case studies demonstrating the implementation of these panels. The case study options range from reusing glass in the demolition and rebuilding of an old office building to the application of newly created glass panels in a sustainably designed, new office building that emphasizes circular material use.

Part 5: Integrated discussion of the research results:
The final section presents a comprehensive evaluation of the research and experimentation. It includes conclusions drawn from the study, reflections on the production and design of recycled glass panels made through casting, and an assessment of the structural performance. The chapter concludes with recommendations for future research.

Literature and general practical references

In conducting my literature research, I have categorized the information into several groups, each aligned with the key elements of the problem statement. These categories include glass behaviour, the life cycle of glass, and production techniques, with a particular focus on research related to casting. Additionally, I have compiled literature on recycled glass and its structural performance. I also created a category for potential case studies and another for previous theses and PhD.

Achintha, M. (2016). 5 - Sustainability of glass in construction. *In Woodhead Publishing Series in Civil and Structural Engineering*.

Allen, E. (2015). The Most Innovative Glass Buildings. Retrieved from https://www.architecturaldigest.com/gallery/the-most-innovative-glass-buildings

Anagnia, G. M., Bristogiannia, T., Oikonomopouloua, F., Rigoneb, P., & Mazzucchelli, E. S. (2020). Recycled Glass Mixtures as Cast Glass Components for Structural Applications, Towards Sustainability. *Challenging Glass, 7*.

ARUP, & Saint-Gobain. (2023). Understanding the carbon footprint of facades and the role of glass.

Ashby, M., Shercliff, H., & Cebon, D. (2013). *Materials, Engineering, Science, Processing and Design* (Vol. third edition): Elsevier.

Bedon, C., Zhang, X., Santos, F., Honfi, D., Kozłowski, M., Arrigoni, M., . . . Lange, D. (2018). Performance of structural glass facades under extreme loads – Design methods, existing research, current issues and trends. *Construction and Building Materials, 163*, 921-937. doi:https://doi.org/10.1016/j.conbuildmat.2017.12.153

Bergmann, G. (2020). VDMA: Recycling flat glass – circular economy with potential. Retrieved from https://www.glassonweb.com/article/vdma-recycling-flat-glass-circular-economy-with-potential

Bray, C. (2001). *Dictionary of Glass. Materials and Techniques* (second ed.): A&C Black Limited.

Bregroup. (2023). BREEAM Refurbishment and fit-out. Retrieved from https://bregroup.com/products/breeam/breeam-technical-standards/breeam-refurbishment-and-fit-out/

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.* (Doctor of Philosophy). Delft University of Technology, TU Delft Repisotory. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A8a12d0b1-fee2-47f1-9fa9-ff56ab2e84c1

Bristogianni, T., & Oikonomopoulou, F. (2023a). Glass up-casting: a review on the current challenges in glass recycling and a novel approach for recycling "as-is" glass waste into volumetric glass components. *Glass Structures & Engineering, 8*(2), 255-302. doi:10.1007/s40940-022-00206-9

Bristogianni, T., & Oikonomopoulou, F. (2023b). Re3 Glass: A new generation of Recyclable, Reducible and Reusable cast glass components for structural and architectural applications. . Retrieved from https://www.restructgroup-tudelft.nl/re3

Bristogianni, T., Oikonomopoulou, F., Barou, L., Veer, F., Nijsse, R., Jacobs, E., . . . Rutecki, K. (2019). Re3 Glass: a Reduce/Reuse/Recycle Strategy. *SPOOL, 6*(2), 37-40. doi:10.7480/spool.2019.2.4372

Bristogianni, T., Oikonomopoulou, F., Justino de Lima, C., Veer, F., & Nijsse, R. (2018). Cast Glass Components out of Recycled Glass: Potential and Limitations of Upgrading Waste to Load-bearing Structures. *Challenging Glass, 6*. doi:10.7480/cgc.6.2130

Bristogianni, T., Oikonomopoulou, F., Justino de Lima, C., Veer, F., & Nijsse, R. (2018). Structural cast glass components manufactured from waste glass

Diverting everyday discarded glass from the landfill to the building industry. Retrieved from http://resolver.tudelft.nl/uuid:f4e41fb0-13b3-4f70-9195-fea304e3f06e

Bristogianni, T., Oikonomopoulou, F., & Veer, F. (2021). On the flexural strength and stiffness of cast glass. *Glass Structures & Engineering, 6*(2), 147-194. doi:10.1007/s40940-021-00151-z

Bristogianni, T., Oikonomopoulou, F., Veer, F., & Nijsse, R. (2021). Exploratory Study on the Fracture Resistance of Cast Glass. *International Journal of Structural Glass and Advanced Materials Research, 5*(1). doi:10.3844/sgamrsp.2021.195.225

Bristogianni, T., Oikonomopoulou, F., Yu, R., Veer, F., & Nijsse, R. (2020). Investigating the flexural strength of recycled cast glass. *Glass Structures & Engineering, 5*(3), 445-487. doi:10.1007/s40940-020-00138-2

Britannica, T. E. o. E. (2023). Glass. Retrieved from https://www.britannica.com/technology/glass

British Glass. (2023). British Glass. Retrieved from https://www.britglass.org.uk/

Clensy, D. (2023). Ten stunning projects set to complete in 2024. Retrieved from https://www.burohappold.com/news/ten-stunning-projects-set-to-complete-in-2024/#

DeBrincat, G., & Babic, E. (2023). *Re-thinking the life-cycle of architectural glass*. Retrieved from https://www.arup.com/perspectives/publications/research/section/re-thinking-the-life-cycle-of-architectural-glass

del Valle-Zermeño, R., Gómez-Manrique, J., Giro-Paloma, J., Formosa, J., & Chimenos, J. (2017). Material characterization of the MSWI bottom ash as a function of particle size. Effects of glass recycling over time. *Science of The Total Environment, 581*, 897-905.

Department, B. (2018). *Code of Practice for Structural Use of Glass2018*. Retrieved from https://www.bd.gov.hk/doc/en/resources/codes-and-references/code-and-design-manuals/SUG2018e.pdf

Dodd, G., & Vinson, J. (2023). Carbon footprint of façades: significance of glass.

Edgar, R. (2008). UK Glass Manufacture.

FEVE. (2021). Record collection of glass containers for recycling hits 78% in the EU. Retrieved from https://feve.org/glass_recycling_stats_2019/

Florian, M.-C. (2023). The 21 Most Anticipated Projects of 2024. Retrieved from https://www.archdaily.com/1011104/the-21-most-anticipated-projects-of-2024

Geboes, E., Galle, W., & De Temmerman, N. (2023). Make or break the loop: a cross-practitioners review of glass circularity. *Glass Structures & Engineering, 8*(2), 193-210. doi:10.1007/s40940-022-00211-y

Glass for Europe. (2013). Recycling of end-of-life building glass. Retrieved from https://glassforeurope.com/recycling-of-end-of-life-building-glass/

Glass for Europe. (2014). EU waste legislation & building glass recycling, Adapting the Waste Framework and Landfill Directives to increase glass recycling. Retrieved from https://glassforeurope.com/eu-waste-legislation-building-glass-recycling/

Glass for Europe. (2020). 2050 Flat glass in climate neutral europe, triggering a virtuous cycle of decarbonisation. Retrieved from https://glassforeurope.com/2050-flat-glass-in-a-climate-neutral-europe/

Glass packaging institute. (2023). Why Recycle Glass? Retrieved from https://www.gpi.org/why-recycle-glass

Gubberman, R. (2021). The Complete Glass Recycling Process. Retrieved from https://www.rts.com/blog/the-complete-glass-recycling-process/

Hartwell, R., Coult, G., & Overend, M. (2023). Mapping the flat glass value-chain: a material flow analysis and energy balance of UK production. *Glass Structures & Engineering, 8*(2), 167-192. doi:10.1007/s40940-022-00195-9

Hubert, M. (2019). Industrial Glass Processing and Fabrication. In J. D. Musgraves, J. Hu, & L. Calvez (Eds.), *Springer Handbook of Glass* (pp. 1195-1231). Cham: Springer International Publishing.

Inano, H., Akemoto, Y., & Asakura, K. (2023). Upcycling of fluorescent light tube glass via kiln-casting using its properties. *Glass Structures & Engineering, 8*(2), 303-314. doi:10.1007/s40940-022-00199-5

Justino de Lima, C., Veer, F., Çopuroglu, O., & Nijsse, R. (2018). Innovative Glass Recipes Containing Industrial Waste Materials. *6*. doi:10.7480/cgc.6.2175

Kozłowski, M., Akmadzic, V., Malewski, A., Vrdoljak, A. . (2019). Glass in structural applications. *E-Zbornik elektronički zbornik radova Građevinskog fakulteta*.

Lendager, A. (2020). Upcycle Windows. *Solution Circular Buildings*, 152-203.

Luible, A., Haldimann, M., & Overend, M. (2008). *Structural use of Glass*.

Martlew, D. (2005). Viscosity of Molten Glasses. In.

Matskidou, I. (2022). *Re-Facade Glass Panels.* (Master). Delft University of Technology, TU Delft Repisotory. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3Ae804092c-5006-428f-b8b7-fce799f4a32b

Mohajerani, A., Vajna, J., Cheung, T. H. H., Kurmus, H., Arulrajah, A., & Horpibulsuk, S. (2017). Practical recycling applications of crushed waste glass in construction materials: A review. *Construction and Building Materials, 156*, 443-467.

Mohamed, J. (2020). *The re-seal window: a redesign of the edge seals of insulated glass units to facilitate easy and fast re-manufacturing.* (Master). Delft University of Technology, TU Delft Repisotory. Retrieved from http://resolver.tudelft.nl/uuid:90a3a7c6-3952-42b0-b26b-0ac63d7726b2

O'Regan, C. (2014). *Structural use of glass in buildings* (second ed.). London: IStructE Ltd.

Oikonomopoulou, F. (2019). *Unveiling the third dimension of glass, Solid cast glass components and assemblies for structural applications.* (Doctor of Philosophy). Delft University of Technology, TU Delft Repisotory. Retrieved from https://repository.tudelft.nl/islandora/object/uuid%3A16f1560f-1739-492c-bd95-3f47bf096182

Oikonomopoulou, F., DeBrincat, G., & Fuhrmann, S. (2023). Glass and circularity. *Glass Structures & Engineering, 8*(2), 165-166. doi:10.1007/s40940-023-00230-3

Ortiz, C. (2007). *Spectroscopy of Terbium doped Sol-gel Glasses.*

Rijksoverheid. (2023a). Klimaatbeleid. Retrieved from https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/klimaatbeleid

Rijksoverheid. (2023b). Nederland circulair in 2050. Retrieved from https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050

Rota, A., Zaccaria, M., & Fiorito, F. (2023). Towards a quality protocol for enabling the reuse of post-consumer flat glass. *Glass Structures & Engineering, 8*(2), 235-254. doi:10.1007/s40940-023-00233-0
Saint-Gobain. (2023a). Glass Recycling from Saint-Gobain. Retrieved from https://www.saint-gobain-glass.co.uk/en-gb/glass-recycling-saint-gobain

Saint-Gobain. (2023b). Mechanical Properties of Glass. Retrieved from https://www.saint-gobain-glass.co.uk/en-gb/architects/physical-properties

Saint-Gobain. (2023c). The UK's leading cullet return scheme offered by Saint-Gobain building glass. Retrieved from https://www.saint-gobain-glass.co.uk/en-gb/glass-recycling-saint-gobain

Schuttelaar & Partners. (2018). 'Circular Netherlands in 2050' – An Impetus for Secondary Raw Materials in the Construction Industry. Retrieved from https://vb.nweurope.eu/projects/project-search/seramco-secondary-raw-materials-for-concrete-precast-products/news/circular-netherlands-in-2050-an-impetus-for-secondary-raw-materials-in-the-construction-industry/

sds industries. (2023). Understanding Kiln Firing Schedules for Glass, Ceramics, Pottery, and Heat Treat. Retrieved from https://www.kilncontrol.com/blog/kiln-firing-schedules/

Shand, E. B. (1968). Engineering Glass, Modern Materials. *6*.

Shelby, J. E. (2005). *Introduction to Glass Science and Technology* (second ed.): The Royal Society of Chemistry.

Surgenor, A., Holcroft, C., Gill, P., & DeBrincat, G. (2018). *Building glass into the circular economy, How to guide*. Retrieved from https://ukgbc.org/wp-content/uploads/2018/10/How-to-guide_Building-glass-into-CE.pdf

Van Marcke de Lummen, G., & Schreuder, N. (2013). Recycling of Glass from Construction & Demolition Waste

Views from the flat glass industry. *AGC Glass Europe*.

Vandaglas. (2024). Spontane glasbreuk door NiS insluiting. Retrieved from https://vandaglas.nl/expertise/nikkelsulfide_insluiting/

Varshneya, A. K. (2016). Industrial glass. Retrieved from https://www.britannica.com/science/industrial-glass

Veer, F. (2007). The strength of glass, a nontransparent value. *Heron, 52*.

Veer, F., & Rodichev, Y. (2011). The structural strength of glass: Hidden damage. *Strength of Materials, 43*, 302-315. doi:10.1007/s11223-011-9298-5

Vlakglas Recycling Nederland. (2022). *Vlakglas Recycling Nederland Jaarverslag 2022*. Retrieved from https://www.vlakglasrecycling.nl/uploads/jaarverslagen/Jaarverslag%202022_VRN_4.pdf

W&WGlass. (2023). The Future of Glass Architecture. Retrieved from https://www.wwglass.com/future-glass-architecture/#:~:text=The%20goal%20for%20the%20future,appear%20to%20be%20ultimate%20simplicity
Warm glass. (2024). Kiln Firing Schedules

Programme your kiln with confidence. Retrieved from https://warm-glass.co.uk/kiln-schedules-cms-74

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 Building Technology Master track within the MSc AUBS program integrates architectural design and engineering, addressing interdisciplinary challenges and fostering innovative solutions. Its focus spans a wide range of engineering and architectural skills crucial for future sustainable design practices, particularly in developing innovative and sustainable building components integrated into the built environment.

This thesis combines structural design with façade and product design within building technology. The objective is the creation of an innovative building envelope and project, with a specific emphasis on circular building products and the utilization of computational design to optimise created cast panels.

The research aims to explore the potential of cast glass in promoting environmental sustainability by reducing CO2 emissions and waste. This involves studying the mechanical properties of glass, analysing (float) glass recycling processes, conducting independent experimental research, and refining methodologies through mechanical testing. The goal is to practically apply acquired insights to design a recycled cast glass panel from C&D glass waste, establishing a closed-loop recycling system, and evaluating its suitability for loadbearing façade applications.

The study involves the creation and optimisation of multiple cast panels made from C&D waste to maximize structural performance while minimizing landfill-bound materials, with a preference for establishing a closed-loop system.

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

Social relevance:
The increasing utilization of glass in structural designs reflects its growing social significance. With its unique combination of transparency and high compressive strength, glass has evolved from a material once perceived as fragile and opaque to one that is durable, optically clear, and structurally viable. This evolution marks a significant shift in architectural and structural applications, highlighting glass as a pioneering material in the building industry. Its ability to facilitate light transmittance and spatial continuity makes it an ideal choice for creating diaphanous structural components. Glass, being relatively new in structural contexts compared to other materials, offers groundbreaking possibilities that could redefine future approaches in building industry, architectural engineering, and structural engineering.

Professional and scientific relevance:
The challenge of glass waste, particularly float glass derived from the C&D sector, remains a critical issue. The absence of an effective recycling system for this type of waste, compounded by quality standard failures due to contamination from coatings, lamination, adhesives, or recipe incompatibilities, often leads to glass cullet ending its lifecycle in landfills. This research holds significant scientific relevance as it explores the potential for recycling C&D glass. By investigating the feasibility of using cast glass in architectural applications, this dissertation aims to bolster confidence among engineers, architects, designers, and the general public in both cast glass as a structural material and glass casting as a viable production technique. The study provides essential data on the types of waste glass that can be utilized, the proportions for use, and the necessary firing schedules, which can guide the industry in the recycling-by-casting process. Furthermore, the research undertaken at TU Delft on waste streams and the potential of (float) glass recycling underscores the necessity for further exploration in this area, particularly regarding the reuse of float glass waste in structural cast glass applications, where comprehensive information is still lacking.