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

To reduce the amount of construction and demolition (C&D) glass waste that ends up in landfills, this thesis, "Recycled Composite Cast Glass Panels made of C&D Waste: Assessing the Structural Performance," explores the potential of recycling C&D glass for innovative façade cladding applications. The research involves collaboration between the chairs of structural design and mechanics, and building product innovation within the Building Technology master's program.

The chair of structural design and mechanics provides essential information on glass behaviour, glass casting methods, and the potential for recycling architectural flat glass. This thesis advocates for the closed-loop recycling of flat glass and demonstrates how glass casting can help mitigate waste problems. The research investigates recycling options for glass through mechanical tests, microscopic validation, and the optimisation of mechanical behaviour using laboratory experiments.

Conversely, the chair of building product innovation offers insights into contemporary manufacturing techniques and methods for reusing (glass) waste materials in innovative building design applications. The production of recycled glass cladding materials focuses on optimising waste usage and recycling processes while ensuring good structural performance. The ultimate goal of this research is to develop a circular, sustainable product that contributes to reducing C&D glass waste in landfills.

2. **How did your research influence your design/recommendations and how did the design/recommendations influence your research?**

a. **Influence of research on design / recommendation**

For my thesis, I investigated the potential for recycling glass waste in new building applications. Reusing cullet in the glass casting process minimises waste. Due to the diverse material compositions of glass waste, each new application of repurposed glass results in a unique composition, enabling the creation of innovative and aesthetic compositions. To explore the possibilities of recycled glass, I produced multiple beams and tested their flexural strength.

To understand the casting process and the influence of individual contaminants on structural performance, I first created homogeneous beams. Since glass typically fails at its surface, it is beneficial for the surface to have a stronger material composition while the bulk can be of a less strong composition, forming composite beams. I researched the material compositions of both the surface and the bulk, as well as the optimal ratio between them, aiming to balance waste recovery and structural optimisation.

However, testing these qualities presented several challenges in the lab, requiring resource adaptation under stringent time constraints. The methodology of the thesis needed to be adjusted weekly to accommodate time planning, supplier issues, and setbacks in the lab. For instance, when the oven was non-operational for several weeks, significant time pressure necessitated quick decisions and adaptations to the methodology.

b. Influence of design/ recommendation on the research

My original design idea was to create a panel that could serve as an alternative to end-of-life architectural glass. However, my mentor highlighted a significant challenge in recycling glass: the presence of contaminants such as glues, sealants, plastics, and CSP pollutants. He questioned the rationale of adding a new glass structure to an existing window, as it would reintroduce these contaminants, which have complicated glass recycling efforts. This insight prompted me to explore various glass recycling strategies, focusing on developing a product that maximizes the use of C&D waste, thereby reducing the percentage of material sent to landfills.

3. **How do you assess the value of your way of working (your approach, your used methods, used methodology)?**

My research consists of five main parts:

Part 1: Introduction
This section introduces the research, outlining the problem statement and explaining the methodology used.

Part 2: Theoretical framework
This section focuses on the behaviour of glass and its production methods, highlighting the differences between float glass and cast glass, the mechanical behaviour of glass, its recyclability, and the current open-loop recycling system. It also explores the potential of using cast glass for recycling and reviews previous research from TU Delft, which forms the basis for this study.

Part 3: Experimental methodologies
This section details the design concept of the beams and the four types of experiments conducted:

- Homogeneous beams
- Composite beams focusing on the ratio between surface and bulk materials
- Composite beams focusing on the material composition of the bulk
- Composite beams focusing on the material composition of the surface

It includes structural feasibility validation of the beams, examining factors such as compatibility, transparency, mould reaction, cracks, breakage, bubbles levels, and overall structural performance. Mechanical testing was performed using a four-point bending machine to assess flexural strength. Post-testing, the cracks were examined, and the origin of the fractures was explored under a microscope. Structural behaviour optimisation was then conducted based on experimental testing.

Part 4: Design application
This part focuses on the creation of the design application.

Part 5: Integrated discussion
This section integrates and discusses the research results, reflecting on the main question and outcomes.

Although my approach is methodical, there are areas for improvement. Currently, I can only test three beams per type, but for statistically feasible results, testing at least thirty beams of each kind is necessary. Time constraints make achieving this level of thoroughness challenging. Additionally, the laboratory setting presents many unknowns, requiring patience and flexibility during the research process.

4. **How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?**
   The research holds high academic value, particularly within TU Delft's ongoing efforts to integrate waste materials into construction practices. This effort, along with lowering CO2 emissions and promoting a circular economy, is in line with the EU's objective of reaching zero waste in building by 2050.

   Glass's expanding social relevance is reflected in its increased application in structural designs. Glass has changed from being thought of as opaque and brittle to offering structural integrity, durability, and optical clarity. This change establishes glass as a developing material in the construction sector and represents a substantial shift in architectural and structural applications.

   To reduce construction waste, ethical issues must be taken into account, especially with regard to recycling glass. Glass recycling helps the environment by lowering the amount of waste that ends up in landfills, but it's important to consider the environmental effects of glass compositions at every stage of their lifespan, taking into account the energy and resource consumption involved in manufacture and recycling. When incorporating recycled glass items into architectural projects, it's critical to be transparent about their origins, composition, and any drawbacks. This way, consumers will be aware of any performance or aesthetic deviations from regular glass products.

5. **How do you assess the value of the transferability of your project results?**
   To facilitate comparisons with current data and to make my research setup available to future students, I'm using comparable settings. To be more precise, I'm using Isidora Matskidou's material settings, adopting her test setup for beam manufacturing and testing, and deciding which defects to pay attention to base on Dr. Telesilla Bristogianni's publications on flexural strength. Regretfully, time restrictions prevent me from testing every element I would like to investigate. But I think changing the beam lengths might provide important information on surface imperfections and structural performance. Furthermore, investigating the production of panels rather than beams may prove to be a fascinating topic for additional study.

6. **To what extent are the results of this thesis applicable in the practice in the built environment?**
   The purpose of the manufactured beams is to explore the potential of transforming C&D glass waste into a new architectural product. The results from the mechanical and microscopic tests on both homogeneous and composite beams serve as a foundation for developing a future strategy aimed at creating more closed-loop, circular building applications. One promising application for the newly developed composite material is its integration into cladding systems. Current cladding materials, typically made of plastics and concrete, have a high CO2 footprint during manufacturing. Utilising C&D glass waste for cladding materials would reduce the overall C&D waste sent to landfills, contributing to more sustainable construction practices.

7. **To what extent is this research innovative?**
   The research exhibits innovation in several key ways. Firstly, it explores new methods of recycling glass for building applications by using casting and analysing the structural behaviour of glass, ultimately creating a composite panel to increase material recycling. This approach

seeks to transition from the current open-loop system to a closed-loop recycling process for glass waste management.

Secondly, by developing a closed-loop application, the research contributes to a more circular and sustainable approach in the construction industry.

Thirdly, while current glass production primarily involves float glass for architectural purposes, this research demonstrates the potential of using casting as a another main production method, thereby expanding the range of building applications for recycled glass.

Fourthly, the creation of composite panels from C&D glass waste results in unique material compositions and appearances for each panel. The variability in contamination rates among different batches leads to the production of beautiful, highly aesthetic, innovative panels.

8. **How does this thesis helps with creating a circular economy in the future?**

   This research significantly advances the concept of a circular economy by establishing sustainable methods that minimize C&D waste and optimise resource efficiency in building construction applications. One of the key aspects of this thesis is the investigation of glass casting, which transforms leftover glass (cullets) into useful structural elements. This method promotes a circular approach to material consumption, facilitating a shift from an open-loop to a closed-loop strategy.

   Practically, the study demonstrates how recycled glass can be effectively integrated into new architectural applications, providing scalable solutions to reduce the demand for raw materials and divert waste from landfills. Additionally, the thesis supports the implementation of closed-loop systems, where recycled materials are continuously reintegrated into production processes, enhancing sustainability and resource management.