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	Catharina Johanna Backer (Karin)
Student number	4552962

Studio		
Name / Theme	Glass Design & Sustainable Structures	
Main mentor	James O'Callaghan	Structural / Glass Design (SD)
Second mentor	Marcel Bilow	Façade / Product Design (FPD)
Argumentation of choice of the studio	-	

Graduation project	
Title of the graduation project	A thin composite glass panel; a new design for monumental glass
Goal	
Location:	Delft, the Netherlands
The posed problem,	In recent decades, more and more attention has been paid to improving the carbon footprint and the climate change. Therefore, within the architecture it is important that existing and future buildings are decently insulated, so less heating and cooling energy is required to control the indoor climate. This is important because the energy is often provided by non-reusable resources that contain a lot of carbon. When looking into the insulation of a building, the openings in the façade are the problem areas. The window frames and the glass have significant higher heat loss than the closed parts, which is mostly due to the higher U-value of the glass. To solve this issue, lots of research has been done so far to design new and better window glazing. Looking at heritage buildings where single glazing is still common, the need for suitable renovation products is even higher. However, the current solutions on the market do not always suit the heritage window frames where the glass thickness of 4 mm is used or are not as good as non-heritage solutions. Therefore, the problem statement in this graduation research states the following: To reduce the heat loss in heritage buildings, modern solutions that replace the single glazing are

	not insulating as good as solutions for non-heritage buildings or not accessible due to high pricing.
research questions	Trying to solve the issue from the problem statement the general objective will be to design a thin glass panel that could replace single glazing in heritage buildings to reduce the heat loss, aiming for similar U-values as solutions for non-heritage buildings. To do so, this graduation research will investigate the use of thin glass in window glazing, resulting in the following research question: **"What alternative solutions arise when thin glass is used to design an insulating glass panel that replaces single glazing in heritage buildings to reduce heat loss?"** The sub-research questions formulated are: - What are the possibilities in designing a 4 mm glass panel that insulates better than single glazing with a coating? - Which materials are suitable to become the layer in between the thin glass sheets to enhance the insulating values? - How is the connection between the layers established? - How well do the prototypes test based on thermal and structural performance? - How well does the final design suit in the case study?
and design assignment in which these results.	Altogether, a detailed literature study must be done to gain specific knowledge on the topic. Based on this, design criteria can be created and first design proposals can be made. Those are then be tested to validate them in order to give a conclusion on the research questions.

Process

Method description

The timeline below shows a global planning of the graduation research. Roughly speaking, it is split into five phases:

PHASE 1: Literature research and case study
PHASE 2: Design proposal
PHASE 3: Modelling and testing
PHASE 4: Evaluate and improve
PHASE 5: Conclusions and reflection

The first phase has been the most time-consuming part until now. This phase focuses on gaining background knowledge on the (thin) glass production techniques, the possibilities of the in between layer and the method on laminating the layer together.

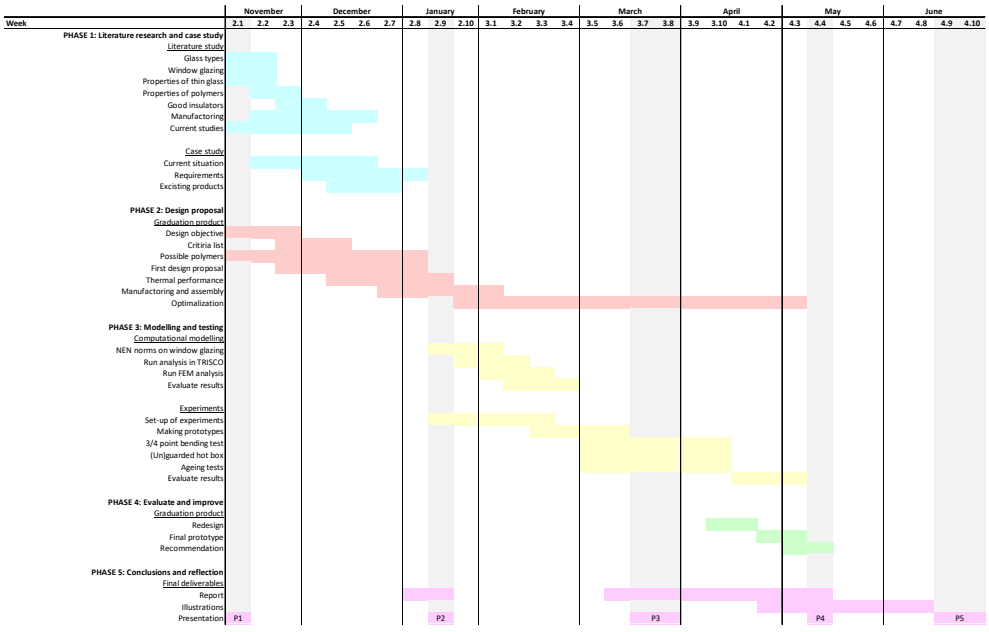
By doing so, the size of the research scope was established. Moreover, a case study has been chosen. This will be the former faculty of Applied Physics at Mijnbouwplein 11 in Delft. The building was built in 1930 and taken over by DUWO in 1975 to accommodate student housing. In 2008 a renovation happened in which the windows where replaced.

Somewhat together to this phase, the design proposal phase started. During this the first drafts are made, and a criteria list is concluded based on the literature review. Halfway through this phase the designs should become more concrete. The manufacturing of the designs should be thought of in more detail and manufactures are approached to ask for samples. At the P2, the first design proposals should be almost finalized.

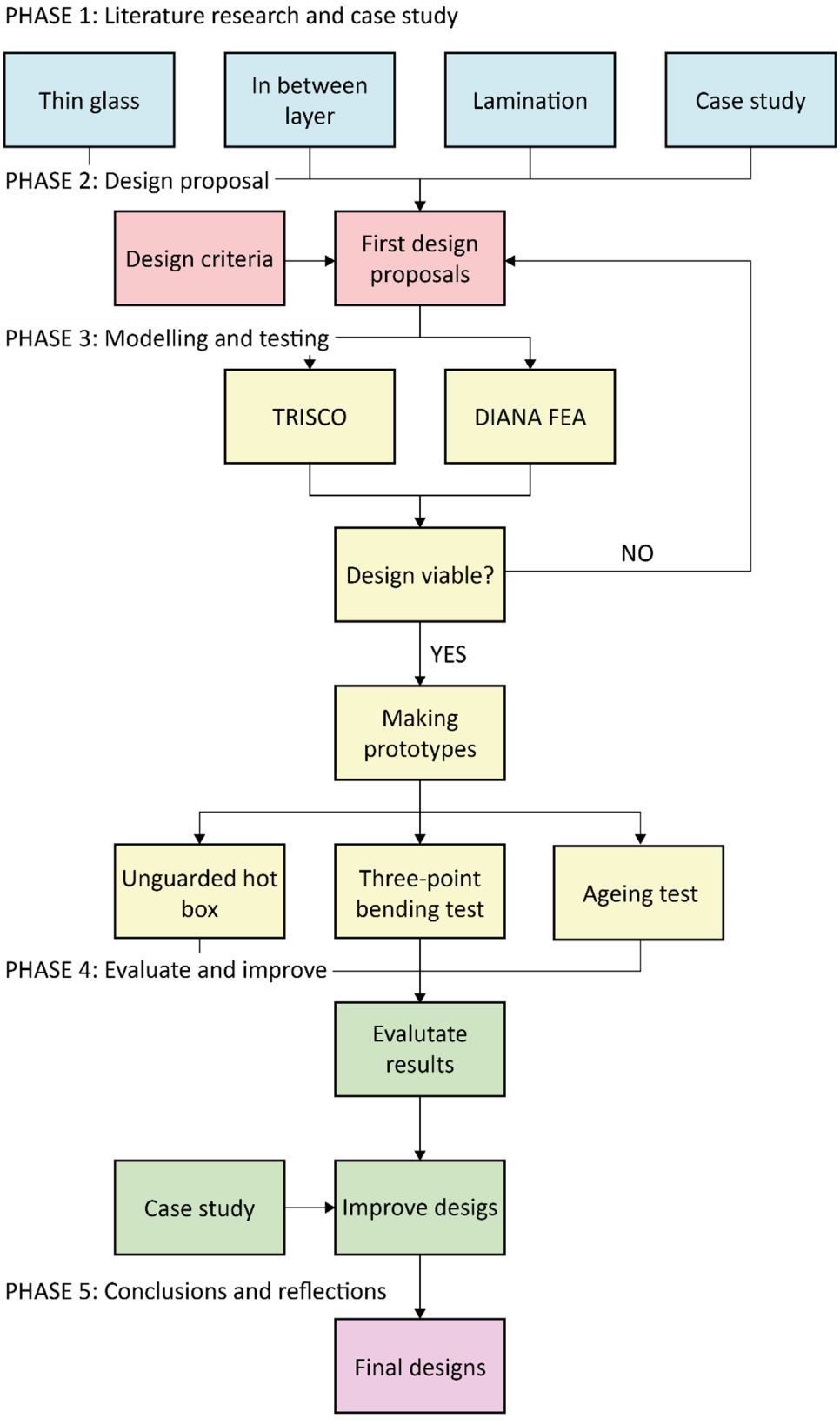
Using the research though design approach, the design proposals are then intensively tested in the modelling and testing phase. First the proposals are analyzed in TRISCO and DIANA FEA. These programs will test the ideas on thermal performance and structural properties. Parallel to this, the preparation for the prototypes need to start. This comes down to gathering the materials and reserving the machines. At the beginning of March, the prototypes should be almost done and the physical testing can begin around the P3. Since testing always takes more time than expected, a timespan of six weeks is taken to make sure all the tests can be done in time.

Once a rough conclusion can be drawn from the testing, the evaluate and improve phase can begin. In this phase all the results are evaluated, and those conclusions are applied to redesign the tested ideas. This will lead to the final products and a recommendation for further research can be written, just before the P4.

This leads to the final phase, the conclusions and reflection phase. In this phase the final deliverables are made for the P5, and an overall conclusion of the graduation research is given.



A larger size of the timeline is given on the final page.


PHASE 1: Literature research and case study
Thin glass
In between layer
Lamination
Case study
PHASE 2: Design proposal
Design criteria
First design proposals
PHASE 3: Modelling and testing
TRISCO
DIANA FEA
Design viable?
NO
YES
Making prototypes
Unguarded hot box
Three-point bending test
Ageing test
PHASE 4: Evaluate and improve
Evalutate results
Case study
Improve desigs
PHASE 5: Conclusions and reflections
Final designs

Literature and general practical preference

Allwin. (2006). Glassique: glas met historisch karakter.

Collins, R. (2019). *Vacuum Insulating Glass – Past, Present and Prognosis*. Paper presented at the GPD, Finland.

Hänig, J., & Weller, B. (2020). Load-bearing behaviour of innovative lightweight glass–plastic-composite panels. *Glass Structures and Engineering, 5*(1), 83-97. doi:10.1007/s40940-019-00106-5

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Schlösser, N. (2018). *Thin Glass as Cold Bent Laminated Panels in Architectural Applications.* TU Delft, Delft. Retrieved from https://repository.tudelft.nl/islandora/object/uuid:cf8fecc0-15f8-4f85-95da-6cb6b35fffa1?collection=education

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Reflection

Social, professional, and scientific framework of the graduation topic

In recent years, the climate crisis, the carbon footprint, and fossil fuels have become part of our daily life and vocabulary. When this is applied to the build environment, it results in a need for a more sustainable and durable structure. Moreover, there is a rise in the need to renovate and repurpose existing buildings instead of demolishing them. This brings along the question on how to make these buildings more sustainable and in line with the building regulations, while leaving the essence intact. Within the graduation work the focus will be on improving façade and in more detail, the glass within the window frame. This is mainly because windows are generally the largest factor in heat loss, but in older buildings this difference is even greater. Improving these glass panels will contribute to the increase of the insulation values, the lifespan of buildings, the ease of renovating existing buildings and the preservation of cultural heritage.

The current possibilities to replace the glass panel are thin glass (2mm) panels with a cavity (4mm) in between, single glazing with an extra coating, or vacuum glazing. However, these options might be too thick to fit into the original window frame, show only a small improvement on the thermal performance, or are quite expensive. The graduation project will research a design with thin glass (0.5-2mm) and a polymer (2-6mm) in between. Preliminary, research has been done on how to design a composite like this, but the graduation research will focus on the thermal performance of the product for the first time. Resulting in transforming the current studies towards a product that could be marketed.

Relation between your graduation topic, the master track BT and MSc AUBS

When making a new glass panel to place in monumental buildings, the designer needs to take a close look into multiple aspects that are relevant within the master track Building Technology. First of all, it is important to consider the climatic influences of the glass in the overall façade and the thermal performance it will have. Moreover, the product needs to be tested on all sorts of mechanical tests to fit within the NEN norms. This is essential since glass is known for its brittleness and unexpected breakage. Additionally, to test the design on structural properties, prototypes should be made. The process and the making of these prototypes are an important part of the façade / product design chair. Furthermore, the designer should check what typical façade elements and window frames are used in a monumental building to confirm whether the design suits the case.

Even though, the final product will mainly be focusing on the building sciences, the outcome should still be applicable for the general building industry. Once the product is maximally optimized, it could become a real product on the market. This could mean

that architects who are involved in the renovation and restoration of monuments can order the product and use it in future designs. As the weight of the design is approximately equal to the original glass, it is an accessible product to implement.

	November			December				January			February				March				April				May				June			
Week	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10
PHASE 1: Literature research and case study																														
Literature study																														
Glass types																														
Window glazing																														
Properties of thin glass																														
Properties of polymers																														
Good insulators																														
Manufactoring																														
Current studies																														
Case study																														
Current situation																														
Requirements																														
Excisting products																														
PHASE 2: Design proposal																														
Graduation product																														
Design objective																														
Critiria list																														
Possible polymers																														
First design proposal																														
Thermal performance																														
Manufactoring and assembly																														
Optimalization																														
PHASE 3: Modelling and testing																														
Computational modelling																														
NEN norms on window glazing																														
Run analysis in TRISCO																														
Run FEM analysis																														
Evaluate results																														
Experiments																														
Set-up of experiments																														
Making prototypes																														
3/4 point bending test																														
(Un)guarded hot box																														
Ageing tests																														
Evaluate results																														
PHASE 4: Evaluate and improve																														
Graduation product																														
Redesign																														
Final prototype																														
Recommendation																														
PHASE 5: Conclusions and reflection																														
Final deliverables																														
Report																														
Illustrations																														
Presentation	P1								P2								P3							P4						P5