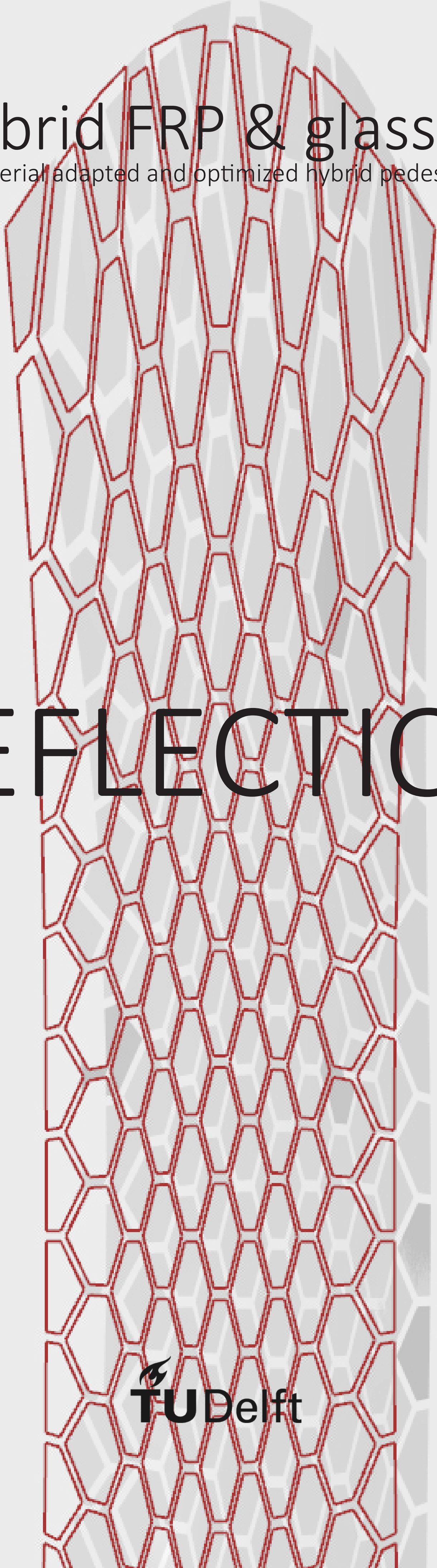
The hybrid FRP & glass bridge

Research for a material adapted and optimized hybrid pedestrian bridge design



REFLECTION

TUDelft

1.1 - Reflection P2

1.1.1 - Reflection process & method

During the first P2 presentation there was not enough clarity about the subject. Whilst no clarity was given I still tried to produce a lot of work. This lead to a vague and sometimes even a childish approach of the subject. The process and method I used was the same as during projects in the bachelor and master. Quick research combined with producing sketches and drawings. However, during graduation it is expected that the subject is researched way more extensively than during "regular" projects. The assignment given during this first - failed - attempt of a P2 was to do more extensive research. This was therefore the new focus point.

In a months time I tripled the amount of research. Still, more research can and should be done concerning certain topics. The research phase of the graduation has therefore not ended yet.

1.1.2 - Reflection project

The project has not yet taken a full shape. However, the subject is promising. All the found and researched glass bridges have lengths less than 20 meters. This is way less than the 30 meters that will be spanned with the hybrid FRP and structural glass foot- and cyclist bridge. This bridge will therefore be a very progressive way to use glass.
A disadvantage of the subject might be the limitations of the materials. There are not many different ways to use glass structurally. This might limit the freedom of the design in a very early stage.

1.1.3 - Conclusion

The amount of theoretical research has been tripled. However, it is not yet fully done: more research on certain topics is necessary. Furthermore, some basic preliminary variants have been suggested, but should be elaborated on in the coming weeks.

1.2 - Reflection P4

1.2.1 - Reflection process & method

The idea to create a hybrid fiber-reinforced polymer and structural glass bridge was driven by earlier research at the TU Delft. This previous research focuses on creating FRP reinforced glass beams and shows the potential of combining these two materials in a structural element. The aim of this thesis was to expand the potential of the combination of materials to a larger structural element: the bridge. To do so I wanted to research both materials, find the optimal properties and then combine these properties in a material adapted design of a hybrid bridge.

By choosing to create a hybrid bridge, two graduation labs and two distinct graduation subjects were combined: bridge design and structural glass design. The combination of two distinct graduation labs resulted in a broader subject than was initially taken into account. As the exact subject of the thesis remained quite vague at the start of the process – only the condition of an optimal hybrid bridge of these two materials was defined – a lot of extra steps were necessary to define the exact research topic. The bridge type was undefined, as were the location of the bridge, the way of combining the materials into a hybrid and the structural concept.
This uncertainty over the exact course of research resulted in a rush through the preliminary research – the theoretical framework – and therefore not an in-depth study at the P2 presentation. The first verdict was therefore a retake (see also reflection P2). In the second try the methodical line of approach (extensive literature research and conclusions) was followed to full extent, resulting in a go.

After extending the methodology and literature research of the thesis considerably, a choice for a structural concept could be made. This choice resulted in the need for a second literature research to conclude in a new theoretical framework regarding the plate shell. This second theoretical framework was very time consuming, particularly when considering that the first theoretical framework was already quite extensive.

The shift of the project towards plate shells brought another consequence. The guidance of a third teacher was necessary for purposes of form-finding and FEM analysis.
While executing the plate shell research and designing the hybrid bridge it became clear that this project was quite ambitious. The thesis strives for a freeform plate shell that is concave and at the same time functions as a bridge while only plate shells that are convex based on part of domes that function as roofs have been built in structural glass.
This research should therefore be seen as a first set-up to show the problems and opportunities affiliated with a freeform plate shell. The final design is probably not yet ideal or most efficient.

A problem that was encountered during research was the limitation of the applied software and the associated waste of time. First of all, it was impossible to use Karamba to perform a FEM-analysis on plate shells. Secondly, it was impossible to perform a hexagonal tessellation on a free form concave shell using Kangaroo. This resulted in several wasted attempts to script these actions, which cost a lot of time.

1.2.2 - Reflection project

The project is an interesting addition to the on-going research into plate shells from structural glass. It gives an overview of the problems that are encountered when designing a free-form (and concave) plate shell and gives possible solutions for these problems in the form of several variants. Additional research can pick up on several unexplored solutions for encountered problems. An example is the use of a part of a torus to create a regular shaped hexagonal tessellation on a concave shell (figure). This solution was dismissed during research as it does no longer include a free-form and form-found shell. It could, however, be a better solution to create a plate shell with free edges than the method proposed in this thesis.

The project also proposes a new way of using glass in footbridges. Several pedestrian and cyclist bridges are increasingly built in the Netherlands. This new bridge can add to the development of sustainable and durable bridges. It shows the potential of the combination of FRP and structural glass to create longer spans in glass structures and an aesthetically interesting design.

However, the final design also shows the presence of flaws. The bridge did not achieve the level of transparency it was supposed to reach. The glass panels had to be smaller and thicker to minimize stress in the FRP connections due to the various loads working on a bridge. These measures affected the transparency of the overall design.

1.2.3 - Conclusion

The overall process took more time than expected due to the extra literature research that was needed and the drawbacks regarding the software and geometry limitations. However, in the end all predefined steps in the process have been followed.

The final product gives a good overview of the problems and possible solutions during the design of a free-form, concave plate shell. Additional research in this field remains necessary to find the most efficient design process for this type of plate shell. Also the final product does not meet the exact aesthetical expectations of the author.

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