REFLECTION - PIM BUSKERMOLEN

Graduation process

The Building Technology master track is positioned between architecture and civil engineering, and incorporates a variety of courses. Across these courses, a design aspect - which is closely related to architecture - is manifested. And with that, the reasoning behind all design decisions is required to be substantiated. The engineering aspect, whether in building physics, material science or structural mechanics, forms the foundation of any of these design decisions. This combination makes the course unique, as it enables its graduates to operate in between architecture and engineering practice.

Throughout my university career I developed an increasing interest in the influence technology can have on architectural decisions. This is why I decided to study Building Technology, and later why I chose to graduate in the track of structural design. The topic of shell structures is relevant for architectural applications, but also helps in exploiting the theory behind its mechanics. In that, a clear mix between design and engineering is found by design through research. In other words, my graduation project explores the mechanics behind shell structures, to better understand how to design them. The parametric tool, which is a product of the project, helps in making these mechanics insightful. Thus, the design and evaluation of shell structures becomes more accessible and understandable to the structural designer or architect.

A number of research methods have been employed throughout. The research process started with a broad literature study, that ranged from basic understanding of curved geometry to thorough study on complex mathematics. Later, iterative testing was done by means of finite element analysis, in order to get a better understanding of the mechanics of shell structures. Part of the process was envisioned early on, but a lot of the methods developed along the way. A combination between theory and application remained present throughout. This proved to be a very effective work-flow, as it allowed for the understanding of otherwise complicated matter. In hindsight, the planning has broadly been followed. Some changes were made along the way, as the direction of the project developed gradually.

Societal impact

Over the years, a lot of research has been done on shell structures. The thrust surface proved to be helpful in understanding the force flow through the structure. The shape of this surface, however, was considered complicated to determine. Philippe Block and his team proposed a method called the Thrust Network Analysis, but this method still produces many possible surface geometries, and not one optimal case. The method also turned out very complicated and tedious to use.

In my project, I propose the use of the Airy stress function in creating the thrust surface, a relation (between form and force diagram) that was already observed in 1870 by Maxwell. This allows to both analyse existing shell structures as well as to design new shells. Further research into the moment hill of certain plates allowed for the generation of better stress functions. Little experience exists on the application of the Airy stress function in assessing and designing shell structures. In my graduation proposal, this possibility has been further explored in combination with the reciprocal figure. The Airy stress as the form diagram and the thrust surface as the reciprocal force diagram is an idea not executed before. At the same time, applying graphic statics to the Airy stress enabled extra possibilities in exploiting this relationship. This provided extra insight into the mechanical behaviour, i.e. where tensile stresses occur, and how these can be minimised.

Shell structures only comprise a small part of the built environment. They can be considered a niche element in the diverse sectors of structural design. Shell structures are, however, significant, in that they require practically all that is known of structural mechanics to come together. In order to understand the behaviour of shell structures, we must understand all these aspects. At the same time this means that our findings on shell behaviour are applicable across the entire discipline, potentially presenting new architectural possibilities.