Delft University of Technology, Faculty of Architecture

Integrated computational approach for the generation and preliminary structural analysis of woven structures during the early design stage

Reflection report

Nikoletta Christidi | 4738594
5-16-2019

The present research is part of the Sustainable Design Graduation studio, within the Building Technology track of the MSc Architecture, Urbanism and Building Sciences programme at TU Delft. The research addressed the need for a computational workflow for the generation and preliminary structural analysis of architectural-scale woven structures during the early design stage.

As this thesis represents the culmination of my studies in Building Technology during the course of the last two years, it focuses highly on the technical aspects of an architectural phenomenon. Woven structures, by definition complex and aesthetically attractive, now become the main subject of a research that discusses the relationship between computational design, architecture, materiality and structural mechanics.

Therefore, the Chairs I collaborated with were deemed the most suitable ones for this research. Firstly, the Chair of Design Informatics supported the process of the development of the main thesis product, a digital tool necessary for the generation and evaluation of woven structure design alternatives. Secondly, the Chair of Structural Mechanics provided the background knowledge surrounding material properties and structural analysis that was essential for the tool development. Both disciplines contributed equally to the establishment of a design workflow and process that, when completed, will render possible the computationally informed optimisation of a traditionally empirical technique.

Looking back at the early research phase, I find my approach to the topic satisfactory; however, I believe that the scope of research was initially too broad and the objectives too ambitious for the Master thesis timeframe. This could be attributed to the fact that the main reason behind the choice of my topic was a genuine passion for structure and computational tools, as well as a desire to learn and reinforce my skillset through an educational process. Thus, the argumentation for my subject was gradually formed and reinforced as I was getting more familiar with the relevant literature, rather than it being present during the initial thesis topic definition phase.

The effect of time on the degree to which I was familiar, comfortable and confident with my topic was very prominent, particularly during the early stages. Initially, the research objectives reflected my understanding of the importance of my research, as well as the fields that interest me. I envisioned a complete tool, that could be deployed without major adjustments to production; a tool that would revolutionise the way architects think of weaving and its possibilities, thus rendering the concept of woven structures more accessible, realisable and up to date with the latest developments in design and construction.

It would soon become evident that the development of such a tool exceeds my knowledge and time capacity, so I had to narrow my objectives down. The initial workflow concept referred to the whole design process, from the modelling stage to the fabrication stage, including a structural analysis component that serves as a catalyst for the form and sizing optimisation. However, due to time constraints, the fabrication component was eliminated from the research scope and the focus was shifted to modelling and structurally analysing woven structures, setting the foundation for a computationally informed fabrication process.

Surprisingly enough, even the target of proposing a structural analysis methodology was proven to be too broad. Through my literature study, I found out that the most defining aspects of the behaviour of a woven structure were the contact between fibres, that led to frictional forces, and the pre-stressed state of the bent elements. However, due to time constraints and the limitations of the tools I used, I focused mostly on contact modelling and trying to simulate it in a digital platform that does not explicitly support it.

An integral part of this simulation is the definition of the mechanical properties of woven structures as functions of the weave parameters and mechanical properties of the materials used. Towards the end of my thesis research, it became obvious that this is a topic of research that requires deep knowledge about material behaviour, perhaps only possessed by material scientists. It also requires a large budget, as well

as appropriate facilities, for the production and testing of a large number of samples, enough to reveal patterns of correlation between weave parameters and structural behaviour. Finally, it requires dedication and thorough documentation over a period of time larger than the master's thesis timeframe. Unfortunately, as my research lacked most of these factors, and the determination of these mechanical properties was not my sole focus, the experimental part of the initial objective remains largely unexplored and available for future development.

Concerning my approach to research, it remained consistent throughout the whole process, but the degree to which each component of the method eventually contributed to the final result varied from the early planning. More specifically, the research strategies stated in P2 were, indeed, included in the research process; however, experimental research is not as prominent as previously planned, since fabrication was eliminated from the research scope, while simulation research was elevated to the main strategy of my thesis.

During times of uncertainty, my mentors acted as a catalyst on helping me choose the most suitable path for the given timeframe and my interests. The time between our meetings was short enough to facilitate the establishment of reasonable goals for the immediate future and long enough for me to reflect on the conclusions of each meeting and define my own path through trial and error. Furthermore, the stance of my mentors allowed me to explore the topic I chose within the limits of a well-defined educational process.

Most importantly, this thesis did achieve its goal in helping me reinforce and enrich my knowledge and skills. Part of this path of growth was my familiarisation with the weaving technique, its components and inherent strengths, as well as the expansion of my understanding of structural analysis to include methods suitable for handling complex matters, such as contact modelling. Finally, a major part of this process was to become acquainted with research, research methods and planning, which motivated me to strengthen my argumentative and organisational skills, essentially setting the foundation for a potential future PhD dissertation.