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	Nikoletta Christidi
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Studio	
Name / Theme	Sustainable Design Graduation Studio
Teachers / tutors	Serdar Aşut, Peter Eigenraam
Argumentation of choice of the studio	The Sustainable Design Graduation Studio is the studio offered by the Building Technology track. Therefore, my choice of track, supported by my interests and principles surrounding engineering and design, correlates with the main theme of the graduation studio.

Graduation project	
Title of the graduation project	Integrated computational approach for the generation and preliminary structural analysis of woven structures during the early design stage
Goal	
Location:	N/A
The posed problem,	The role of the architect as a "master builder", or someone who possessed a deep knowledge about the materials and ways to use them, disappeared in favour of technical specialisation and knowledge fragmentation (Booth, 2009) after the industrial revolution and the emergence of mass-production. The building process is now divided to various stages of design and implementation, each one of which requires a specialised team of architects, designers, structural engineers and other construction-related disciplines. The distancing of the architect from the actual construction site coincides with the emergence of digital design environments that provide seemingly abundant design choices yet draw the attention away from the fabricability of them. In order to enable the realisation of the concept, a collaboration between architects and structural engineers is often needed. However, what sounds like a collaborative, feedback-based collaborative process is often handled with

	a top-down approach, where the materialisation of the initial design is perceived as the last step of a serial procedure. Often, matter is considered as a homogeneous element that “receives” the form, instead of being an active agent in the design process. The fact that material properties are not included in the set of design parameters during the early design stage halts the uncovering of the full potential of computational design tools, as their role is diminished to simply facilitating the realization of the architect’s vision. An interesting example of the impact of the nature of matter on the form of the final product is weaving, an ancient craft-based technique that takes advantage of the inherent properties of the materials it uses towards a structurally and aesthetically satisfactory result. Known and developed long before the industrial revolution and the invention of synthetic materials, weaving traditionally made use of natural, flexible fibres such as wool, in textile production, and bamboo, in architectural applications. In recent years, the need for energy-efficient, renewable and recyclable materials, which can at the same time enable a broad spectrum of architectural articulation (Menges & Knippers, 2015), has increased the architects’ interest for structures made of natural fibres. The concept of circularity has reinforced the demand for bio-based materials, that are reused and recycled within the material consumption process. Understanding and controlling the complex behaviour of fibrous systems in a digital workspace requires redefining the role of materiality in contemporary design workflows, as a successful fabrication process using fibres is largely dependent on their properties and the method of assembly. In order to optimise the final structure in terms of structural performance and material usage, it is crucial that these two factors are incorporated early in the design phase.
research questions and	Research question: How can an architectural-scale woven structure be modelled and structurally analysed in a parametric setting? Sub-research questions: 1. How can a woven structure be parametrically modelled with integrated material performance information? 2. What are the advantages of parametrically modelling a woven structure?

	3. Which are the factors that significantly affect the structural behaviour of a woven structure? 4. In what way the weave parameters affect the structural behaviour of a woven structure? 5. Which are the limitations of structurally analysing a woven structure in a parametric setting?
design assignment in which these result.	The aim of this thesis is to develop a theoretical framework, as well as propose a digital workflow, to facilitate the generation and preliminary structural analysis of an architectural-scale woven structure and set the foundations for a computationally informed fabrication process. The digital workflow will lead to the creation of a digital tool, serving as a proof of concept.

Process

Method description

This thesis is intended to be a research by design, as it aims to generate, justify and evaluate a methodology which will be applied on an architectural case study. The case study will be the design of a woven pavilion which will serve as an exhibition space for the craft of weaving. It will be both exploratory, as it will investigate the potential of weaving and generate knowledge that goes beyond the existing literature, and descriptive, as it will illustrate and make use of the existing knowledge surrounding weaving applications in other engineering fields.

The structure of the case study is linear-analytic, following the traditional outline for an academic research study (Wang & Groat, 2013). It starts with setting the research framework through a problem statement, a definition of the research question and methodology and a literature review. Afterwards come the descriptive and prescriptive stages of the research, which include findings, and subsequently knowledge generation, as well as discussion of these findings. Finally, the conclusions summarize the process and evaluate the research content.

For such a complex architecture and engineering-wise topic, a combination of research strategies needs to be applied, in an attempt to collect, analyse and use a large amount of often disparate data. First of all, a historical research is deemed essential in order to investigate weaving as a traditional building technique, as well as different ways of traditionally working with fibrous materials. A small part of the research has to also be qualitative, as understanding the weave architecture often happens intuitively, in a descriptive and approximating manner, through observation and sketches.

In fact, as part of the objective of this thesis is to make the transition from a qualitative or empirical description of woven structures by architects to the understanding and reproduction of their mechanisms, two more research strategies will be applied, mainly during the second half of the research: experimental and simulation research. Experimental research will focus on causality, attempting to showcase the correlation between variables of the weave architecture, such as the fibre thickness and density, and the structural performance of a selected woven module. For this purpose, part of the design object will be fabricated and tested in the laboratory.

Finally, the simulation research strategy focuses on the generation of a model, in this case a digital 3D representation of the design object, which will provide us with knowledge about the real-world conditions without actually recreating those conditions. The simulations done with the help of this model are not expected to predict future behaviour, but rather to reveal patterns that will lead to a better understanding of the analysed system. In a later phase, the comparison of the simulation and physical testing results will facilitate the evaluation of the simulation method, which is part of the thesis objectives.

Literature and general practical preference

Weaving is a technique acknowledged as one of the oldest surviving crafts, with its most antique artefacts being dated to between 10,000 and 12,000 years old (Naboni & Breseghello, 2016). The use of weaving in architecture was first described by the famous German architect and art critic Gottfried Semper in 1851 in his book "The four Elements of Architecture". According to Semper, the walls of the ancient houses were merely woven "mats" instead of solid structures (Semper, 1989). Weaving fibrous materials to create a shelter has been an architectural practice that spans across different civilizations and locations, such as New Zealand, Ethiopia and Northern India.

Concerning the reinvention of weaving in contemporary architecture, Naboni and Breseghello distinguish three approaches: the first one mimics the weaving patterns as an aesthetical element, the second one applies traditional woven materials on the façade, while the third one explores the potential of weaving in the generation of complex architectural forms. The third approach is the one followed by the writers in their "Weaving Enclosure" project, as well as by Georgiou M., Georgiou O. and Kwok T. in their "God's Eye" pavilion (2014) and architects EMBT in collaboration with structural engineers MC2 for the Spanish Pavilion for the Expo 2010, in Shanghai (Calzón & Jiménez, 2010).

The present thesis also belongs to the third category, as it aims to showcase the potential of weaving as a technique that exploits the inherent structural properties of the fibrous materials that are used; its emergent structural properties are attributed to the frictional and bending resistance generated by the interlacing fibres. Therefore, it is critical for this research to define weaving as "forming by interlacing threads, yarns, strands, or strips of some material" (definition of weaving," 2018), where the keyword is "interlacing", while the presence of at least two distinct sets of threads is implied.

Despite their deviation from the strict definition of weaving deriving mainly from the textile industry, projects that reinterpret the weaving mechanisms or interpret the term more loosely still provide valuable insight into the subject, especially on a theoretical level. Rizal Muslimin focuses on the combination of a computational design framework with traditional principles for the development of affordable fabrication techniques (Muslimin, 2010), while the documentation of the ICD/ITKE "woven" pavilions (2013-14, 2014-15, 2016-17) contributes to the literature on matters such as the active role of matter in the form generation process, the emergence of fibrous structures in modern-day architecture and the need for computationally informed design and fabrication processes.

In order to understand the weave architecture, terminology will be based on publications about textiles and composites, such as papers drawn from the journals "Composites Science and Technology" and "Composites Part A: Applied Science and Manufacturing". These papers contain extensive references on relative literature and illustrate the need for an adequate modelling method of woven structures, as the accurate representation of their complex internal architectures facilitates the understanding of their overall structural properties. For instance, the widely used 3D mosaic or "brick" method for predicting the behaviour of woven composite structure, which is based on the splitting of the structure into "3D voxel" finite elements, lacks information on local deformation and the detailed architectural features of the composite (Mahadik & Hallett, 2010).

For the definition of the input parameters that will affect the computational weave model and subsequently its structural behaviour, the main source of the terminology was the extensive article "Failure Analysis of Woven and Braided Fabric Reinforced Composites", written by Rajiv A. Naik and published in 1995 in the "Journal of Composite Materials". Despite the fact that it is not recent, it is referenced often in the composites literature. According to this article, among the most governing parameters that affect the woven structure stiffness and strength are weave parameters such as weave architecture (patterns) and yarn spacing, laminate parameters such as stacking orientations, and material parameters such as yarn stiffness (Naik, 1995). As these refer to the internal structure of a composite material, it will be investigated if and how they can be applied to the components of an architectural scale woven object.

Reflection

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

The reinvention of a traditional craft-based technique, made possible through an integrated computational workflow, aims to contribute to the building industry by highlighting not only a new way of building structures, but also a new way of thinking about structures. Therefore, the graduation topic is deemed relevant to the Building Technology master track, as it introduces the concept of materiality and its properties being an integral part of the architectural process, as well as to the principles of the Sustainable Design Graduation Studio.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

There are two major movements emerging in the architectural field in the past few years: these are the rise of the new technologies and advancements in design and construction, especially through the increasingly popular use of BIM (Building Information Modelling) software and parametric tools, and the need for a paradigm shift towards more sustainable buildings.

Not surprisingly, a combination of these two movements can be used as a catalyst to shape the future of the building industry. The necessity for lightweight, environmentally friendly, recyclable and easy to disassemble structures has led engineers to reconsider the use of natural fibrous materials such as bamboo for their new projects. However, the transition between building with conventional, largely homogeneous materials to building with fibres is not an easy one, as the behaviour of the latter is often unpredictable, while their mechanical properties are also evidently different to the ones of conventional materials. In this context, the use of computational tools becomes imperative, as it enables the engineers to simulate the mechanics of the new-found systems and approach a prediction of their behaviour, leading to safer structures. This is also the basic premise and the starting point of the present thesis.

References

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