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	Lucy Elizabeth Flieger
Student number	5680387

Studio		
Name / Theme	Building Technology Graduation Studio	
Main mentor	Dr. Stijn Brancart	Structural Design & Mechanics (Building Technology)
Second mentor	Dr. Mariana Popescu	Civil Engineering
Argumentation of choice of the studio	I elected to work with these professors because of my interest in structural design and textile design, and specifically in CNC-knitted flexible formwork. This graduation project would not be possible without Dr. Popescu due to her expertise in CNC knitting and flexible formwork.	

Graduation project	
Title of the graduation project	Flexible Formwork: A textile-centric approach to CNC-knitted flexible formwork design
Goal	
Location:	Not currently applicable
The posed problem,	(see below)
research questions and	(see below)
design assignment in which these result.	(see below)

[Problem Statement]:

Traditional methods of building with concrete are wasteful, polluting, and often structurally inefficient. Despite the amorphous properties of concrete, we force it into rigid formworks that in turn produce heavy, orthogonal elements of high material volume. Flexible formwork, alternatively, makes it possible to shape concrete into complex forms that exploit its compressive capacity and align more closely with natural force flows in the material. Within the field of flexible formwork research, CNC knitting has recently emerged as an innovative technology to manufacture flexible membranes, which offer significant structural and formal advantages inherent to knit textiles. While significant research has been conducted into the potential role of CNC

knit textiles as flexible formwork, more effort is required to understand how different knit patterns affect the physical behavior of the textile membrane under hydrostatic loading. This research will support a more precise and informed design process for creating building elements from CNC knit flexible formwork. Further, the reusability of CNC knit formwork membranes has not been examined in great detail. Understanding the impact of the knit pattern on a textile's reusability as a flexible mold is essential to developing this technology's potential as a low-waste and low-material construction practice.

[Research Questions]:

(General)
How can the use of CNC knitted textiles as flexible formwork improve the way we build with concrete for architectural applications and shift construction industry practices towards lighter and more sustainable structures?

(Specific)

1. How do different knit patterns affect the behavior of a CNC knit textile mold and therefore the physical properties of the cast concrete element?

2. Can knit patterns be categorized by their impact on the properties of a concrete element produced with a CNC knit textile mold?

3. What is the impact of the knit pattern on potential reuse of the same CNC knit textile formwork for 1 or multiple permutations of a building element?

[Design Assignment]:

In employing flexible formwork as a construction method for building with concrete, new forms with architectural applications can emerge. By focusing in particular on how the knit patterns affect the and behavior of the textile mold and the resulting form of concrete, an important knowledge base can be developed. With this knowledge, informed combinations of knit patterns can be applied to a flexible formwork textile toward the design of building elements with particular formal aspects or functionalities. As a result of this investigation, the intended output is the development of one or multiple architectural building elements. Further, the influence of the knit patterns on the reusability of the textile mold will be explored. The design assignment is therefore two-fold, including the formal design of building elements and the design of a low-waste, reusable fabrication method.

Process

Method description

The project will begin with a literature review as described in the following section.

Following the literature review, a physical repository of swatches will be knitted on a Steiger 9 flatbed weft CNC knitting machine in the faculty of Civil Engineering at TU

Delft. The swatches will catalogue pattern type, loop dimension, machine gauge, knitting point, yarn type, etc. The swatches will be photographed and measured at rest and in axial/bi-axial tension to visually document their behavior. The patterns for testing will be chosen from various sources in the literature review as well as the author's own knowledge of knitting. Currently, the patterns are being developed as bitmap files in Python for translation to the Steiger 9 software, although this workflow may change. Following swatch production and documentation, the swatches will undergo cement coating tests that will study physical deformations under hydrostatic loading, overall permeability/capillary action, and degree of adhesion toward a potential for reuse. Where applicable, some swatches should be tested multiple times to establish which patterns are 'most' reusable.

In the next phase, multiple patterns will be combined into larger swatches to understand what kinds of building elements/forms can be designed through the synthesis of multiple patterns and the overall shaping of the textile. Certain principles extracted from the literature review will guide the nature of the forms tested with a potential focus on funicular compression forms such as catenary arches, vaults, or hyperbolic paraboloids. However, the knowledge gained during the creation of the repository should primarily influence the formal explorations.

Through these explorations, certain pattern-dependent formal characteristics of the cast concrete elements might emerge which would suggest a practical application as an architectural building element. Also, the degree of adhesion and reusability opportunities per knit pattern should become more clear. From this knowledge, a more detailed building element(s) for architectural applications will be developed as a physical prototype and documented in drawings that explain its use potential. Finally, a critical analysis of the results will be performed, focusing on advantages and disadvantages, conclusions from the experiments, application within the construction industry, and other topics not yet determined.

This research is part of the Tailored Materiality research group led by Dr. Mariana Popescu at TU Delft. Therefore, there are opportunities for collaboration and knowledge-sharing between other students and researchers that could influence this work and vice versa.

Literature and general practical references

The literature review will situate the project within the appropriate environmental, technological, and research contexts. The relevance of CNC knitted flexible formwork will be demonstrated through a discussion of its technological significance, structural and architectural design innovation, and considerable material and cost savings as compared to traditional formwork methods. Current barriers to adoption in the broader construction industry will also be discussed. Further, a state-of-the-art review will address (1) the latest applications of CNC knitting technology, (2) current computational methods for creating CNC knitting patterns, (3) a brief overview of

flexible formwork throughout history, and (4) connections between flexible mold typologies and specific building elements. The unique cooperation of complex funicular forms, concrete material properties, and CNC knit formwork will also be discussed throughout. The primary goal of the literature review is to understand the current state of this emerging field and to identify areas where more research must be conducted. From initial study, these areas include a more detailed study of knit patterns as they relate to formal characteristics and reusability potential.

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)?

Of the four main topics within Building Technology, this topics relates primarily to the structural design and mechanics group. This graduation project will address themes of sustainability, structural design, building component design, and likely some computational design. It will take an exploratory approach to the design of a building element or element(s) using an innovative building technology. The building technology master track emphasizes the 'design of innovative and sustainable building components and their integration into the built environment.' Therefore, this graduation project is highly related to the Building Technology track within the MsC AUBS programme.

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

Sustainability

Cement and concrete production accounts for approximately 7% of global CO_2 emissions. Current fabrication methods for building with concrete are materially intensive, wasteful, and polluting. Flexible formwork presents an opportunity to drastically reduce the amount of material required in both the fabrication process and resulting building elements.

Technical and Scientific Contribution

Although the use of flexible formworks is not new, the development of CNC knit textiles as the membrane in flexible formwork is a fairly recent field of research. Few references exist that describe the specific implications of knit patterning on form creation nor on the potential for reusability. Until recently, CNC knitting technology has mostly been restricted to the garment industry and has not been broadly integrated into mainstream construction practice. While many barriers still exist to widescale adoption, this graduation project will contribute to the further development of this emerging technology for the design and construction industries.