M.Sc. Programme
Department of Architecture KIT
Seminar
Winter Semester 2021/2022
LV1720807

TEXTILE STEEL

Course offered by:
DDF - Professur Digital Design and Fabrication
IEB - Institute of Design and Construction Engineering

Team:
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DDF
ddf.ieb.kit.edu

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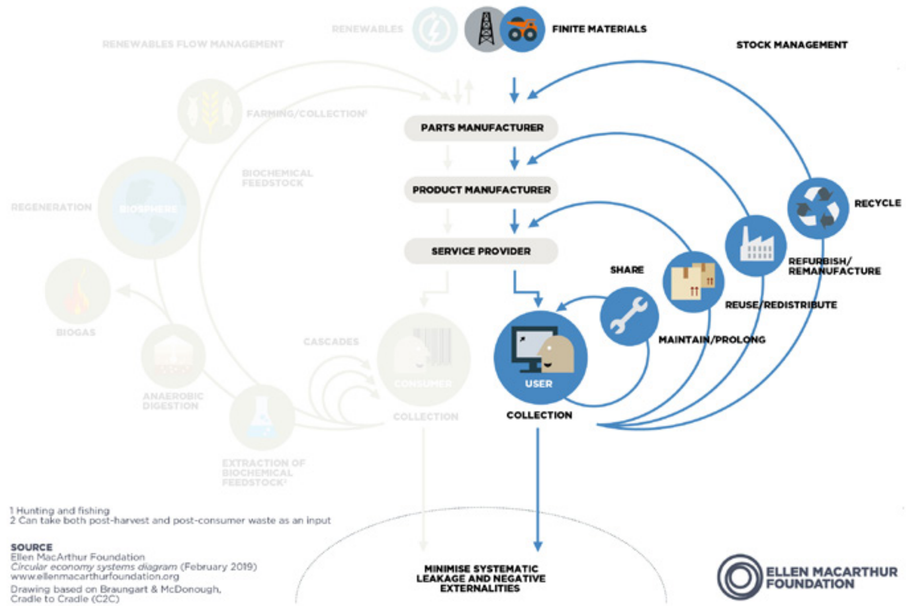
01 INTRODUCTION AND CONTEXT



Circular economy diagram by Ellen MacArthur Foundation, here highlighting the technical cycle

Steel is a material that can be recycled without loss of properties, a huge potential for urban mining and the circular economy. Yet, the demand for new steel is higher than the offer of secondary raw material. The construction industry accounts for 50% of global steel production and consumes more than 3 billion tonnes of raw materials.

Steel is therefore a perfect case study for the implementation of circular material cycles in construction. Based on the principles of the technical cycle as described in the concept of circular economy by the Ellen MacArthur Foundation, the aim should be to avoid the extraction of materials through the primary route and focus instead on the use of secondary raw material, which can be extracted through urban mining.

However, the recycled products must use the material more efficiently: recycling a conventional steel component into a multitude of components with locally tailored material distribution, while delivering the same function and strength as those created by traditional methods, could enable the industry to meet growing global demand.

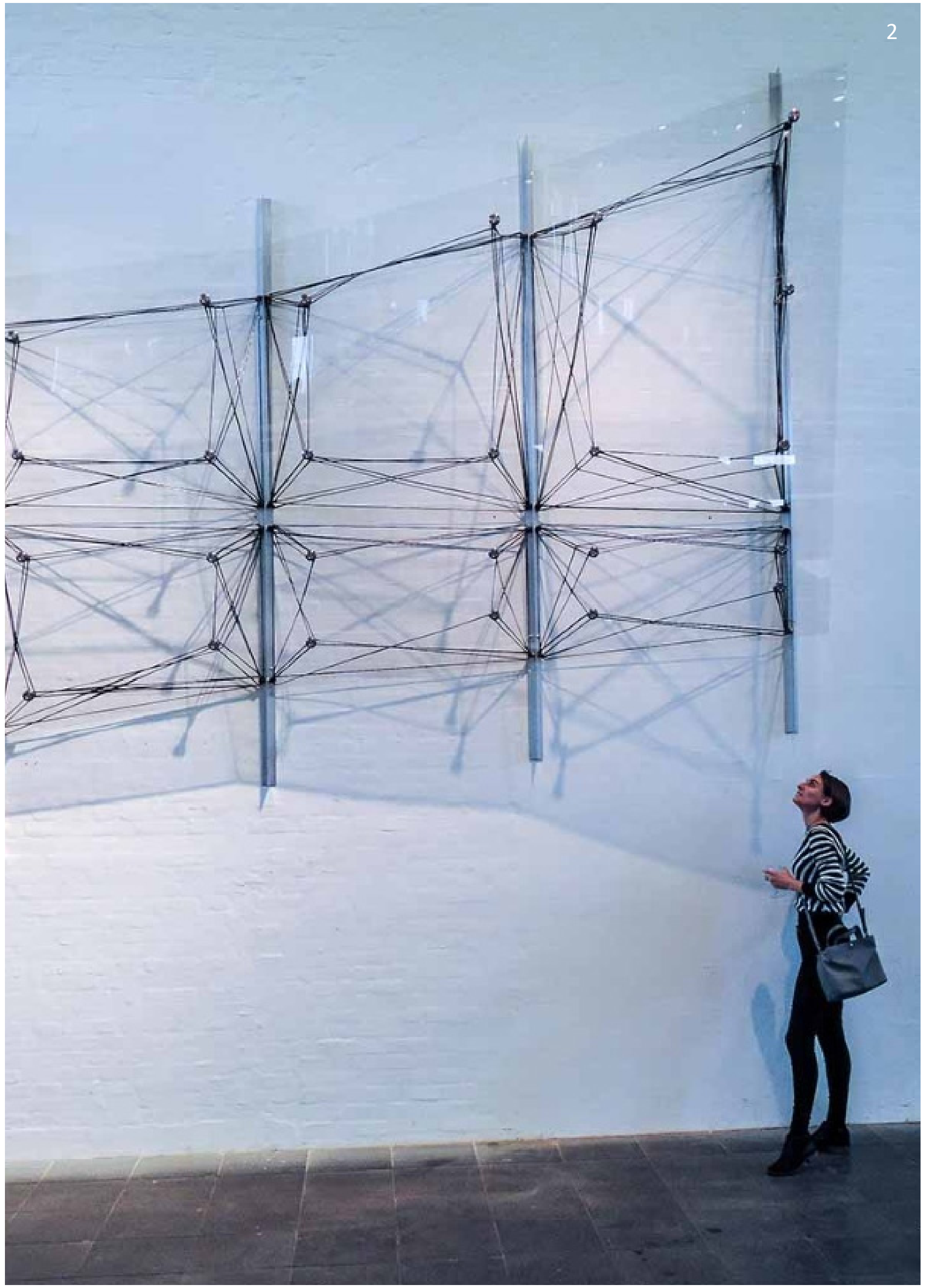
In this scenario, digital design and fabrication

1

Example of material efficiency optimisation for structural building elements

processes could enable the shift from the serial production of identical parts to the custom production of material-optimized components.

Textile steel is one of the topics being explored by the Professur Digital Design and Fabrication (DDF) at KIT, which focuses on computational design and digital fabrication processes that enable novel concepts for circular economy in construction.



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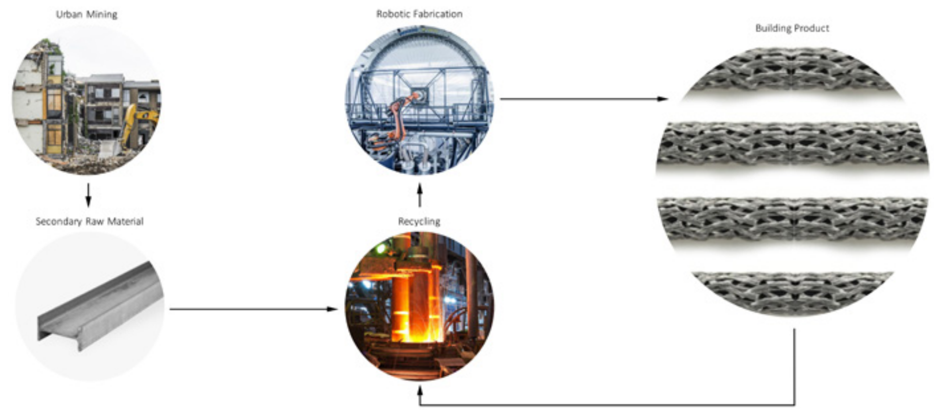
Example of implementation of textile techniques for material-efficient structures for facade panels

02 AIM



Goal of Textile Steel: recycling one traditional building component to create multiple, material-efficient elements

Textile Steel investigates how to apply innovative processes for digital textile production (braiding, 3d knitting, etc.) to manufacture complex, large-format and resource-efficient steel building components, made of recycled secondary building materials.

By applying fabrication concepts from textile technology, we will experimentally redesign a series of steel building elements with locally tailored material distribution, based on the interplay between geometry and structural behaviour.

The goal of the seminar is to realise two to three experimental prototypes made of steel wire and yarn, that showcase a novel concept for implementing circular digital construction. The final prototypes will be displayed together as a catalogue demonstrating a range of applications and concepts in different structural and design contexts.

03 METHODS

Focusing on hands-on explorations and concept models, the seminar employs a design-through-making process, in which prototyping iterations are used as a medium to explore ideas related to materiality, form, systems and structure.

At the intersection of research and teaching, the seminar Textile Steel allows students to develop their own concepts, starting from an understanding of materials and techniques and to question and rethink existing methods.

Guided through a series of development phases, the seminar will begin with investigations on processes, techniques and material properties to provide students with the technical foundations for the seminar. The second phase entails the construction of exploratory prototypes to iteratively refine a technique for material-efficient building components, in teams of two to three. At the end of the seminar, students will fabricate physical prototypes on a 1:1 scale, which showcase the function and concept intent.

A series of skill-building tutorials at the beginning of the semester introduces students to selected topics, processes and workflows in digital design and fabrication, although their use is optional. No pre-knowledge is required.

04 DEVELOPMENT PHASES

DEVELOPMENT PHASE 01: Research

DEVELOPMENT PHASE 02: Exploratory prototyping

DEVELOPMENT PHASE 03: 1:1 Prototype

PHASE 01
RESEARCH

weeks 1 - 3

TEXTILE TECHNIQUES

ex. braiding

DIGITAL FABRICATION TECHNIQUES

MATERIAL RESEARCH

ex. types of steel; coating and corrosion

STEEL MECH. TECHNIQUES

ex. mechanical interlocking vs. welding

CONTEXTUALISATION

Research-design approach

RHINO AND GRASSHOPPER TUTORIALS

- basic 3d modelling in Rhino
- basic workflows in grasshopper
- structural analysis tools in gh (karamba, millipede, ..)

PHASE 02
EXPLORATORY PROTOTYPING

weeks 4 - 8

HANDS-ON EXPLORATIONS

smaller scale (ex. 1:2 / 1:5)

TECHNIQUE 1

ex. wire + frame

TECHNIQUE 2

ex. yarn + hanging

TECHNIQUE 3

ex. wire + incremental stiffening

SELECTION OF BUILDING COMPONENT

(ex. facade panel, beam, column)

ANALYSIS FOR DIFFERENTIATION IN MATERIAL ARRANGEMENT

(ex. differentiation based on different supports and loads positions; differentiation through Karamba)

PHASE 03
1:1 PROTOTYPE

weeks 9 - 14

FINAL PROTOTYPE

scale 1:1

YARN/WIRE TYPE 1

ex. wire of low stiffness

YARN/WIRE TYPE 2

ex. medium stiffness

YARN/WIRE TYPE 3

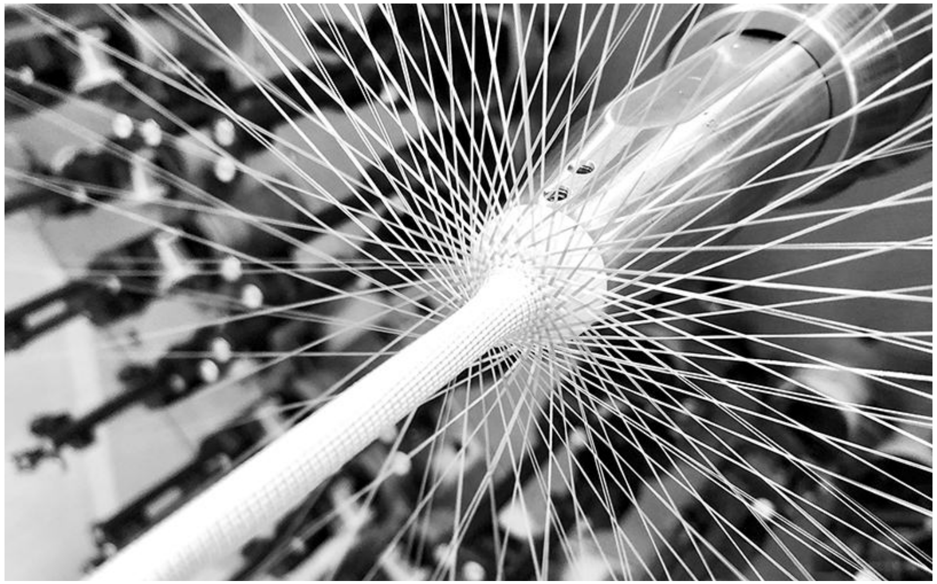
ex. high stiffness

DEVELOPMENT PHASE 01:

Research

Students will investigate a varied range of textile processes, digital fabrication techniques, with a lookout for manufacturing and processing techniques that enable resource-efficient, functional arrangements, as well as material properties and mechanical techniques for steel. This will create a reliable repertoire on which to base the following development phases.

This first stage will be complemented by a contextualisation introduction by the tutors and skill-building tutorials for Rhino3d and Grasshopper, which are focused on specific cases related to the seminar's topic.

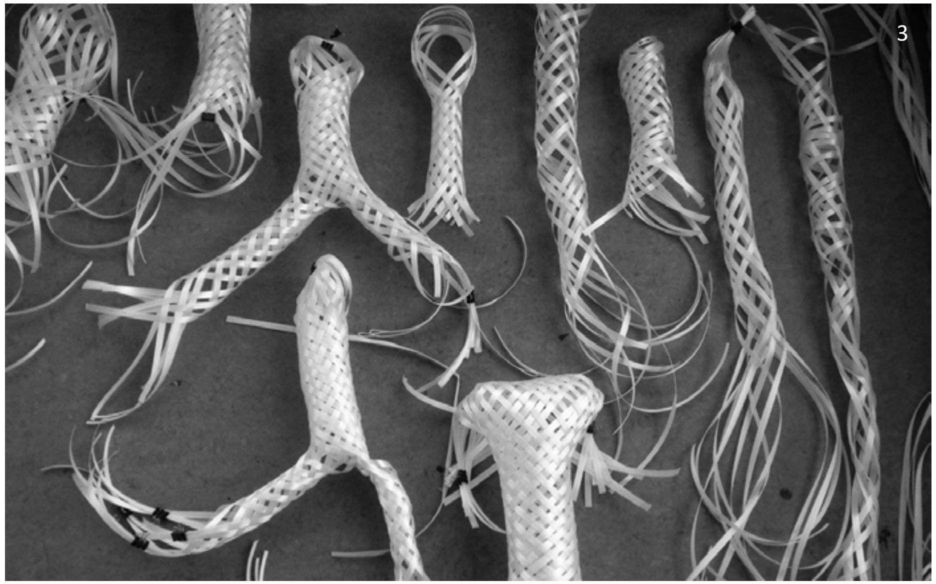


DEVELOPMENT PHASE 02:

Exploratory prototyping

Exploratory prototypes are small experiments that can be used to gain insights into materials, systems and structures as well as test key assumptions, strengths and weaknesses of a concept. Produced in rapid iterations, they help discover further research questions and solve them in the next evolution, but also narrow the investigation through research-based decision-making.

Aided by the supervision of a mechanical engineer, we will explore different textile techniques and underlying production concepts for material-efficient building components.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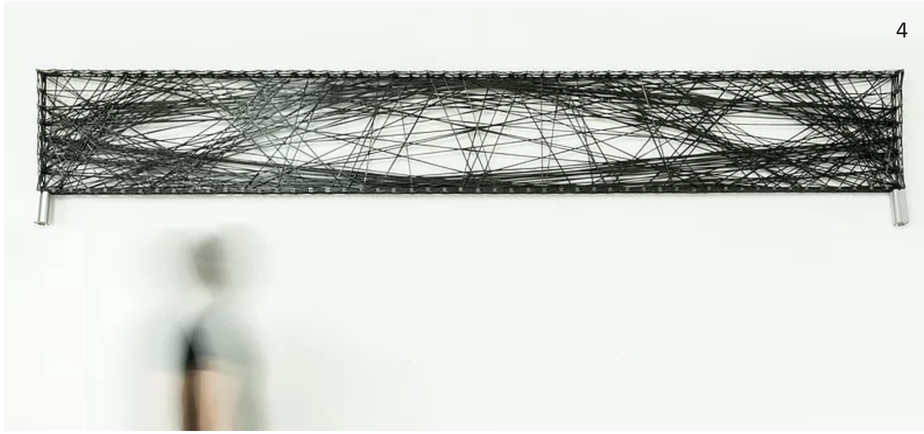
DEVELOPMENT PHASE 03:

1:1 Prototype

In the third phase, the research is driven by concept developments for the bottom-up translation of the techniques and production concepts from the previous stage into material-efficient building components based on simple structural models.

Within the limited scope of a selected building element (e.g. column, façade panel etc.), each group will carry out early qualitative design explorations for loading conditions to inform the material layout in high resolution and cross-reference them for potential differentiation with the textile techniques investigated thus far.

This will result in a physical 1:1 scale, handcrafted prototype (min. 1x1 metre), made of steel wire and yarn and produced according to the techniques explored in the previous phases. The final prototypes will serve as a proof of concept at the intersection of research and teaching and validate the architectural potential. These models might be developed as full-scale digital fabrication in the following semesters.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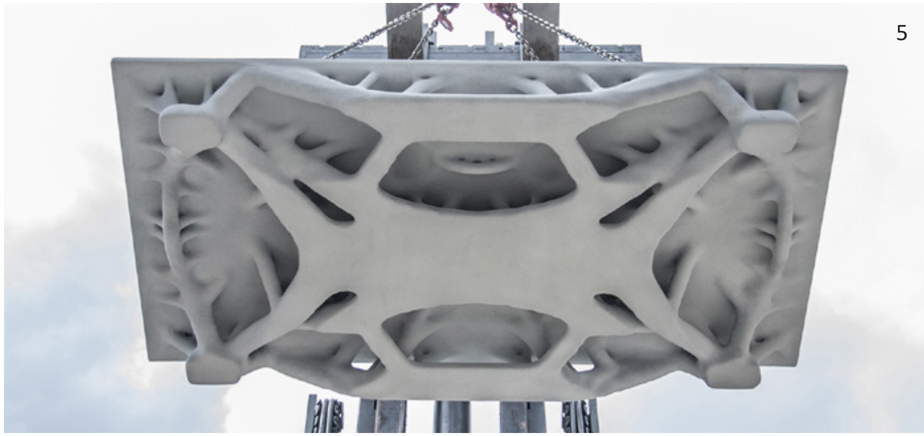
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05 DELIVERABLES

FINAL EXAMINATION

FINAL PRESENTATION – 01.03.2022
Group presentation – max. 20 minutes

- Storyline of each project, from research to design
- exploratory prototypes
- 1:1 prototype
- posters showing the process, technique and structural design of building component

PER DEVELOPMENT PHASE

DEVELOPMENT PHASE 01: Research
02.11.2021 - Individual presentation – 5 minutes per person

- Presentation on the results of the research
  Followed by group discussion on findings and relevance for further developments

DEVELOPMENT PHASE 02: Exploratory prototyping
07.12.2021 Group presentation (2-3 people) – 20 minutes per group

- Material samples, random findings and comparative studies (e.g. how different textile patterns give different stiffness to materials)

DEVELOPMENT PHASE 03: 1:1 prototype
01.02.2022 Group presentation (4-5 people) – 15 minutes per group

- Structural design of building component and fabrication strategy for 1:1 prototype
- 1:1 prototype (min. 1m x 1m) progress

06 SCHEDULE

Seminar dates:
Tuesday, 12:00 pm – 1:30 pm

Seminar room:
Studio room 134- 1st floor- Building 20.40

Month	KW	Week	Nr.	Day	Studio dates	Studio phases
October	42	18.10 -24.10	1	Tu.	19.10 Intro & workshop	
	43	25.10 - 30.10	2	Tu.	26.10 Desk crit & workshop	**Development phase 01: Research**
November	44	01.11 - 07.11	3	Tu.	02.11 Presentation	
	45	08.11 - 14.11	4	Tu.	09.11 Desk crit & workshop	
	46	15.11 - 21.11	5	Tu.	16.11 Desk crit	
	47	22.11 - 28.11	6	Tu.	23.11 Desk crit	**Development phase 02: Exploratory prototyping**
December	48	29.11 - 05.12	7	Tu.	30.11 Desk crit	
	49	06.12 - 12.12	8	Tu.	07.12 Presentation	
	50	13.12 - 19.12	9	Tu.	14.12 Desk crit	
	51	20.12 - 26.12	10	Tu.	21.12 Desk crit	
January	2	10.01 - 16.01	11	Tu.	11.01 Desk crit	
	3	17.01 - 23.01	12	Tu.	18.01 Desk crit	**Development phase 03: 1:1 Prototype**
	4	24.01 - 30.01	13	Tu.	25.01 Desk crit	
February	5	31.01 - 06.02	14	Tu.	01.02 Presentation	
	6	07.02 - 13.02			Magic Week	
	7	14.02 - 20.02			Präsentationen Entwürfe	**Presentation preparation**
	8	21.02 - 27.02			Prüfungen/Abgaben Wahlmodule	
March	9	28.02 - 06.03	15	Tu.	01.03 Final presentation	

07 REFERENCES

Images

1 https://www.arup.com/-/media/arup/files/pdf-downloads/additive_manufacturing_report_for_iass_21015.pdf

2 https://www.itke.uni-stuttgart.de/research/built-projects/fibre-facade-prototype/

3 https://www.florarobotica.eu/?page_id=21598

4 https://www.itke.uni-stuttgart.de/research/current-research-projects/virtual-prototyping-frp-innochain-esr08/

5 https://dbt.arch.ethz.ch/project/topology-optimisation-concrete-slab/

6 https://dbt.arch.ethz.ch/project/concrete-choreography/