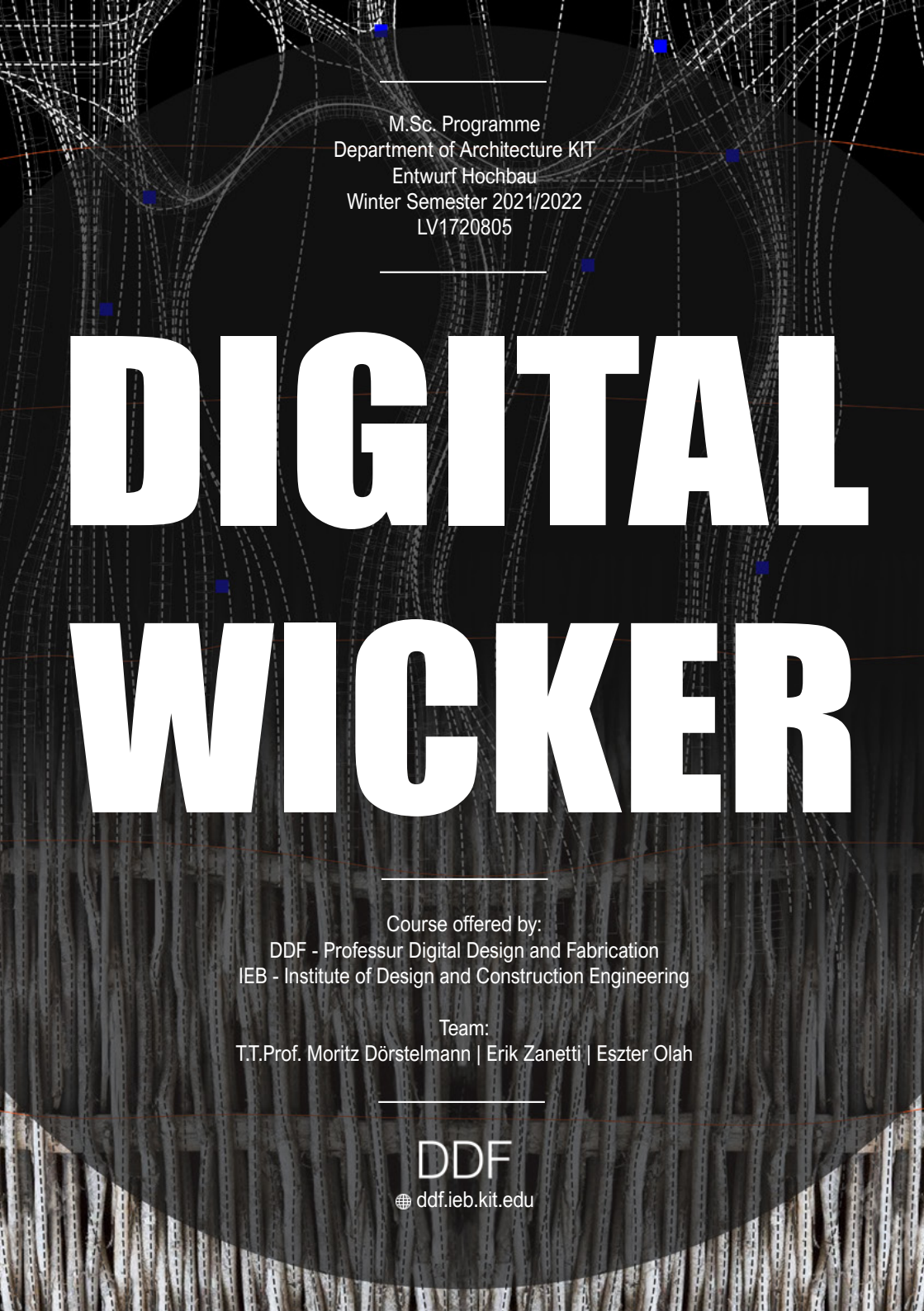


M.Sc. Programme
Department of Architecture KIT
Entwurf Hochbau
Winter Semester 2021/2022
LV1720805

DIGITAL WICKER

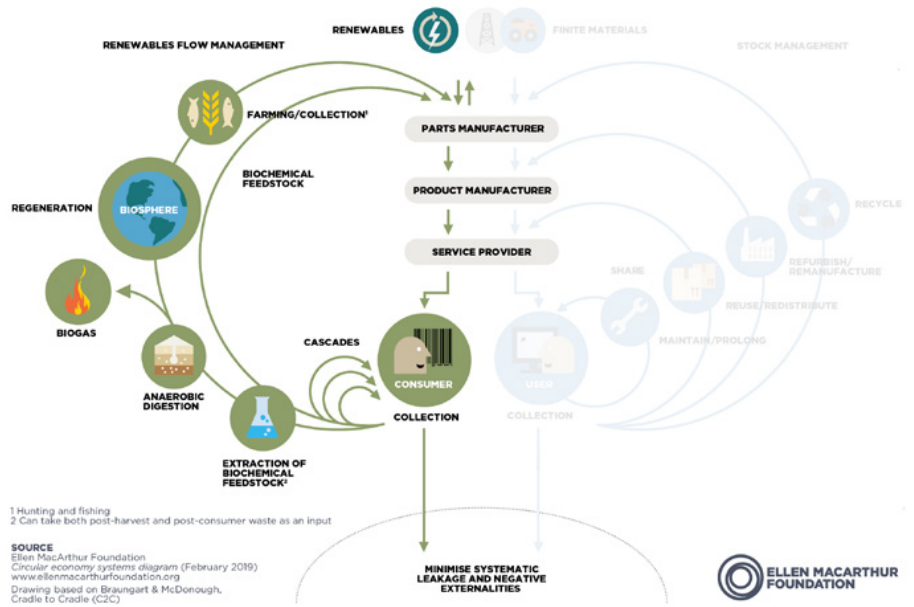
Course offered by:
DDF - Professur Digital Design and Fabrication
IEB - Institute of Design and Construction Engineering

Team:
T.T.Prof. Moritz Dörstelmann | Erik Zanetti | Eszter Olah

DDF
ddf.ieb.kit.edu

CONTENTS

01 INTRODUCTION AND CONTEXT



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

The building sector is responsible for more than a third of the global resource consumption, making it a key sector for the global transformation towards a circular economy (Klep, 2015).

A paradigm shift towards natural and regenerative material sources and the implementation of biological cycles represent a major opportunity for the construction industry to curtail the depletion of raw materials.

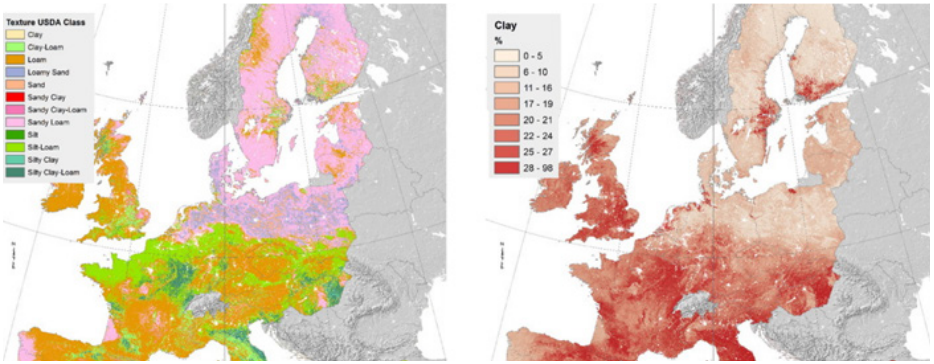
Digital design and fabrication methods can address these global challenges and enable novel concepts of digital circular construction through tailored processes for renewable and natural materials.

“Digital Wicker”

Wicker weaving is a technique where long thin sticks, stems or reeds are woven together to make works such as baskets and furniture. It represents an important analogy of how to exploit geometry and techniques, especially textile, to give structural stiffness not otherwise inherent in the materials.

Typical of traditional manufacturing, “wicker” expresses the intention of looking back at local, renewable materials and techniques that used to be part of the architectural and construction repertoire but have been sidelined in the first industrial revolution. Their use as a building method is exemplified by the European vernacular “wattle and daub” (Flechtwerkwand in German), in which renewable and natural materials are combined into a low-impact sustainable composite.

In light of the fourth industrial revolution, which is envisioned as a fusion of technologies blurring the lines between the physical, digital and biological spheres (Schwab, 2017), digital design and fabrication can sustain the industrialisation of natural materials thanks



Prevalent types of soils and clay percentage in soil in Europe

to their flexibility and versatility. In particular, they can accommodate for deviations and abnormalities, which currently represent one of the biggest obstacles in standardised serial production systems. Digital fabrication techniques can significantly increase the performance of traditional building materials such as clay, wood and natural fibres by combining them into new material systems with functionally graded properties.

Besides, traditional construction methods, which made use of natural materials, are often not structurally scalable and, due to their complexity and dependence on craftsmanship know-how, cannot be used economically on a large scale. Digital fabrication can enable the large-scale, automated production of such components, and thus their implementation in construction, both in terms of construction technology and economics.

Circular Economy in Construction - the biological cycle

As described by Ellen MacArthur Foundation, the concept of circular economy distinguishes between technical and biological cycles. “Digital Wicker” plays within the biological cycle: renewable and plant-based resources are used, regenerated and returned to the biosphere.

While other sectors, particularly the food industry, have already reflected this urgency of change, the construction industry is still “permeated by a number of detrimental factors

Use of rapidly renewable materials and earth-based materials in vernacular repertoire

Robotic fabrication implemented in textile industry

such as the use of high impact materials, non-reversible building solutions, low-efficiency processes and manufacturing”(Cara et al., 2017). The development and use of natural materials, and their combinations into hybrid materials, would trigger a new paradigm for construction.

Digital Design and Fabrication

Digital Design and Fabrication have allowed construction and architecture to shift the focus in construction from serial production of identical parts to individualised mass production of bespoke parts, prefabricated or on-site, and create new design methods that aim for functional integration and performance-oriented approaches.

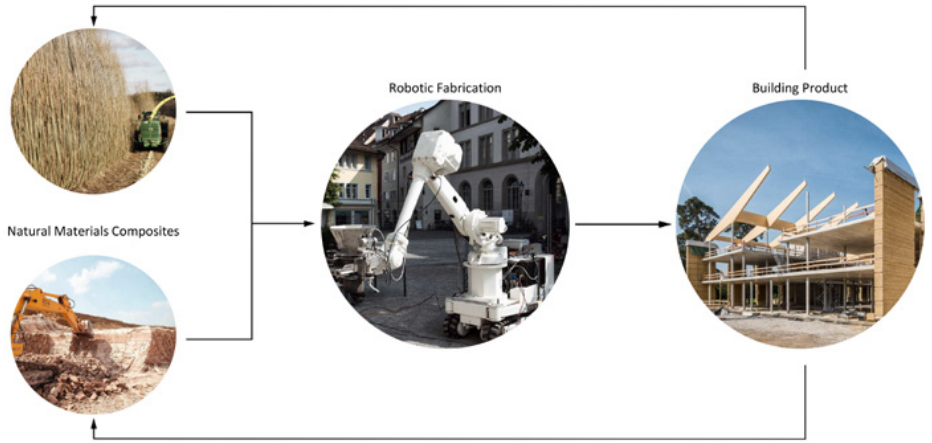
The increased degree of control and versatility allows the construction of complex structures that go beyond what has traditionally been possible and the automation of construction processes can counteract the issues of an ageing workforce, the decline of craftsmanship and lack of skilled labour.

Professur Digital Design and Fabrication

Digital Wicker is an integral part of the research topics of the Professur Digital Design and Fabrication (DDF) at KIT, which explores computational design and digital fabrication processes that enable novel concepts for circular economy in construction

Diagram showing the positioning of DDF’s research

02 AIM



Overarching goal of Digital Wicker

The studio “Digital Wicker” aims at developing circular construction solutions that are sustainable, circular and locally sourced by combining 3D braided structures made of rapidly renewable materials (e.g. willow, cottonwood etc.) with extruded or additively manufactured alternatives to conventional aggregates (e.g. loam or clay), resulting in hybrid materials with functionally-graded propertied.

This is implemented through the design of a research demonstrator, which will be realised at the “Das Fest” festival in Karlsruhe in the following semester. The design of this experimental structure is based on an integrated concept that considers design, digital fabrication, assembly and reconfiguration, as well as disassembly and recycling. It will serve as a base to conceptualise the transfer of such construction solutions to large-scale architectural and construction concepts, through automated production in the form of modular, reusable components or as structures fabricated on-site.

A 1:1 scale proof-of-concept prototype will showcase the tailored architectural solution resulting from research-based exploratory prototypes, in which material behaviour, manufacturing, aesthetics, structural capabilities as well as technical solutions and environmental performance are explored.

03 METHODS

At the intersection of research and teaching, the studio offers students the opportunity to develop their own concepts and inform them through an understanding of material, construction and digital fabrication processes.

The studio uses a series of development phases (see chapter 04), meant to guide the students through the implementation of the studio methodology, starting from materiality and fabrication and leading to design and large-scale architectural and construction applications.

A first research on specific topics of the studio, based on five overarching fields, will be conducted by students individually. Subsequently, students will merge into groups of 2-3 people, combining knowledge from the different fields and develop initial concepts through exploratory physical prototypes, which are used as a medium to explore ideas related to materiality and fabrication. Based on a research-led and design-through-making approach, these experiments are carried out in rapid iterations, with rigorous and iterative refinements.

The architectural potential of these concepts is then explored by groups of 4-5 people through design iterations for experimental structures and a research demonstrator, and a final full-scale prototype, merging the knowledge developed in the previous phases.

The methodology of the studio is meant to create a novel design and construction repertoire, while progressively selecting the best concept.

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

04 DEVELOPMENT PHASES

WS 21-22

SS 22

RESEARCH & DESIGN

FABRICATION & IMPLEMENTATION

PHASE 01
RESEARCH ON NATURAL MATERIALS AND DIGITAL FABRICATION TECHNIQUES

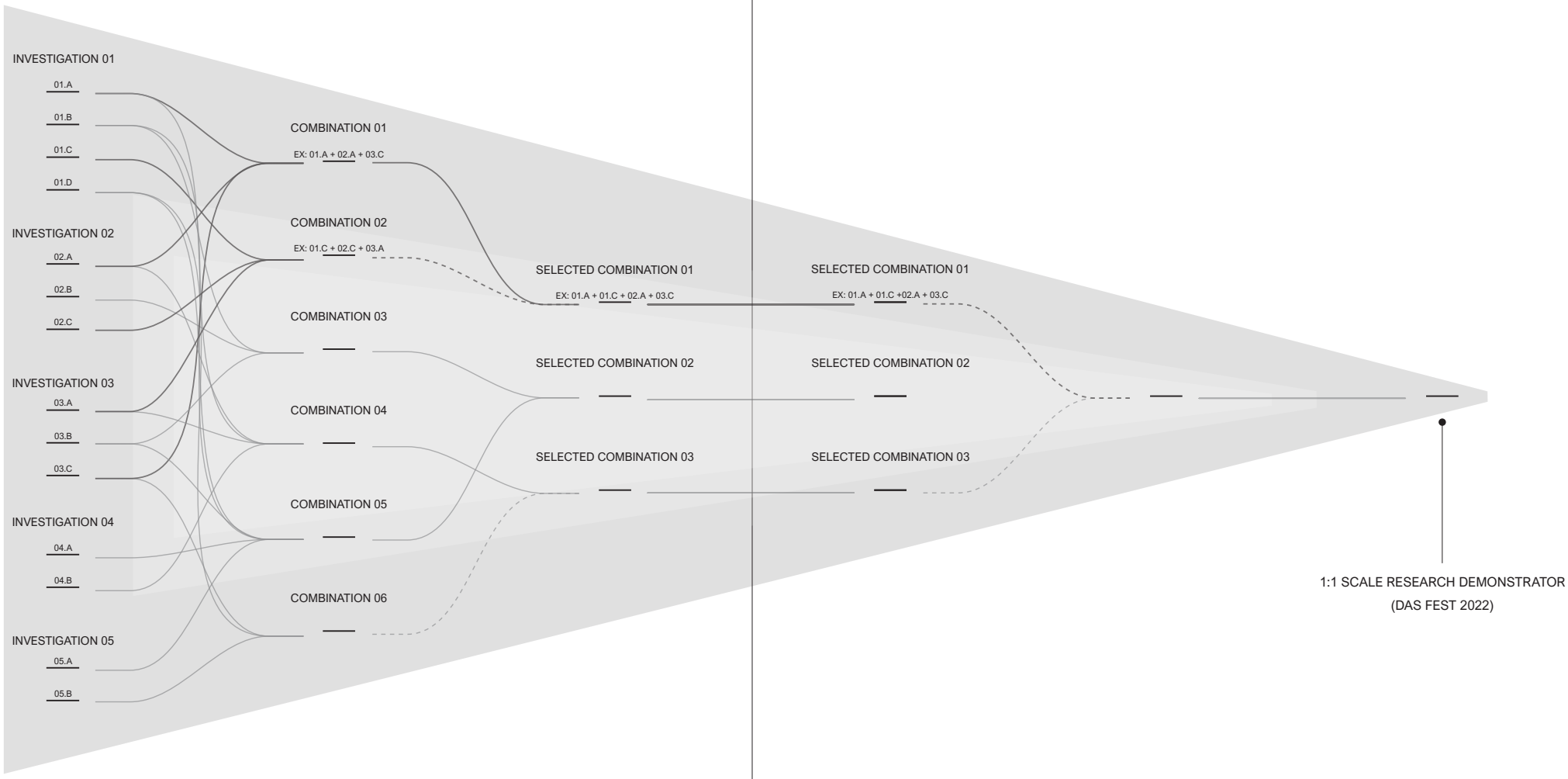
PHASE 02
EXPLORATORY PROTOTYPING

PHASE 03
1:1 PROTOTYPE DEVELOPMENT AND RESEARCH DEMONSTRATOR DESIGN

PHASE 04
TRANSFER TO LARGE-SCALE ARCHITECTURAL AND CONSTRUCTION CONCEPTS

DIGITAL FABRICATION

ASSEMBLY AND INSTALLATION



weeks 1 - 2

weeks 3 - 7

weeks 8 - 12

weeks 13 - 14

PHASE 01
RESEARCH ON NATURAL MATERIALS AND DIGITAL FABRICATION TECHNIQUES

PHASE 02
EXPLORATORY PROTOTYPING

PHASE 03
1:1 PROTOTYPE DEVELOPMENT AND RESEARCH DEMONSTRATOR DESIGN

PHASE 04
TRANSFER TO LARGE-SCALE ARCHITECTURAL AND CONSTRUCTION CONCEPTS

CONTEXTUALISATION
Research-design approach

INTRO ON DIGITAL DESIGN AND FABRICATION
Existing technologies repertoire
Potential for industrialisation

RHINO AND GRASSHOPPER TUTORIALS

INVESTIGATION 01
Plant-based materials

ex. willow

INVESTIGATION 02
Earth-based materials

ex. clay

INVESTIGATION 03
Digital fabrication techniques

ex. textile techniques

INVESTIGATION 04
Historical references

ex. wattle and daub

INVESTIGATION 05
Contemporary references

ex. bamboo structures

COMBINATION 1

ex. willow + clay + textile techniques

COMBINATION 2

COMBINATION 3

COMBINATION 4

COMBINATION 5

COMBINATION 6

SELECTED COMBINATION 01

ex. willow + secondary wood + clay + textile techniques

SELECTED COMBINATION 01

ex. willow + secondary wood + clay + textile techniques

SELECTED COMBINATION 02

SELECTED COMBINATION 02

SELECTED COMBINATION 03

SELECTED COMBINATION 03

research

design

DEVELOPMENT PHASE 01:

Research on natural materials and digital fabrication techniques

The first development phase consists of a range of investigations on materials, techniques and historical and contemporary references to create a varied repertoire on which to base the following research. These investigations will be guided through a series of specific research questions.

To familiarise students with the underlying themes of the studio, this first phase will be complemented by tutorials, during the studio times, on computational software as well as introductory lectures on computational and digital fabrication thinking.

Investigation 01: Plant-based materials (page 20)

Investigation 02: Earth-based materials (page 22)

Investigation 03: Digital fabrication techniques (page 24)

Investigation 04: Historic references (page 26)

Investigation 05: Contemporary references (page 28)

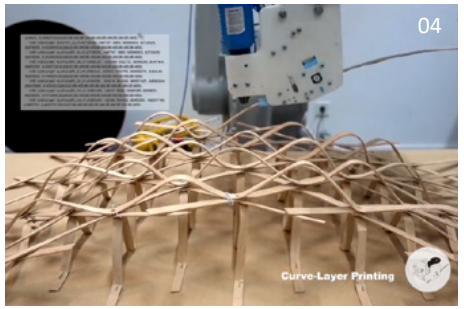
INVESTIGATION 01: PLANT-BASED MATERIALS

Among the natural materials, plant-based materials have one of the highest potentials for introducing sustainable and circular principles into construction: as renewable materials, defined as “materials that are continually replenished at a rate equal to or greater than the rate of depletion”, they can replace the portion depleted by usage and consumption.

At present, wood is the only significant renewable building material but its regeneration rates are slow and the wood industry is already struggling to keep up with demand (Rademaker, 2021).

A solution is provided by rapidly renewable materials, such as willow, cottonwood, bamboo, cork and straw, which can be grown and harvested within one to ten years through the implementation of agricultural methods already in place for energy crops, such as short rotation forestry and short rotation coppice.

While bamboo is a fundamental reference to study, “Digital Wicker” represents an attempt at identifying solutions that can be applied in the European context.

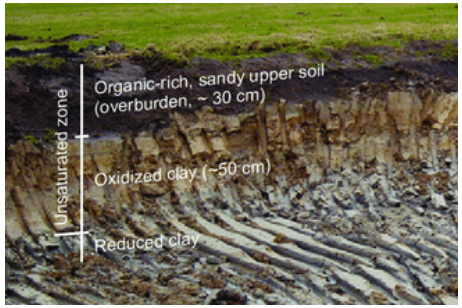


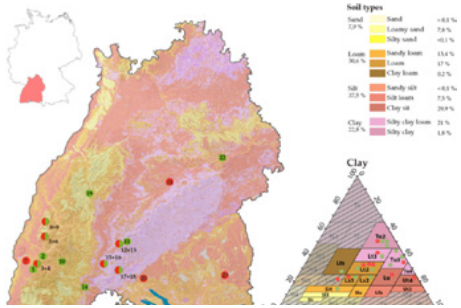
INVESTIGATION 02: EARTH-BASED MATERIALS

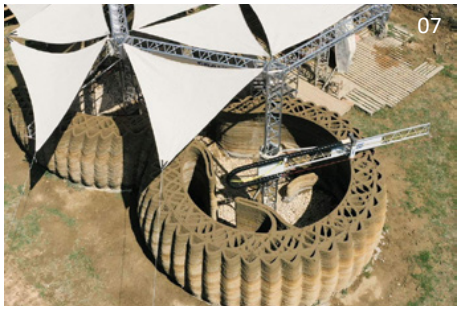
Construction sand and gravel are being extracted faster than they can be replaced (Bendixen et al., 2019).

Materials such as earth, loam or clay are found abundant in nature and used to be part of the vernacular repertoire but have yet to be streamlined for contemporary architecture, possibly becoming alternatives to the currently predominant aggregate materials. Such materials offer alternatives for sustainable, zero-waste, locally-sourced and fire-resistant construction options in addition to advantages at the architectural level, especially for climate control (e.g. self-moderating humidity) and energy efficiency (e.g. naturally maintaining a stable internal temperature throughout the seasons through its thermal mass).

Such materials are of interest for combinations with renewable materials, to harness the potentials of both: for example, the lightweight properties of the renewables and the fireproof properties of the non-renewable.







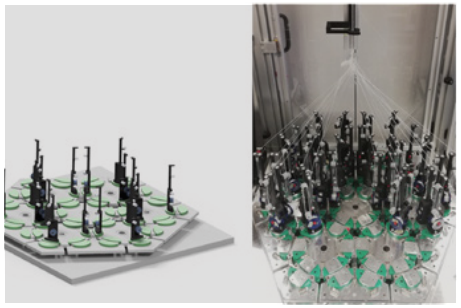
INVESTIGATION 03: DIGITAL FABRICATION TECHNIQUES

Digital fabrication enables bespoke solutions, in addition to complex high-performance designs that can be guided by a variety of priorities such as optimisation of material properties, creation of specific forms or transfer of specific craftsmanship to industrial contexts.

In addition, robotic fabrication enables digitally controlled strategies that achieve higher levels of construction precision, and mini or swarm robotics can create scalable strategies for collaboration through specialised tasks.

This investigation aims to create a repertoire that includes examples of the advantages of each technique, from additive manufacturing, which allows tailoring of material distribution, to textile fabrication techniques, which can provide structural stiffness not otherwise inherent in materials.

The results of this investigation will help students to familiarise themselves with the variety of digital fabrication techniques and their potential, thus enabling them to choose the appropriate techniques in the subsequent development phases.



INVESTIGATION 04: HISTORICAL REFERENCES

Understanding the precedents for the plant- and earth-based materials in investigation 01 and investigation 02 can help us understand traditional craftsmanship and techniques, with a lookout to possibilities of transferring them to digital fabrication techniques or other materials, but also to reconsider their architectural advantages but also the challenges to their industrialisation.

Soils or earth were widely used in the past, as a primary resource to manufacture materials and structures of vernacular architecture. Centuries of empirical practices have led to a variety of techniques to implement earth, such as rammed earth, cob and adobe.

In combination with plant-based materials, particularly thin branches, they were used for the wattle and daub, a technique typical of many European vernaculars.

Other plant-based materials typical of the vernacular are for example straw, water reed or wheat reed, which were widely employed for roof thatching.






INVESTIGATION 05: CONTEMPORARY REFERENCES

Focusing on contemporary applications of the materials analysed in Investigation 01 and Investigation 02, the aim is to create a state of the art, which is used as a starting point for Digital Wicker. Considering both architectural projects and research applications, this investigation concentrates on their innovation value.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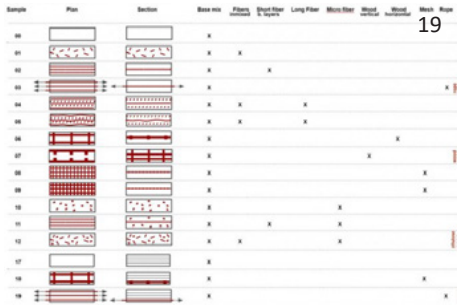
DEVELOPMENT PHASE 02:

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.

Fabrication choices and construction strategies are developed through hands-on physical project-based learning and are at the base of design-through-making, a process in which concept design and prototyping alternate back and forth in rapid iterations, prompting unified thinking about conceptual, material and production aspects. This process helps to discover further research questions and solve them in the next evolution, but also to narrow the concept through research-based decision-making.

These early-stage, handcrafted models will focus on exploring material system behaviour and production concepts. They are an essential first step towards the ideation of a novel digital fabrication strategy and should therefore be conducted rigorously, considering the potential as well as constraints of the production concept. The following semester will build on these explorations to digitally fabricate the 1:1 scale research demonstrator. Students will be supported in this process not only by the previous investigations and introductions in Development Phase 01 but also through the expertise of a mechanical engineer.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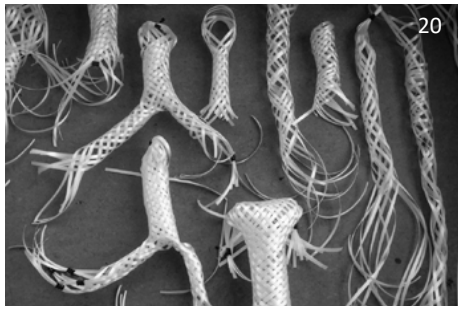
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DEVELOPMENT PHASE 03:

1:1 prototype development and research demonstrator design

A research demonstrator is a medium-sized structure that showcases the possibilities and architectural potential harnessed by the novel digital circular construction concept developed in the previous phase.

In this studio, the research demonstrator will be designed for the “Das Fest” festival in Karlsruhe and should consider different aspects including function, production, assembly and reconfiguration, as well as disassembly and recycling. The best concept or a combination of multiples will be built the following semester.

The 1:1 scale prototype, minimum 1x1 metres, is a proof-of-concept model that results from the evolution of the exploratory prototypes and demonstrates the design, material and fabrication aspects of the project and validates their architectural potential.


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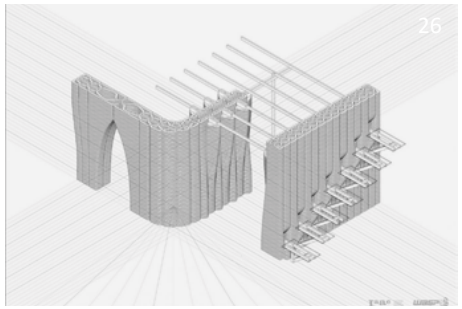
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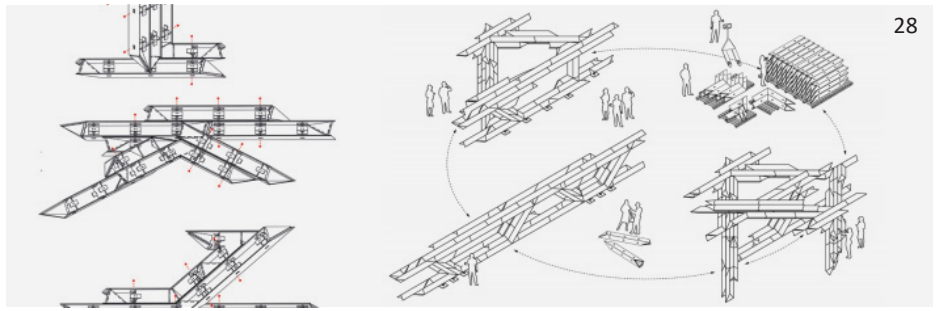
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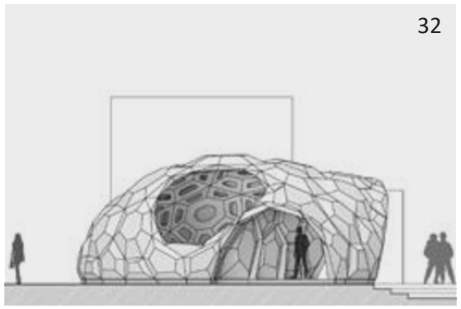
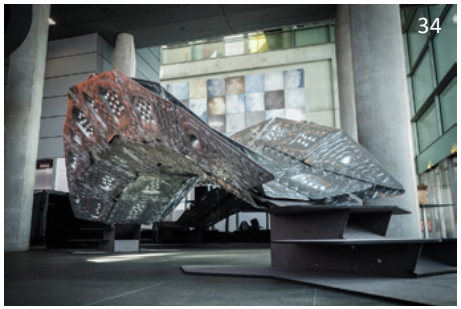
1:1 prototype and fabrication logic

DEVELOPMENT PHASE 03:

1:1 prototype development and research demonstrator design

Das Fest Festival in Karlsruhe





Research demonstrators

DEVELOPMENT PHASE 04:

Transfer to large-scale architectural and construction concepts

In this phase, students will speculate on the underlying architectural design repertoire emerging from the proposed construction concepts as a way to reflect on the impact of the novel construction system along the continuous line of investigation developed thus far.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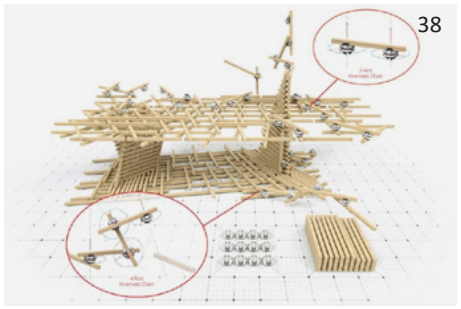
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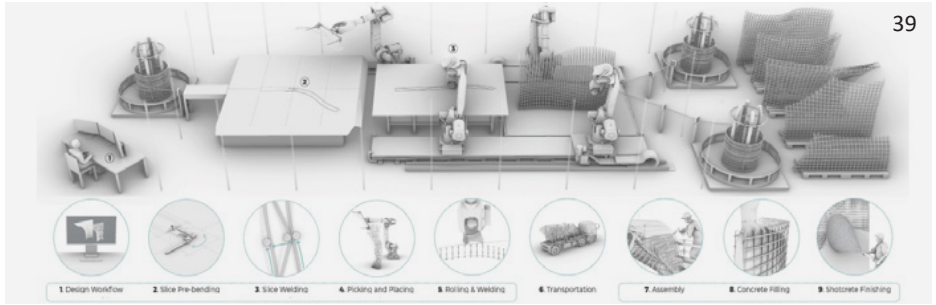

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05 DELIVERABLES

FINAL EXAMINATION

FINAL PRESENTATION – 17.02.2022
Group presentation – max. 20 minutes

- Storyline of each project, from research to design
- 1:1 prototype and exploratory prototypes
- Detailed design and implementation proposals for the research demonstrator at the “Das Fest” festival
- Large-scale architectural and construction concept

BOOKLET – Deadline: 27.02.2022
Individual and group hand-in

- Documentation of the progress at the different phases based on template by DDF

PER DEVELOPMENT PHASE

DEVELOPMENT PHASE 01: Research on natural materials and digital fabrication techniques
28.10.2021 - Individual presentation – 10 minutes

- Presentation on the results of the investigations (depending on the topic; e.g. data for comparative studies on material properties, slides presenting advantages and current obstacles for the implementation of the material or process in construction, current or historical architectural and construction application)
  Followed by group discussion on findings and relevance for further developments

DEVELOPMENT PHASE 02: Exploratory prototyping
02.12.2021 Group presentation (2-3 people) – 15 minutes

- Presentation (e.g. videos of prototype making, slideshows showing step-by-step development, pictures of tests showing progression, tables showing qualitative results of tests for comparison)
- Material samples, random findings and comparative studies (e.g. how different weaving patterns give different stiffness to materials)
- Initial proposals for 1:1 prototype and related architectural and construction application according to prototyping iterations (e.g. sketches showing different directions)

DEVELOPMENT PHASE 03: 1:1 prototype development and research demonstrator design
20.01.2022 Group presentation (4-5 people) – 20 minutes

- 1:1 prototype (min. 1m x 1m)
- Detailed design of research demonstrator for Das Fest based on the architectural and construction concept developed in the prototype (site plan, sections, details, rendering, site logistics, assembly)

DEVELOPMENT PHASE 04: Transfer to large-scale architectural and construction concepts
03.02.2022 Group presentation (4-5 people) – 10 minutes

- Speculation on the underlying architectural design repertoire emerging from the proposed construction concepts (e.g. rendering, diagram)

06 SCHEDULE

Seminar dates:
Thursday, 10.00 am – 5.30 pm

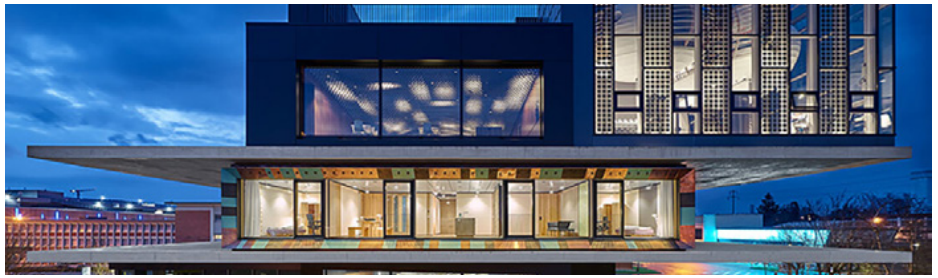
Seminar room:
Studio room 134- 1st floor- Building 20.40

Month	KW	Week	Nr.	Day	Studio dates	Studio phases
October	41	11.10 -17.10		We.	13.10 Vorstellung Lehrprogramm	Studio presentation
	42	18.10 -24.10	1	Th.	21.10 Intro	
	43	25.10 - 30.10	2	Th.	28.10 Presentation & workshop	**Development phase 01: Research on natural materials and digital fabrication techniques**
	43	25.10 - 30.10	2	Fr.-Sa.	29.10 - 01.11 Excursion	
November	44	01.11 - 07.11	3	Th.	04.11 Desk crit & workshop	
	45	08.11 - 14.11	4	Th.	11.11 Desk crit	
	46	15.11 - 21.11	5	Th.	18.11 Desk crit	**Development phase 02: Explorative prototyping**
	47	22.11 - 28.11	6	Th.	25.11 Desk crit	
December	48	29.11 - 05.12	7	Th.	02.12 Mid-Term	
	49	06.12 - 12.12	8	Th.	09.12 Desk crit	
	50	13.12 - 19.12	9	Th.	16.12 Desk crit	**Development phase 03: 1:1 prototype development and research demonstrator design**
January	2	10.01 - 16.01	11	Th.	13.01 Desk crit	
	3	17.01 - 23.01	12	Th.	20.01 Presentation	
	4	24.01 - 30.01	13	Th.	27.01 Desk crit	**Development phase 04: Transfer to large-scale architectural and construction concepts**
February	5	31.01 - 06.02	14	Th.	03.02 Presentation	
	6	07.02 - 13.02			Magic Week	
	7	14.02 - 20.02	16	Th.	17.02 Final presentation	**Presentation preparation**
	8	21.02 - 27.02	17	Su.	27.02 Booklet Hand-in	

07 EXCURSION

ZURICH 29.10.2021

ETH Zürich



NEST- Next Evolution in Sustainable Building Technologies

STUTTGART 30.10.2021

ITKE - Institute of Building Structures and Structural Design | University of Stuttgart

FibR GmbH

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