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M.Sc. Programme  
Department of Architecture KIT  
Entwurf Hochbau  
Summer Semester 2022  
LV1720805

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# DIGITAL WICKER 2.0

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Course offered by:  
DDF - Professur Digital Design and Fabrication  
IEB - Institute for Building Design and Technology

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with the participation of DoS - Professur Design of Structures  
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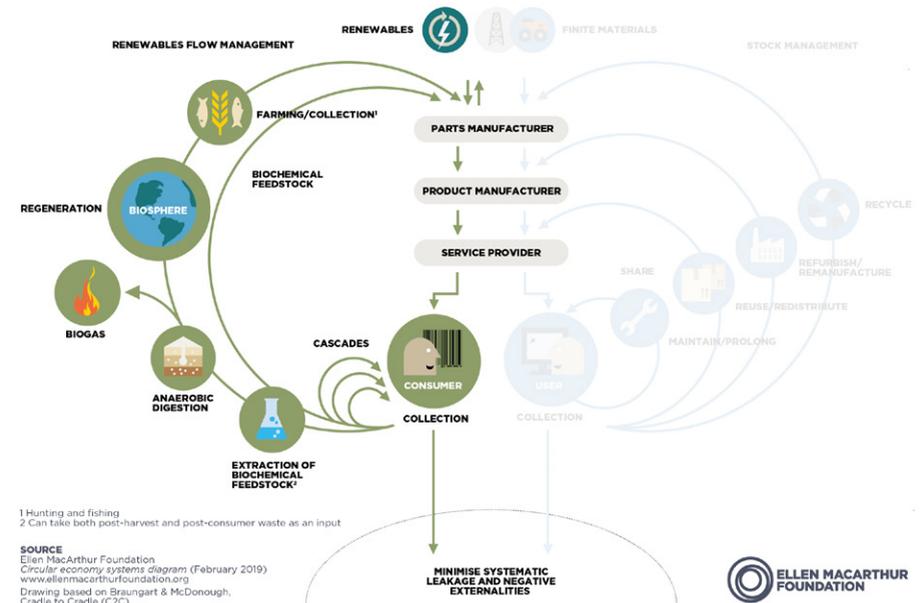
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Circular economy diagram by Ellen MacArthur Foundation, here highlighting the biological cycle

## 01 INTRODUCTION AND CONTEXT

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.

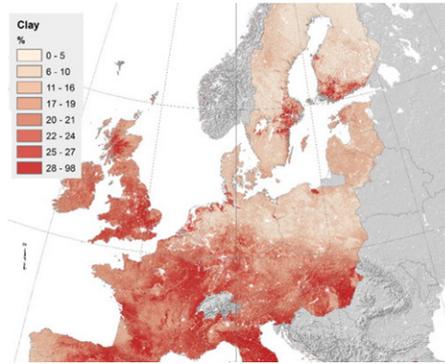
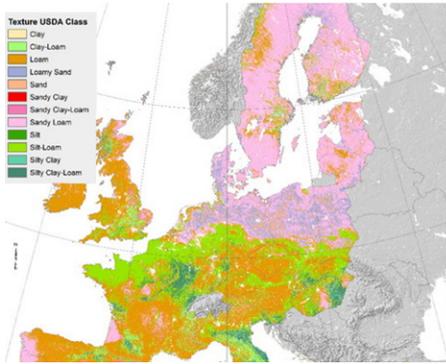
### Wicker turns digital

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.



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



Robotic fabrication implemented in textile industry

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 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.

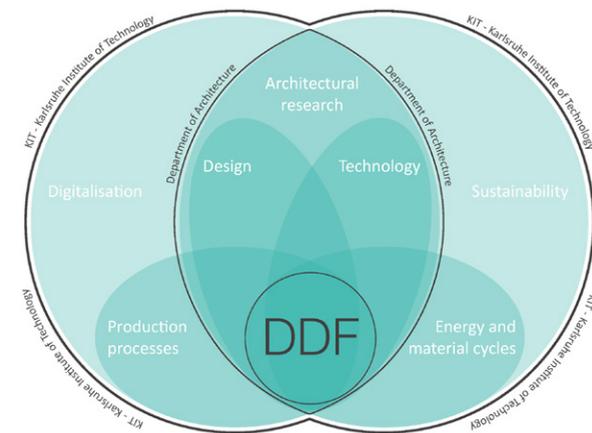


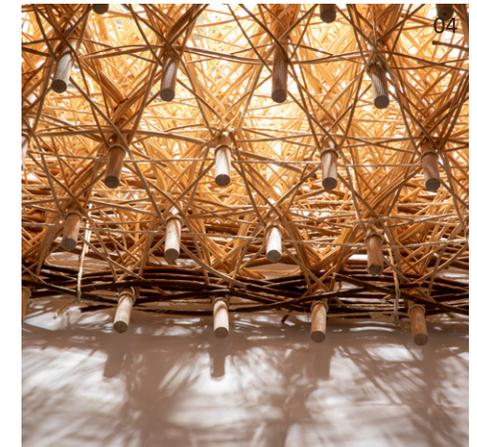
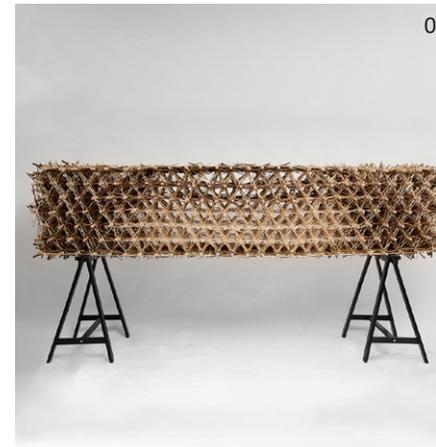
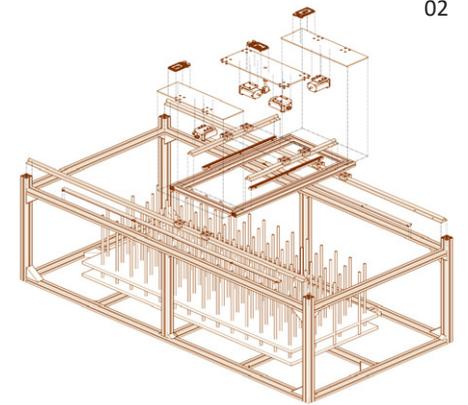
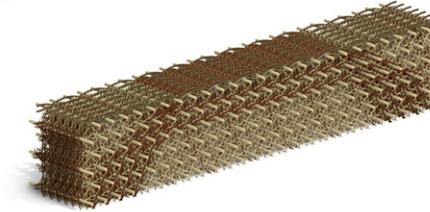
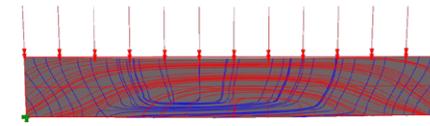
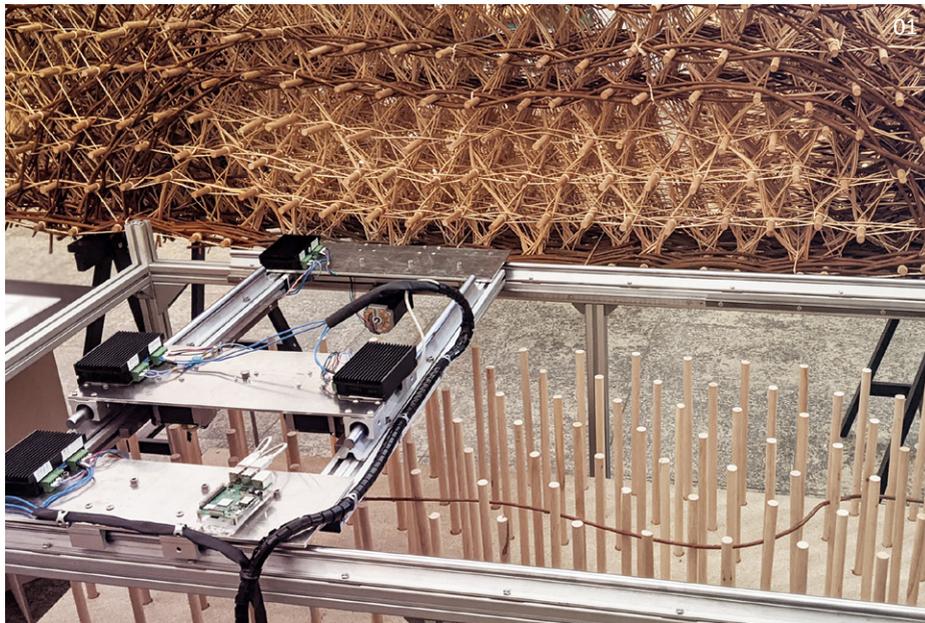
Diagram showing the positioning of DDF's research

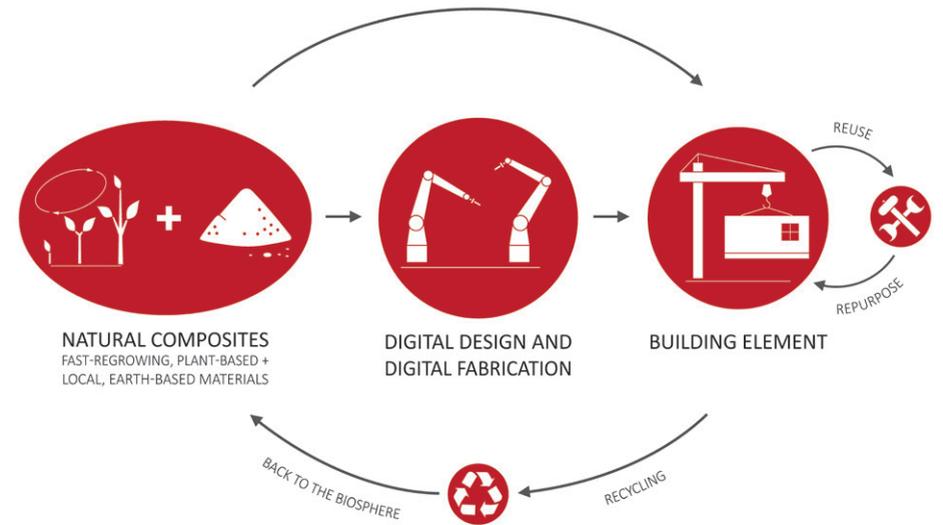
## Digital Wicker 2.0

The studio builds on the first iteration of the studio, "Digital Wicker", which took place in the winter semester 2021/2022. Different concepts were developed for the implementation of a variety of fast-regrowing materials in architecture and construction. Starting from exploratory prototyping, students developed three final concepts emerging from different digital fabrication techniques and structural principles to provide structural stiffness to otherwise flexible and relatively weak materials. The concepts were tested at 1:1 scale, together with initial work

on their digital fabrication and architectural application, and represent the groundwork for this studio.

Continuing the development of one of these concepts, "Digital Wicker 2.0" aims to deliver it to the next scale, a 1:1 research demonstrator. Through a series of rigorous research-based explorations, the studio will advance and expand on the concept to include all aspects of construction including architectural design, structural design, digital fabrication and component production.





Overarching goal of Digital Wicker

## 02 AIM

The studio “Digital Wicker 2.0” aims to design and build a research demonstrator, a medium-sized structure, at 1:1 scale for the “Das Fest Festival” in Karlsruhe in July 2022, which showcases the possibilities and architectural potential harnessed by a novel digital circular construction concept enabled by digital fabrication. Hybrid components made of fast-regrowing and earth-based materials will showcase the implementation of circular biological cycles as an alternative to conventional construction methods and enable the exploration of a novel design repertoire that is driven by digital fabrication techniques

and innovative structural solutions.

At the intersection of research and design, the studio will tackle several objectives for the realisation of the project: from architectural design to structural design and testing to the construction of custom machines and hands-on digital fabrication as well as the installation of the final structure. The experimental structure will also serve as a base to conceptualise the transfer of such construction solutions to large-scale architectural and construction concepts and to develop future development trajectories.

## 03 METHODS

At the intersection of research and teaching, the studio offers the opportunity to gain project-based experience in developing a system for circular architecture that is informed by a structural understanding of natural materials, by digital fabrication processes and by construction logic, in addition to the architectural concept. Students will gain first-hand knowledge of the potential of digital design and fabrication within circular construction and develop expertise in technologies for the digital fabrication of architectural systems in a research-based environment.

The studio uses a series of development phases (explained in more detail in chapter 04), meant to guide the students through the implementation of the studio methodology, starting from the contextualisation within the broader discourse and leading to the design, production and installation of the research demonstrator as well as to the reflection for future developments. These enable the students to participate in all phases of the project development.

A first investigation phase on specific topics for contextualising the studio, based on four overarching fields, will be conducted by students individually (Development Phase 01). Subsequently, students will merge into groups of 4-5 people and will focus on specific development topics that are needed to advance the current state of the art, ranging from machine design and assembly to component

design and construction systems. Based on a research-led and design-through-making approach, these developments are carried out in rapid iterations, with rigorous and iterative refinements. At the same time, each group will propose a design for the research demonstrator at the “Das Fest” Festival (Development Phase 02). In the following two phases, students will work as a whole group in close collaboration with each other, merging the knowledge developed in the previous phases, and concentrate on the final developments for the research demonstrator. This entails producing the final 1:1 scale components through digital fabrication and hands-on production, structural and assembly tests as well as planning for the exhibition at the “Das Fest”, where we will attend to showcase the demonstrator to the public (Development Phases 03 and 04). The architectural potential and future possible research trajectories will then be explored by groups of 4-5 people (Development Phase 05).

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

The studio will be composed by architecture and engineering students. In addition to having an interdisciplinary team of researchers, this ensures that our expertise spans a wide range across digital design and fabrication from architectural design to mechanical and civil engineering.

## *04 DEVELOPMENT PHASES*

DEVELOPMENT PHASE 01:

Contextualisation

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DEVELOPMENT PHASE 02:

Multiscalar development

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DEVELOPMENT PHASE 03:

Implementation

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DEVELOPMENT PHASE 04:

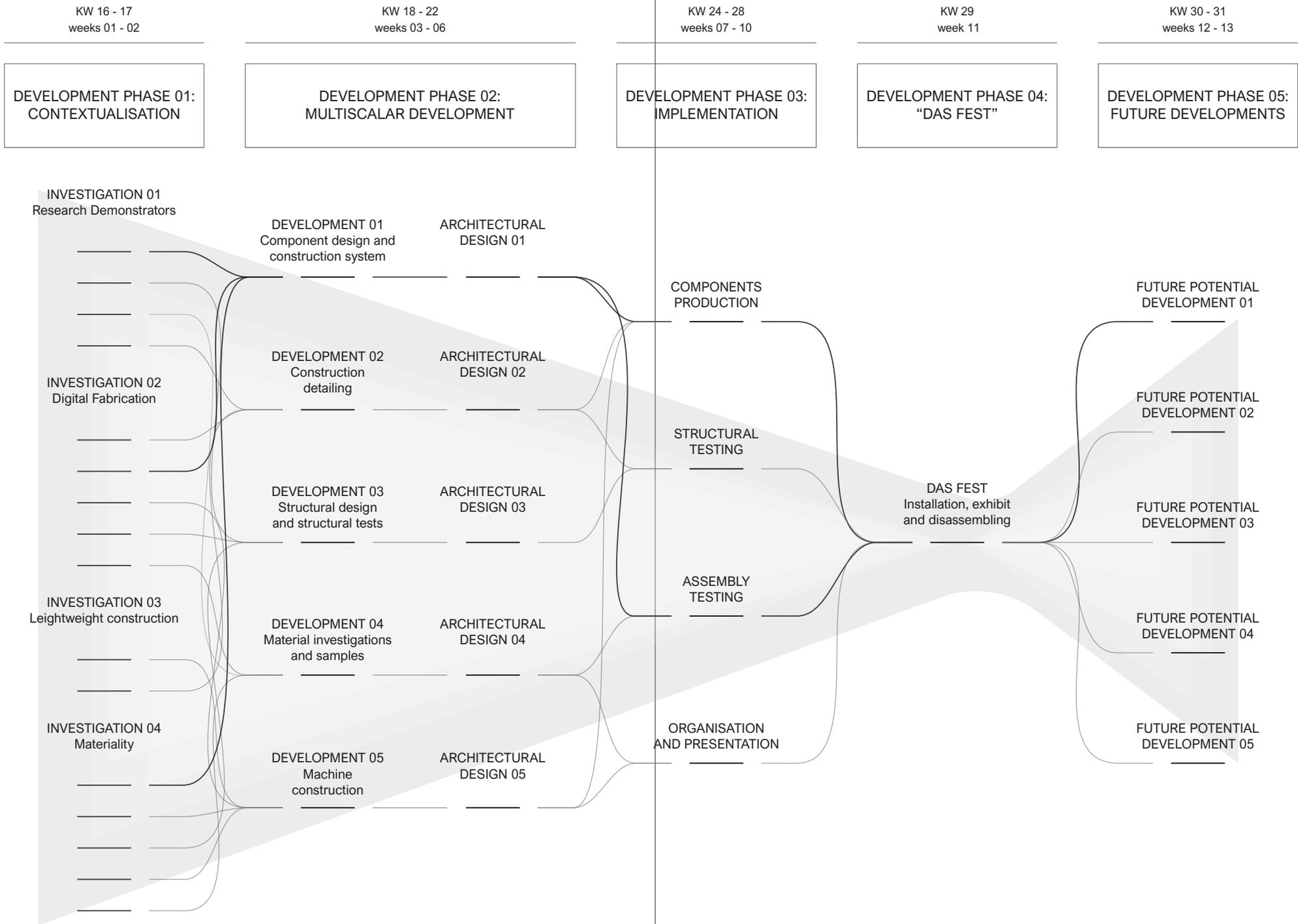
“Das Fest”

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DEVELOPMENT PHASE 05:

Future potential developments

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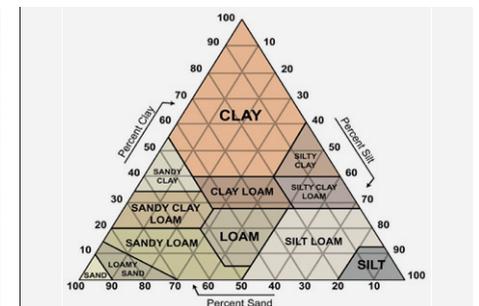
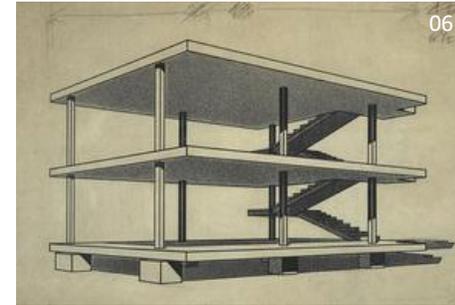


DEVELOPMENT PHASE 01:

Contextualization

The first development phase consists of a range of investigations on the state of art, including materials, digital fabrication techniques and industrial or architectural references. This will serve to create a varied repertoire on which to base and position the upcoming 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 introductory lectures on computational and digital fabrication thinking as well as on the research carried out in the previous semester. First introductory tutorials on computational software will be offered during the studio times.



## DEVELOPMENT PHASE 02:

### Multiscalar development

This phase will deal with preparing the research framework for the realization of the demonstrator at “Das Fest”. It operates across multiple scales, each representing a specific research subtopic, whose results will give shape to the detailed design and set the basis for the 1:1 fabrication of the experimental structure. Five different development topics will be explored simultaneously with an integrative approach, aimed at the ideation of a unified novel construction and architectural concept. They should therefore be conducted rigorously, considering the potential as well as constraints of the concept and in a design-through-making process, in which concept design and hands-on prototyping alternate back and forth in rapid iterations. At the same time, each group will develop design iterations for the research demonstrator, which will showcase the possibilities and architectural potential harnessed by the novel digital circular construction concept under development. The design 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 selected for the research demonstrator.

The development topics are:

- Component design and construction system: design of the overarching strategy that will prompt unified thinking about conceptual, material and production aspects through the

design of its components.

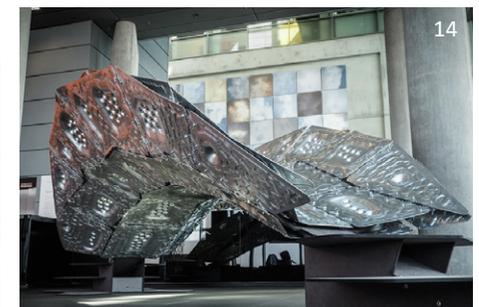
- Construction detailing: The aim is to design the details that will render this emerging material system viable for construction.

- Structural design and structural tests: design structural components based on the initial concepts for plant-based materials and optimize them according to digital simulations. Initial small-scale qualitative tests will be carried out in order to plan a structural testing process for 1:1 components.

- Material investigations and samples: these will focus on the combination of earth- and plant-based materials. The aim is to explore material system behaviour and production concepts and test them with an eye to real-life application. Initial small-scale qualitative tests will be carried out in order to select the best combinations according to their performance.

- Machine construction: the aim is to design, build, test and operate custom machinery for the digital fabrication of the demonstrator's components.

Students will be supported in this process not only through the findings from the previous semester but also through the expertise of the interdisciplinary team of researchers and students, ranging from architecture to mechanical and civil engineering.



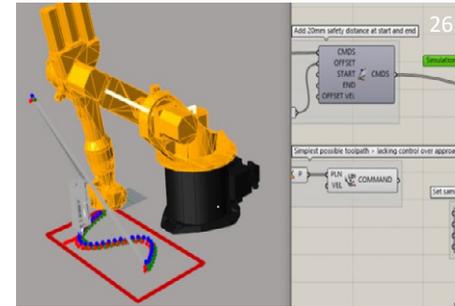


## DEVELOPMENT PHASE 03:

### Implementation

Based on the results of the research carried out in the previous development phase, a detailed design of the research demonstrator that considers all the aspects from computational and structural design to digital fabrication and assembly on-site will be drawn up. This development phase will focus on the hands-

on 1:1 digital fabrication of the components, for which students will work as a group with shifts throughout the week. Throughout the development phase, 1:1 structural testing of the components, test assemblies as well as planning for the "Das Fest" will be carried out.

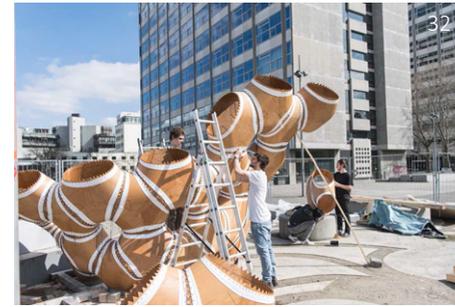


DEVELOPMENT PHASE 04:

"Das Fest"

The research demonstrator will be displayed at the Günther-Klotz-Anlage in Karlsruhe for the "Das Fest" festival, which will take place from the 21st till the 24th of July. The medium-scale experimental structure will represent a 1:1 proof-of-concept of the digital circular concept developed throughout the semester

and demonstrate the design, material and fabrication aspects of the project, thus validating its architectural and construction potential. We will not only install the structure but also attend the festival throughout the four days to show the research to the public with a small exhibition space.

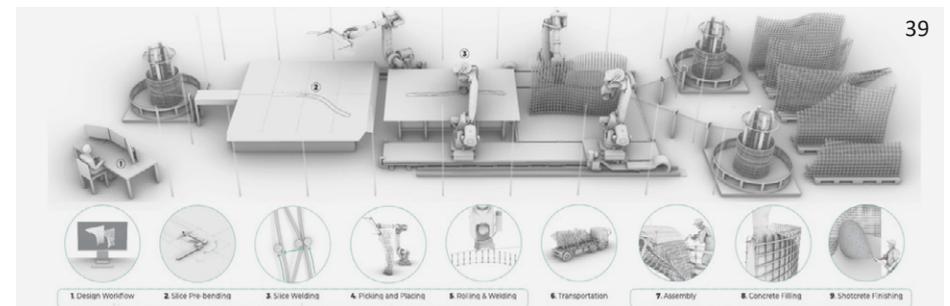
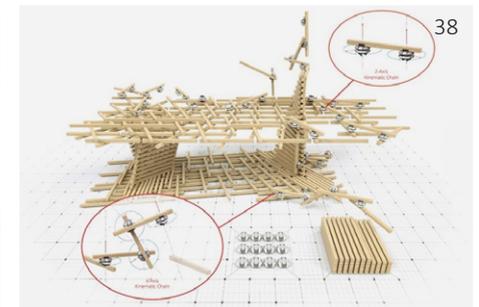


DEVELOPMENT PHASE 05:

Future potential developments

In this phase, students will, on one hand, speculate on the underlying architectural design repertoire emerging from the proposed construction concept as a way to reflect on the impact of the novel construction system along

the continuous line of investigation developed thus far. On the other hand, they will propose future trajectories for further improvements and developments of the research.



- 1 Design Workflow
- 2 Slice Pre-bending
- 3 Slice Welding
- 4 Piling and Placing
- 5 Bolting & Welding
- 6 Transportation
- 7 Assembly
- 8 Concrete Filling
- 9 Shotcrete Finishing

## 05 DELIVERABLES

### DELIVERABLES FOR FINAL EXAMINATION

*FINAL PRESENTATION – 04.08.2022*

*Studio group presentation (15-18 people) divided into smaller groups for subtopics – 40 minutes*

- Storyline of the project, from research to design, that collects and highlights the main findings. Divided into subtopics, such as structural and material development, machine development, architectural design (e.g. slideshows showing step-by-step development, pictures of tests showing progression, tables showing qualitative or quantitative results of structural tests for comparison, videos of prototype making, renderings, diagrams etc.)
- Exploratory prototypes and 1:1 prototypes
- Documentation of the research demonstrator, including detailed design, assembly and installation of the structure at the “Das Fest” festival
- Large-scale architectural and construction concepts and future potential developments (e.g. renderings, diagrams, new machine designs or improvements, new materiality systems etc.)

*BOOKLET – Deadline: 14.08.2022*

*Individual and group hand-in*

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

### DELIVERABLES PER DEVELOPMENT PHASE

*DEVELOPMENT PHASE 01: Contextualization*

*28.05.2022 - Individual presentation – 10 minutes*

- Presentation on the results of the investigations (depending on the topic; e.g. relevant repertoire of architectural and construction references, slides presenting advantages and current obstacles for the implementation of the material or process in construction, data for comparative studies on material properties)

*Followed by group discussion on findings and relevance for further developments*

*DEVELOPMENT PHASE 02: Multi-scale development*

*02.06.2022 Group presentation (3-4 people) – 15 minutes*

- Presentation on the outcomes of the different development topics (e.g. slideshows showing step-by-step development, pictures of tests showing progression, tables showing qualitative or quantitative results of structural tests for comparison, videos of prototype making)
- Physical results of the developments (e.g. machine for digital fabrication, material tests, connection types for building components)
- Initial design proposals for research demonstrator and related architectural and construction application according to construction system (e.g. initial design(s) based on the potentials of the digital circular construction concept such as gradient for material arrangement, quick renderings or visualisations, concept diagrams, proof of assembly logic and fabrication concept)

*Followed by group discussion on findings and relevance for further developments*

*DEVELOPMENT PHASE 03: Implementation*

*No formal presentation, only deliverables and attendance for fabrication - Group work (15-18 people) with specific subtasks*

- Fabrication of the building components for the research demonstrator at the “Das Fest” festival
- Detailed design of research demonstrator for Das Fest based on the architectural and construction concept developed in the development phase 02 (site plan, sections, details, rendering, site logistics, assembly)
- “Das Fest” preliminary work (assembly test, exhibition at “Das Fest”)

*DEVELOPMENT PHASE 04: “Das Fest”*

*No formal presentation, only attendance for installation and presentation at Das Fest - Group work (15-18 people) with specific subtasks*

- Installation of the research demonstrator at “Das Fest”
- Exhibition and presentation at “Das Fest” (e.g. videos/slideshows explaining the development and concept of the research demonstrator)

*DEVELOPMENT PHASE 05: Future potential developments / Transfer to large-scale architectural and construction concepts*

*Rehearsal for final presentation (date to be decided) - Group work (3-5 people)*

- Speculation on the underlying architectural design repertoire and future research developments emerging from the construction system (e.g. renderings, diagrams, new machine designs or improvements, new materiality systems etc.)

## 06 SCHEDULE

Studio dates:  
Thursdays, 10.00 am – 6.00 pm

Studio room:  
A. Room 206 - 2nd floor- Building 20.40  
B. DDF Fabrication Lab - Karlsruhe (address will be  
communicated in due course)

Month	KW	Week	Nr.	Day	Studio dates	Studio phases
April	15	11.04 - 17.04		We.	11.04 Vorstellung Lehrprogramm	Studio presentation
	16	18.04 -24.04	1	Th.	21.04 Intro	
				Fr.-Sa.	22.04 - 23.04 Excursion	<u>Development phase 01:</u> <u>Contextualisation</u>
	17	25.04 - 01.05	2	Th.	28.04 Presentation	
May	18	02.05 - 08.05	3	Th.	05.05 Desk crit	
	19	09.05 - 15.05	4	Th.	12.05 Desk crit	
	20	16.05 - 22.05	5	Th.	19.05 Desk crit	<u>Development phase 02:</u> <u>Multi-scale development</u>
	21	23.05 - 29.05		Th.	26.05 Holiday	
June	22	30.05 - 05.06	6	Th.	02.06 Mid-term	
	23	06.06 - 12.06		Th.	Seminarwoche	
	24	13.06 - 19.06		Th.	16.06 Holiday	
	25	20.06 - 26.06	7	Th.	23.06 Desk crit	
	26	27.06 - 03.07	8	Th.	30.06 Desk crit	<u>Development phase 03:</u> <u>Implementation</u>
July	27	04.07 - 10.07	9	Th.	07.07 Desk crit	
	28	11.07 - 17.07	10	Th.	14.07 Desk crit	
	29	18.07 - 24.07	11	Th.	18.07-21.07	<u>Development phase 04:</u> <u>"Das Fest"</u>
	30	25.07 - 31.07	12		Magic Week	<u>Development phase 05:</u> <u>Future potential developments</u>
	31	01.08 - 07.08	13	Th.	04.08 Final presentation	<u>+ presentation preparation</u>
				Su.	14.08 Booklet Hand-in	

## 07 REFERENCES

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