
AMC
TRR277
[AM]
to
[ARC]
FROM
ADDITIVE MANUFACTURING
TO
ARCHITECTURE
MASTER ENTWURF / PROJECT
TU MUNICH / TU BRAUNSCHWEIG

FROM
ADDITIVE MANUFACTURING
TO
ARCHITECTURE

MASTER ENTWURF / PROJECT
Summer 2022

Cooperative Project TU Munich & TU Braunschweig

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In association with the Collaborative Research Center,
Additive Manufacturing in Construction, TRR277.

INTRODUCTION

Additive Manufacturing (AM) offers a variety of technological perspectives that will influence all aspects of building construction in the future: materiality, structure, detailing, thermal envelope, building climate. Based on the AM technologies currently being developed, three currently relevant topics are to be addressed in the architectural design project: the creation of living space, urban densification, and sustainable building. At the beginning of this project work, the different methods of AM will be studied, and then structural principles and parameters will be derived. An inner-city residential building will be designed with this "toolbox" of AM methods. The focus is on the development of an intelligent construction configuration and a robust apartment typology. Structures should be developed that find a balance between durability, material justice, resource conservation, and flexible, spatial playability, and that take up the need for sustainability in various facets.

Following the project in the summer semester, specialization will be offered in the winter semester 2022/23, in which sections of the design can be additively manufactured on a scale of 1:1 in the Additive Manufacturing in Construction Laboratory of the TU Munich or the Digital Fabrication Lab, TU BRaunschweig. Due to the amount of work involved, the design is worked on in groups of two students.

The cooperation between the Technical University of Munich and the TU Braunschweig requires mutual attendance of face-to-face events. For this purpose, excursions with overnight stay to Braunschweig and Munich are planned. The final presentation will take place at Bayrische Landwirtschaft Herrsching, Ammersee.

SEMESTER STRUCTURE

27.04.-03.05. Warm-Up Research
Two fieldtrips, one to Munich and one to Brunswick introduces the students to the A-Projects of the AMC. Insider talks given by the AMC researchers in the AMC labs provide the students with preliminary access to the semester's project task. Furthermore, analizing various projects from the fields of Additive-Manufacturing-Research (AM) and Architecure gives all participants first knowledge of the core themes of the design course. Each group chooses one topic and summarizes the essential information. Results are presented during the fieldtrip in Brunswick.

03.05. - 10.05. Hackathon
At the Hackathon the process of AM is experienced. All students receive a Rhinoceros 3D script to work with. The script allows the digital design of a 3D printable object. After a short design phase, groups of 3-4 students implement the scripted object in the AM fabrication process. Finally the clay printed object should be evaluated and presented to all participants, including a documentation of the process of design and production (Film & Foto).

10.05.-24.05. Site & First Idea
In the first phase of the project design, three key topics should be adressed:
-interpretation of program / organization concept
-building concept / urban form
-construction concept / AM Method

24.05.-21.06. Construction & Design Concept
In the second phase the typology and construction concept are developed simultaneously. The focus is on the combination of the spatial program with an intelligent construction system, based on the methods of (AM). Depending on the fabrication method an execution concept (on site or off site) needs to be invented.

21.06. - 26.07. Completion Phase
The project design will be completed.
The project objectives need to checked:
-Typology and program
-AM Method and execution concept
-Architectural and urban concept

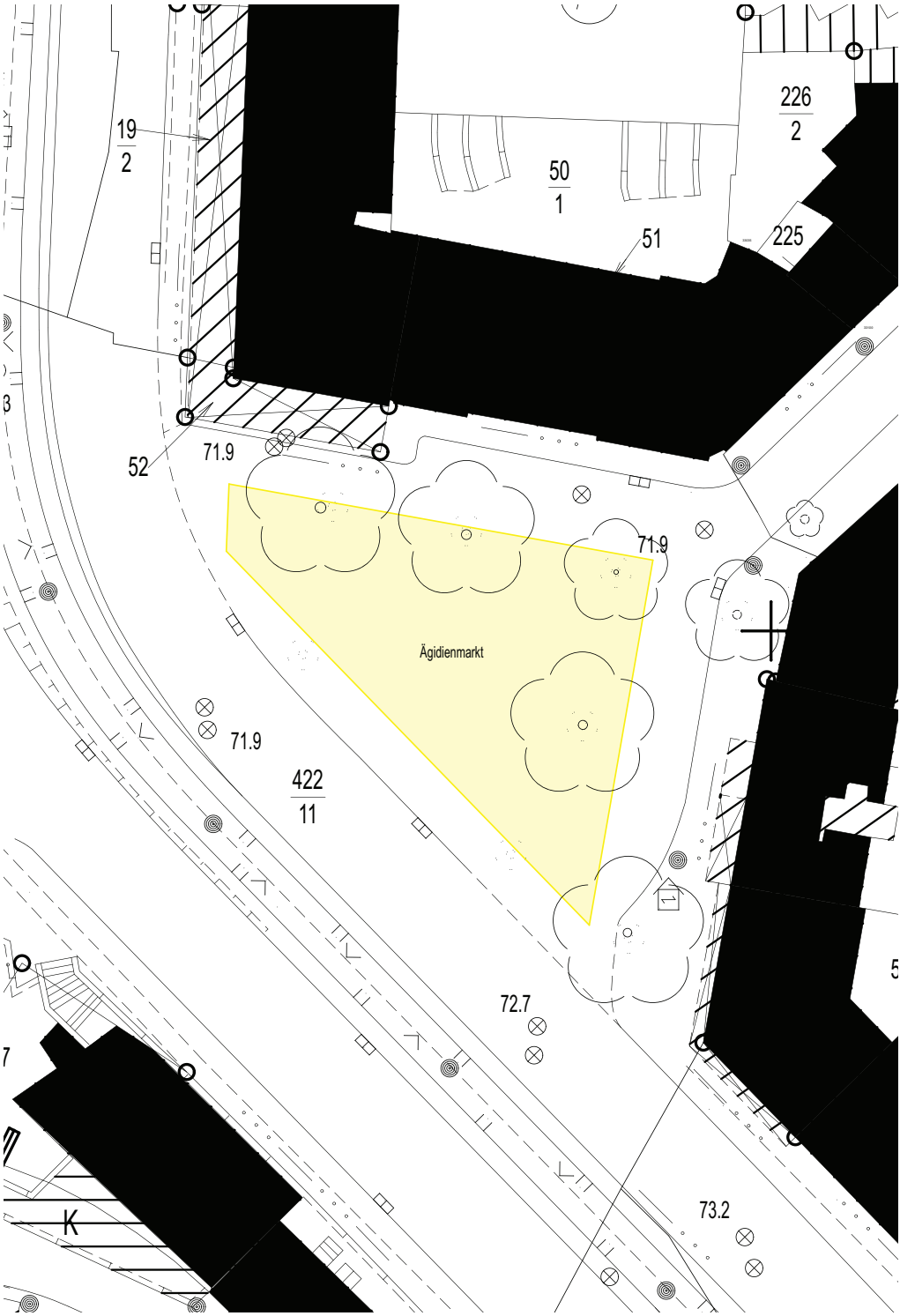
SITE - ÄGIDIENMARKT BRAUNSCHWEIG

SITE - ÄGIDIENMARKT BRAUNSCHWEIG

The Ägidienmarkt is one of the medieval marketplaces in downtown Braunschweig. In the Middle Ages it was the social and economic center of the Altewiek area, today it lies between the Magniviertel and the Aegidienviertel and is part of the city ring road. It was named after the Aegidienkirche and the associated Aegidienkloster. The pottery market was one of the most important markets on the Ägidienmarkt.

Today we experience Ägidienmarkt as a blank spot in a heterogenic, yet historically emerged downtown structure. The expansion of street infrastructure after World War II led to the implenetation of the so called City Ring, which nowadays crosses the former market place and only leaves relicts of what was formerly a subcentre of the city. By establishing a new buliding structure that contributes to the urgent necessity of residential use, the underestimated place could be reactivated and newly interpretated as a part of the city structure.

Siteplan Ägidienmarkt 1889 - Ludwig Winter


19
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Ägidienmarkt
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DESIGN TASK

„Are you are seeking flexibility? Keep on building your walls of stone.“
Luigi Snozzi, Parole Nr. 12

With the project „From Additive Manufacturing to Architecture“ two main topics shall be adressed. Firstly: an architectural form and structure for the application of Additive Manufacturing Methods and by this new perspectives for the execution of massive building. Secondly: typologies of mixed and residential use that can change over coming decades and that are intelligently interacting with the construction structure.
Luigi Snozzi is arguing flexibility with a massive, unflexible material. The intention is to emphasize on robust, yet smart grids and structures to host a variety of functions throughout their lifecycle. The goal of sustainablity results from a wide range of factors. The intention with this design project is to take a closer look on long lasting structures, efficently built with methods of Additive Manufacturing.

Gramazio Kohler - Digital Materiality

DESIGN TASK

Duplex Architekten - Mehr als Wohnen

The spatial program contains a market hall for the ground floor and therefor generates a reminiscence to the former function of the site.

While organizing the program on site, at least one of the existing trees needs to be conserved and integrated in the position and design of the building volume.

The upper floors should provide space for residential typologies and community areas. Residential concepts can reach from multigernerational living over shared appartement typologies to micro appartements.

However, the design concept should be developed in a constant dialogue between AM construction concept and flexible typologies. It is important to follow the idea of explorative design: understanding and incorperating the technical consequences of additive manufacturing fabrication methods on the one hand and examination of sustainable architectural structures for flexible long-term use on the other.

Joris Jan Burger - Eggshell

DESIGN PROGRAM

SITE	
Footprint	550-650 m²
GROUND FLOOR	
Market Hall	min. 400 m²
including Storage/Sanitary Rooms	
Room Height	5m
UPPER FLOORS	
Appartements	min. 1000 m²
Community Space	min. 200 m²

SUBMISSION

Site Plan	M 1:500
Plans, Sections, Elevations	M 1:200
AM Details	M of choice

Schemes/Diagram/Animation
of the Construction Process and the overall esign Concept

Urban Model	M 1:200
Model of Construction Concept	M of choice

Visualization Exterior
Visualization Interior


Ten Studio - 500 Year Tower

RESEARCH

Scientific Publications

1. *Aejmelaeus-Lindström et al. - 2020 - Rock print Pavilion*
2. *Anton et al. - 2021 - A 3D concrete printing prefabrication platform for bespoke columns*
3. *Architecture of Continuity - 2019 – IAAC Blog*
4. *Dörfler et al. - 2019 - Mobile robotic fabrication beyond factory conditions case study Mesh Mould wall of the DFAB HOUSE*
5. *Gramazio, Kohler - 2012 - Digital materiality in architecture*
6. *Jan, Falcon - 2020 - Eggshell Ultra-Thin Three-Dimensional Printed Formwork for Concrete Structures*
7. *Minibuilders - 2014 - web_robots_iaac_net*
8. *Einfach Bauen - Ein Leitfaden, Hrsg. Florian Nagler*

Architectural Projects

9. *Marcel Breuer, IBM Research Center, 1960*
10. *Toyo Ito, Sendai Mediatheque, 2001*
11. *Duplex Architekten, Mehr als Wohnen, 2005*
12. *FAR frohn&rojas, Wohnregal, 2019*
13. *Summecumfemmer/Juliane Greb, Wohnaus San Riemo, 2021*
14. *Ten Studio, 500 Year Tower, Unbuilt*


WASP / Gaia Crane Wasp

PROJECTS

[MARRIAGE ~~BATTLE~~ OF TWO MATERIALS]
Luisa Durst & Mauritz Renz / TU München

[BREUER X AM]
Mia Düpree & Mareen Fechner / TU München

[PLAYING WITH BLOCKS]
Amber Alvarez & Elke Meiersonne / TU München

[HALF-TIMBERED HOUSE RETHINK]
Natalia Comet & Zhiyuan Wang / TU München

[POSITIVE SUBSTRACTION]
Kerem Yilmaz & Christina Schwalm/ TU München

[STONE-TIMBER STRUCTURES REIMAGINED]
David Meister & Fabian Schneider / TU München

[HOLD ON, TIMBER!]
Shi Zhan & Tianpu Zhou / TU München

[RAMMED ARCHITECTURE]
Gabriela Kienbaum & Julian Tesche / TU Braunschweig

[SHELLTECTONICS]
Leon Kremer & Thilo Schlinker / TU Braunschweig

[THE RENEWED POTENTIAL OF A FORMAL LANGUAGE]
Philip Nünning / TU Braunschweig

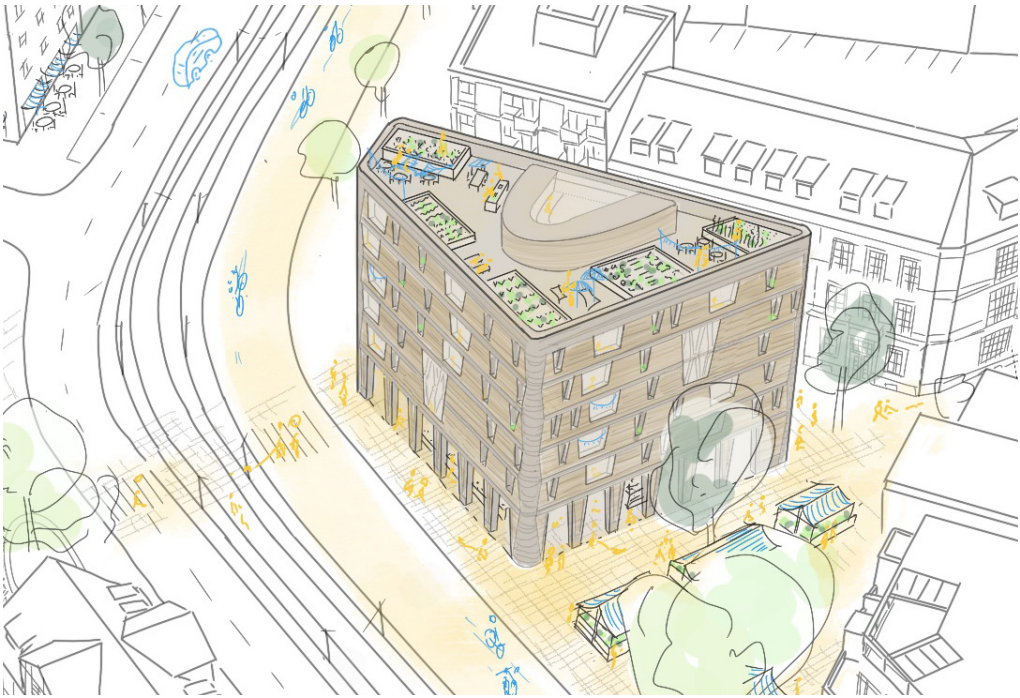
[VORONOI STACKING]
Cong Zhou / TU Braunschweig

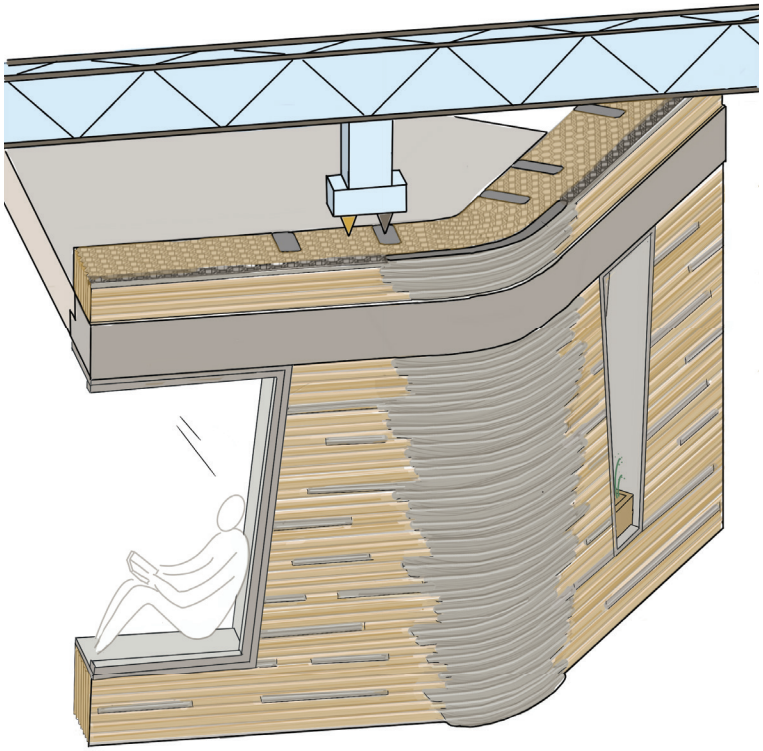
[MARRIAGE ~~BATTLE~~ OF TWO MATERIALS]

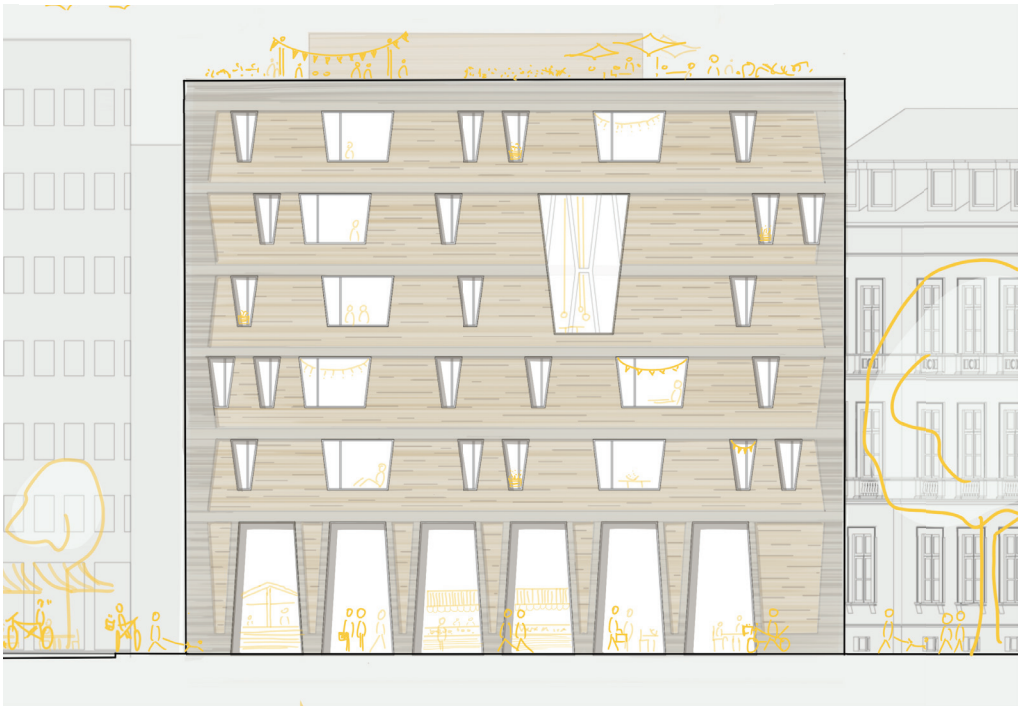
Luisa Durst & Mauritz Renz / TU München

A03

The project aims at a simple construction with a dual nozzle system for clay and concrete, that uses the advantages of each material to compensate for the limitations of the other. Through the simultaneous printing process of both materials, each layer serves to support the other and allows new geometric freedom. The on-site production of all vertical elements is supplemented with prefabricated horizontal elements. Here, the concrete takes over the load transfer and, as a pure compression structure, can dispense with reinforcement. Furthermore it provides erosion protection for the clay. The clay serves as a thermal envelope and offers the possibility of component activation. This is made possible by a hexagonal, printed structure, which also reduces the material consumption.





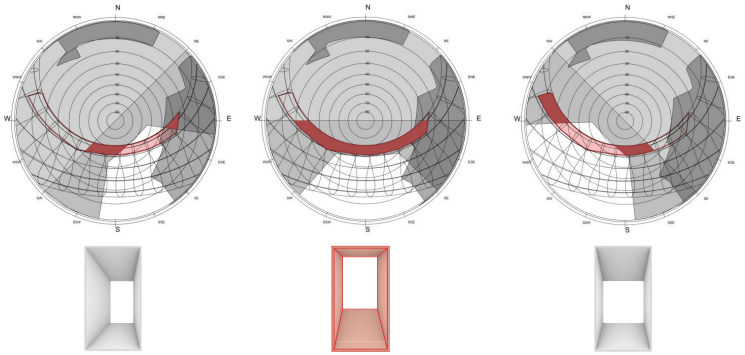


[BREUER X AM]

Mia Düpree & Mareen Fechner / TU München

A01

This design presents architectural design strategies of bespoke façade modules informed by solar control aspects within the potential of SCA as AM technology. Geometry-based graphical methods for solar control support the design explorations by unfolding the relationship between the form of the modules and their shading performance. The modular and precasted concrete modules of Marcel Breuer's IBM Research Center in La Gaude, France serve as design inspiration for the proposed design with the objective of reinterpreting Breuer's design and fabrication methods used at that time towards customization. Applying computational tools to explore the vast design space allowed by AM, it has been possible to develop bespoke self-shading façade components for a circular oriented building.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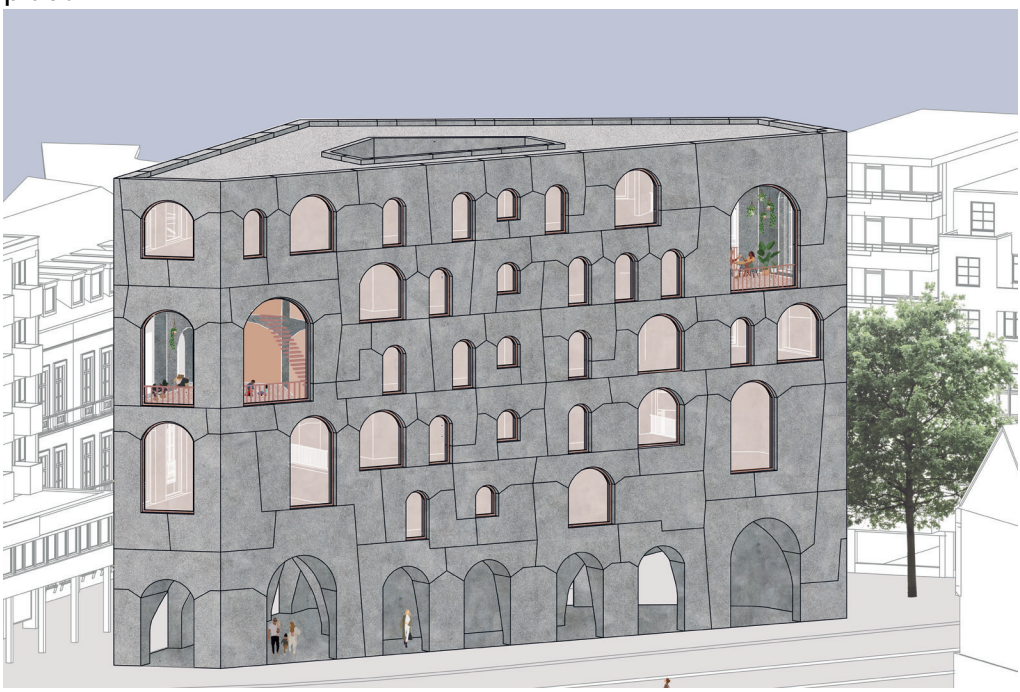
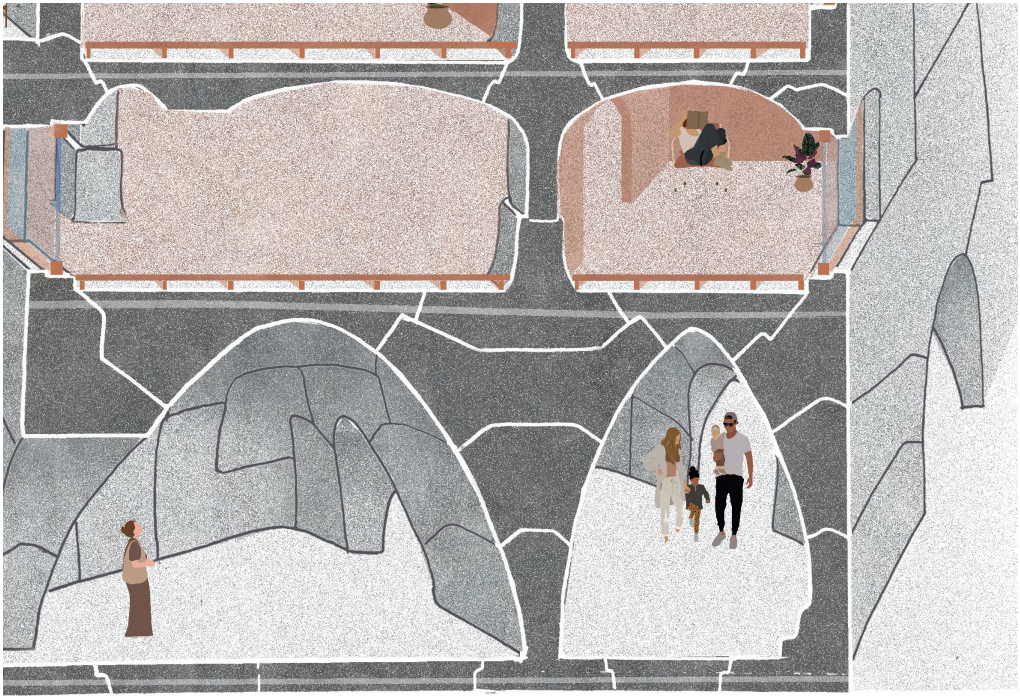
South-East
South
South-West

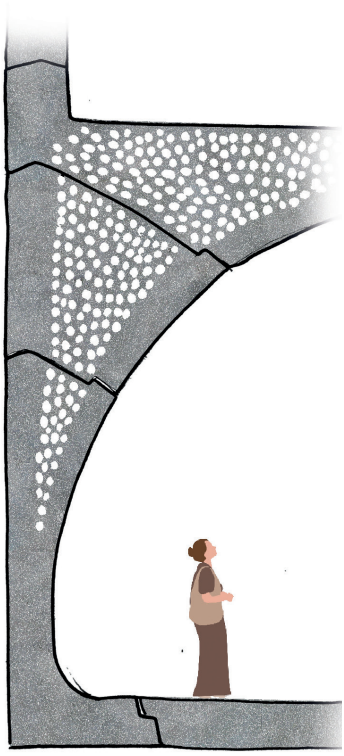
[PLAYING WITH THE BLOCKS]

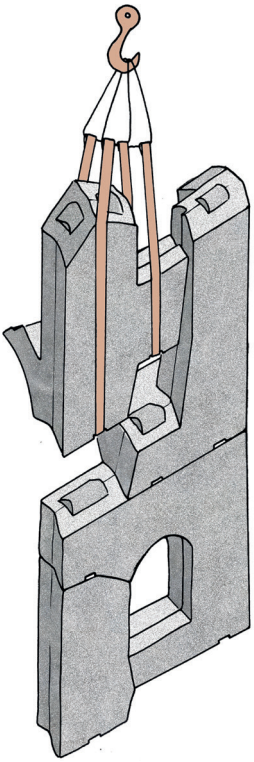
Amber Alvarez & Elke Meiersonne / TU München

This project explores design strategies of traditional compression-dominant construction principles in combination with the design freedom given by AM technologies using the SPI method to fabricate interlocking, customized building components. With the SPI method, artificial ‘stones’ are fabricated with lightweight concrete off-site. The inner composition of the components is tailored to fulfill both the static and thermal requirements within a reasonable wall thickness. Since the rough surface is typically for the SPI method, the architectural spaces will experience a unique character. Once the elements are pre-fabricated, they are transported on site and stacked onto each other, without the need for temporary support. Tension cables are installed in each floor slab to tie the entire building assembly in place.









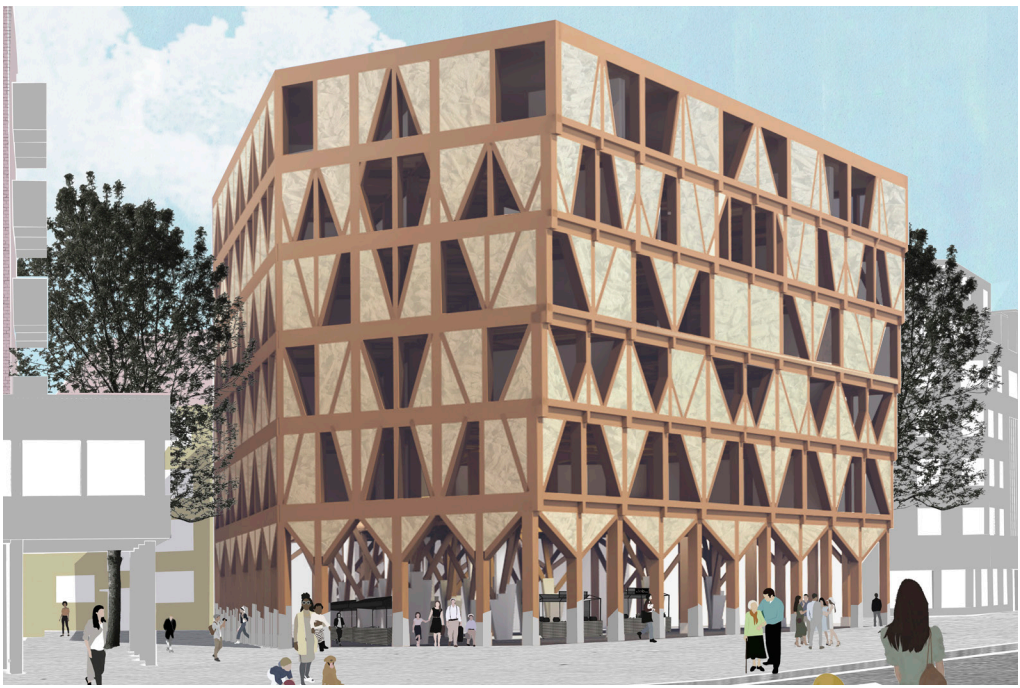
[HALF-TIMBERED HOUSE RETHINK]

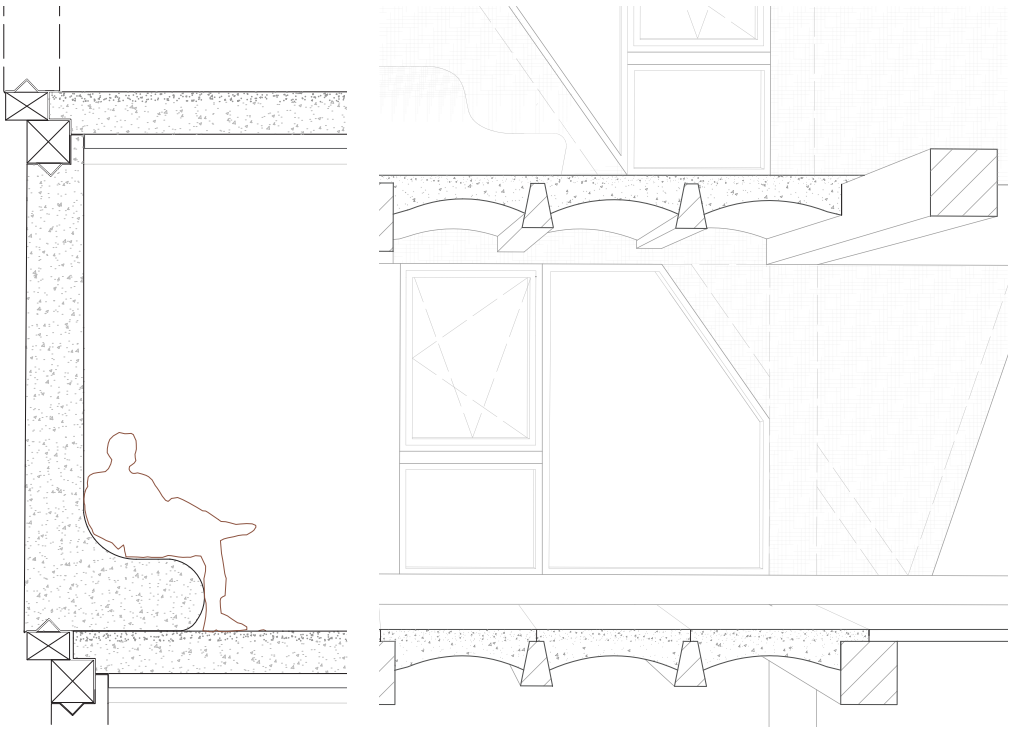
Natalia Comet & Zhiyuan Wang / TU München

A08

A traditional half-timbered house, made of a load-bearing timber structure and brick or clay infills, is generally known for its ecological friendlyness as well as for its lack of adequate insulation values. In addition, the rather complex and highly customized façade requires a high degree of manual labor to build on site.

Therefore, our project at the historic site of the Ägidienmarkt in Brunswick presents a new interpretation of the historic half-timbered house, which is prefabricated as a lime-bonded wooden structure. The timber framework with 3d-printed insulation infill panels is fabricated off-site and assembled on-site in the form of customized modules.

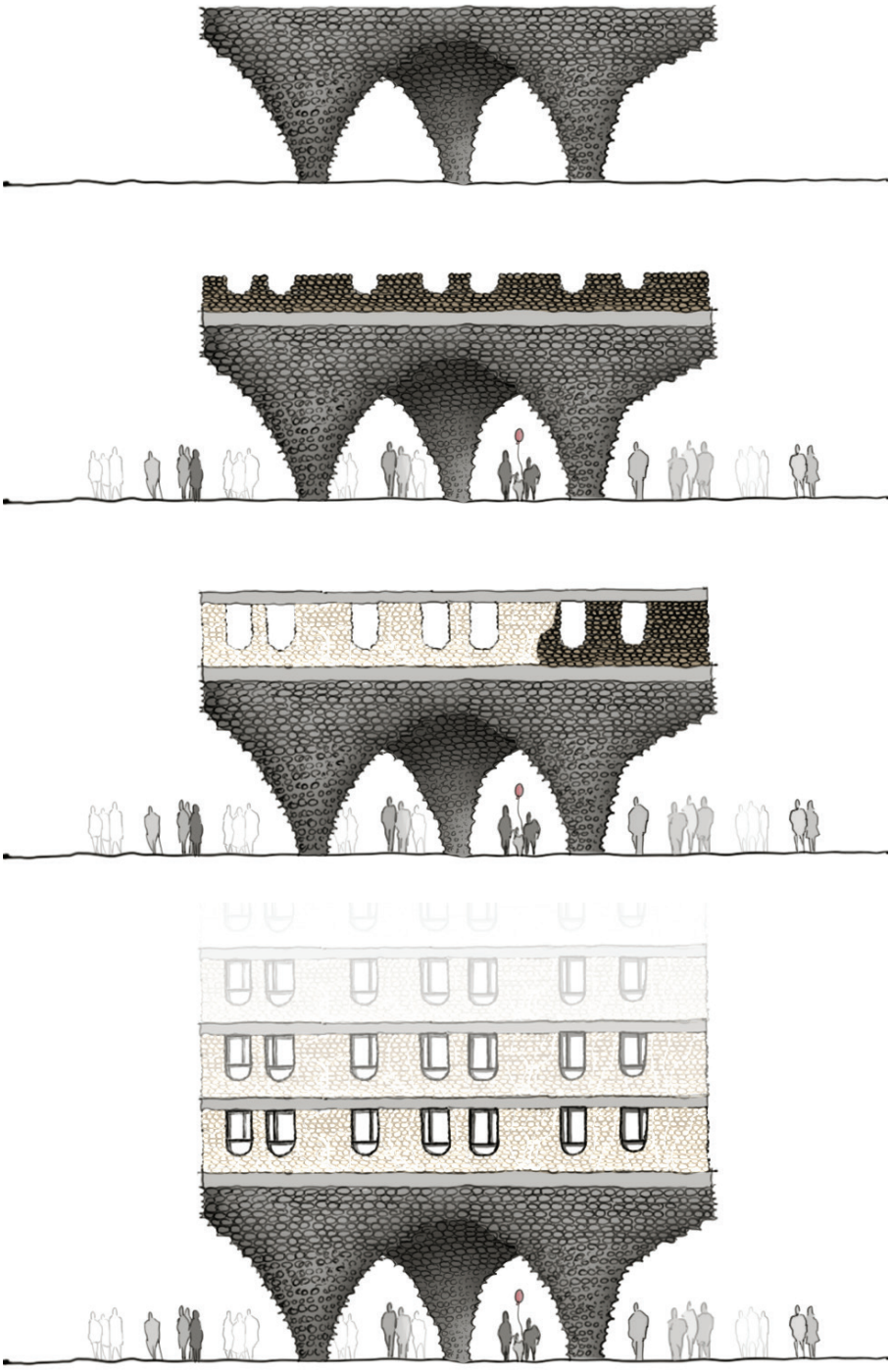




[POSITIVE SUBSTRACTION]

Kerem Yilmaz & Christina Schwalm / TU München

This experimental project is a building design composed of two core concepts: a negative clay cast on the first floor and a clay-printed façade placed above it, but both fabricated exclusively with AM technologies. 3D-printed converging clay domes serve as a mold to shape the ground-floor market hall, which is casted with concrete and then washed off after setting. The re-cycled clay is then re-used to fabricate the façade of the residential building above. To protect the residential facade from weathering, it is then coated with spray plaster.

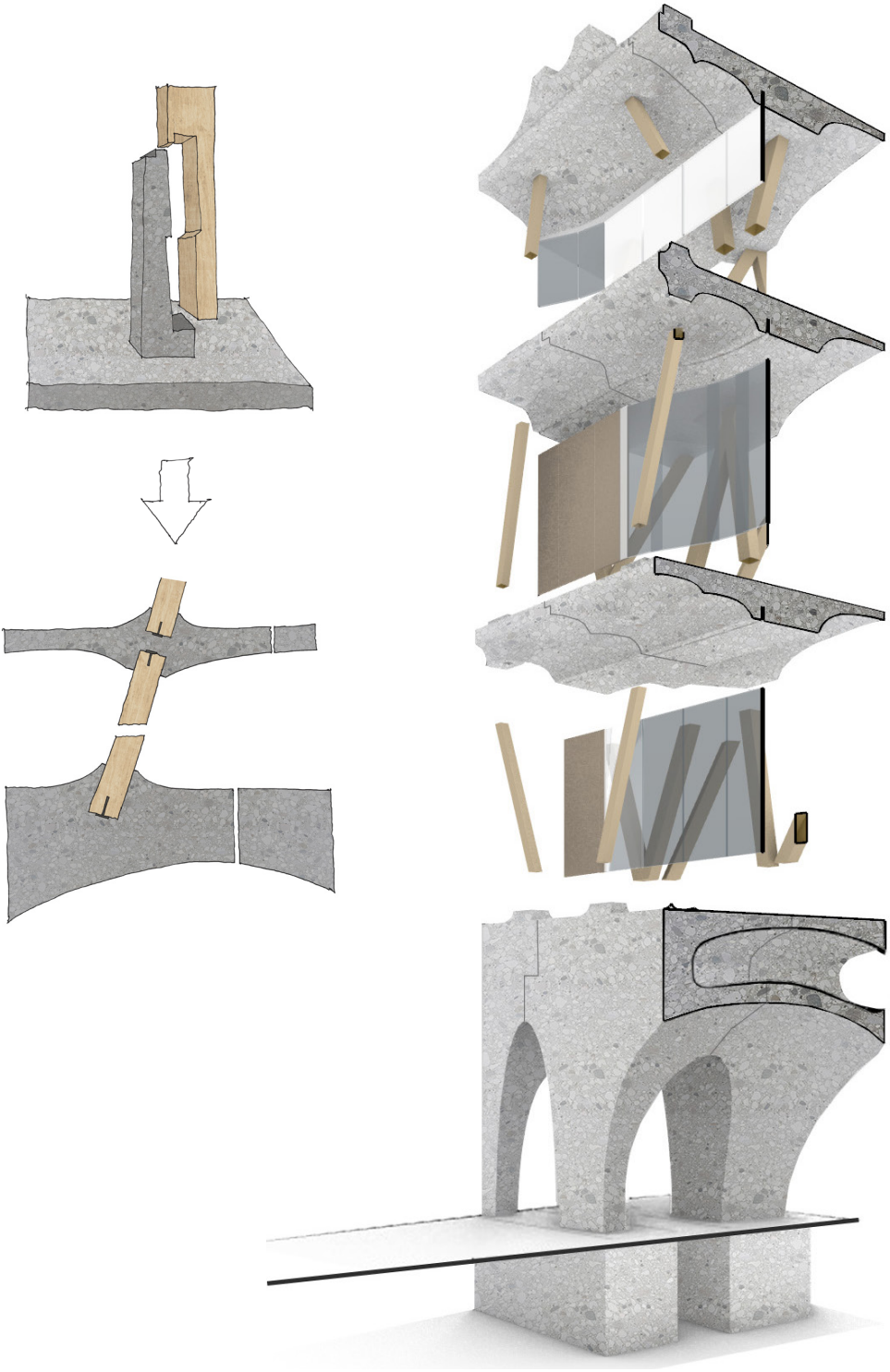


[STONE-TIMBER STRUCTURES REIMAGINED]

David Meister & Fabian Schneider / TU München

A02

Throughout history, stone and wood have been among the most important materials used for buildings, supporting each other with their respective strengths. Reflecting on this, our project reinterpretes how stone in the form of SPI technology and timber can come together. The open market area on the ground floor is sculpted by vaults of different sizes and various uses, thus acting as a filter for the old Magni district from the urban context in Brunswick, fabricated with SPI method. The upper floors also use SPI slabs with vaults, with the difference that the vaults are somewhat compressed and the vertical elements are substituted by wood. The position of the timbers is determined along three constitutive zones throughout the building and the angle of inclination is based on the vaults of the market hall, to which the timber beams are oriented in tangents up to 35°.

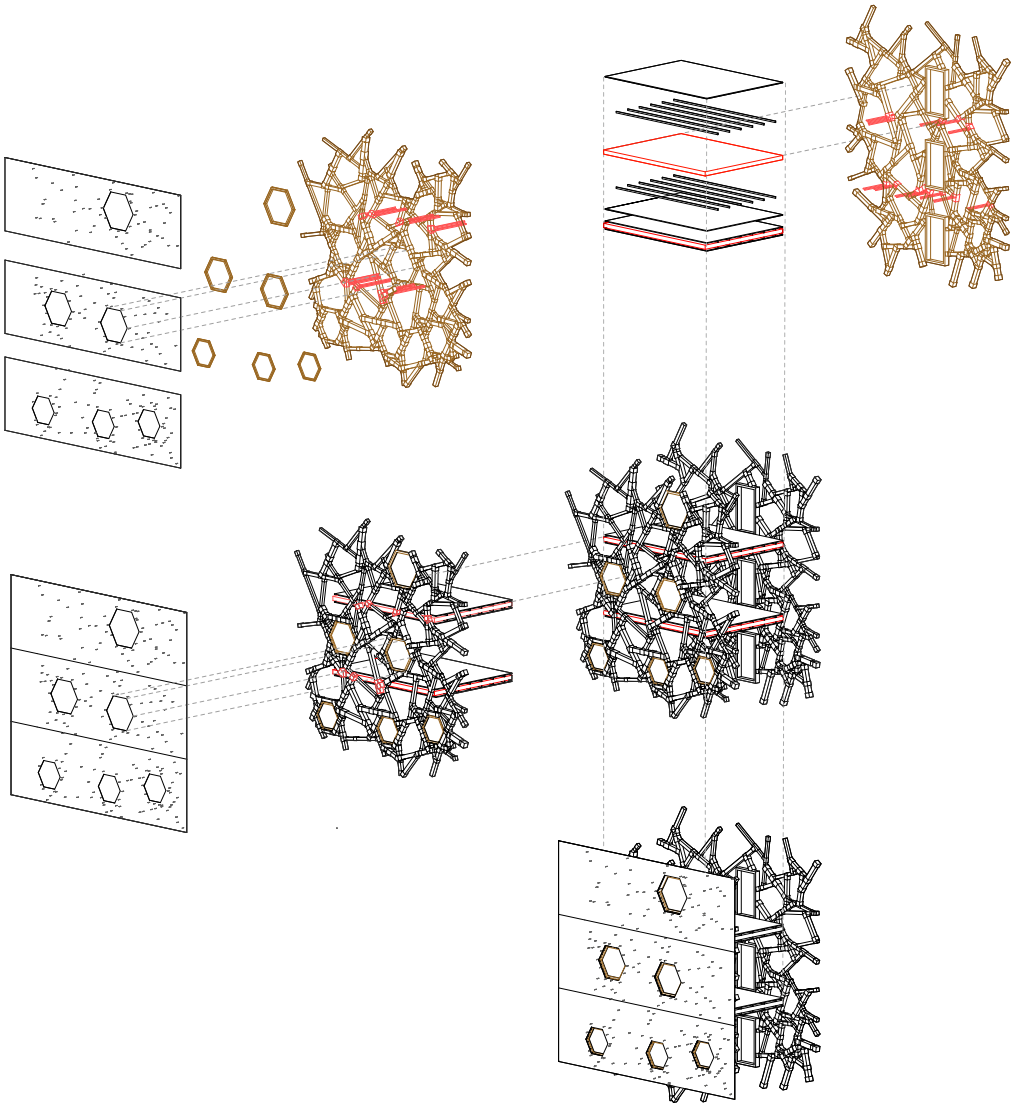


[HOLD ON, TIMBER!]

Shi Zhan & Tianpu Zhou / TU München

A07 A06

This project investigates AM strategies for the pre-fabrication of a load-bearing structure from reused wood components with bespoke metal joints with WAAM or SLM technologies. The structural system is based on the principle of structural reciprocity, which composes a spatial configuration with unclear structural hierarchy, and is generated by an optimization algorithm that allows minimizing the material waste and maximizing the short stock elements use. AM methods such as WAAM SLM enable connections between beam elements of different angles and different cross-section in three dimensions. This combination of metal joints strengthens and extends the properties of timber structure, creates a dry-joint structural system and allows components to be easily disassembled and replaced.

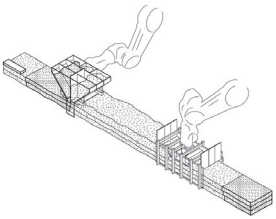


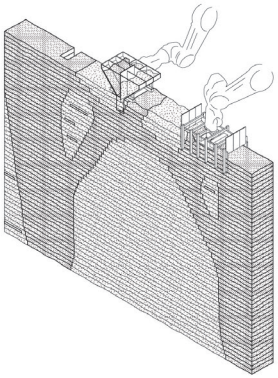
[RAMMED ARCHITECTURE]

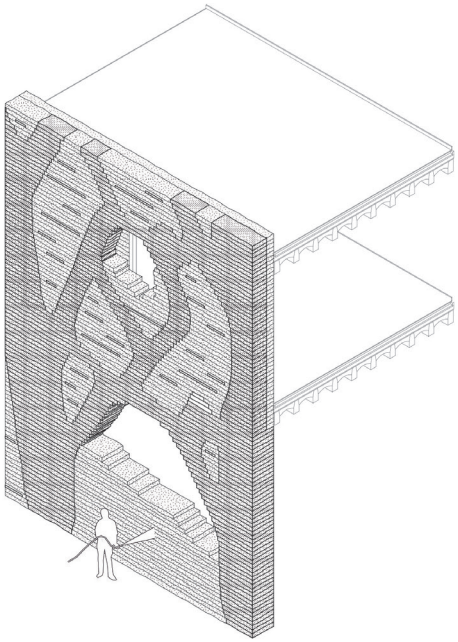
Gabriela Kienbaum & Julian Tesche / TU Braunschweig

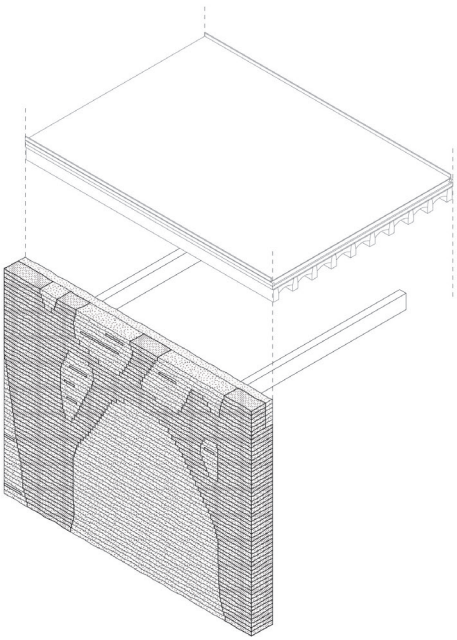
A10

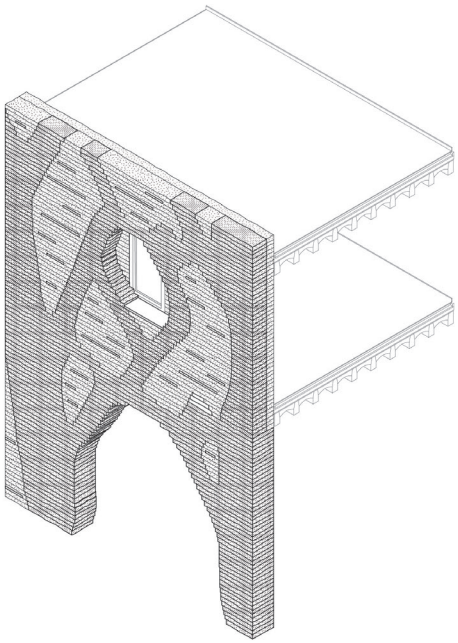
The building concept is based on the idea of a differentiated nozzle system which allows combining clay, concrete and lightweight clay in a robotic ramm process. Rammed clay provides the building shell and serves as formwork for integrated load bearing structures made of rammed concrete. On the interior side a layer of lightweigth clay is rammed simultaneously and provides the insulation of the bulding. The result is a 3-in-1 structure that is parametrically developed following an optimized force flow. Concrete is only embedded where necessary, regarding the load bearing structure. All other parts are filled with rammed earth or left open für windows and doors.









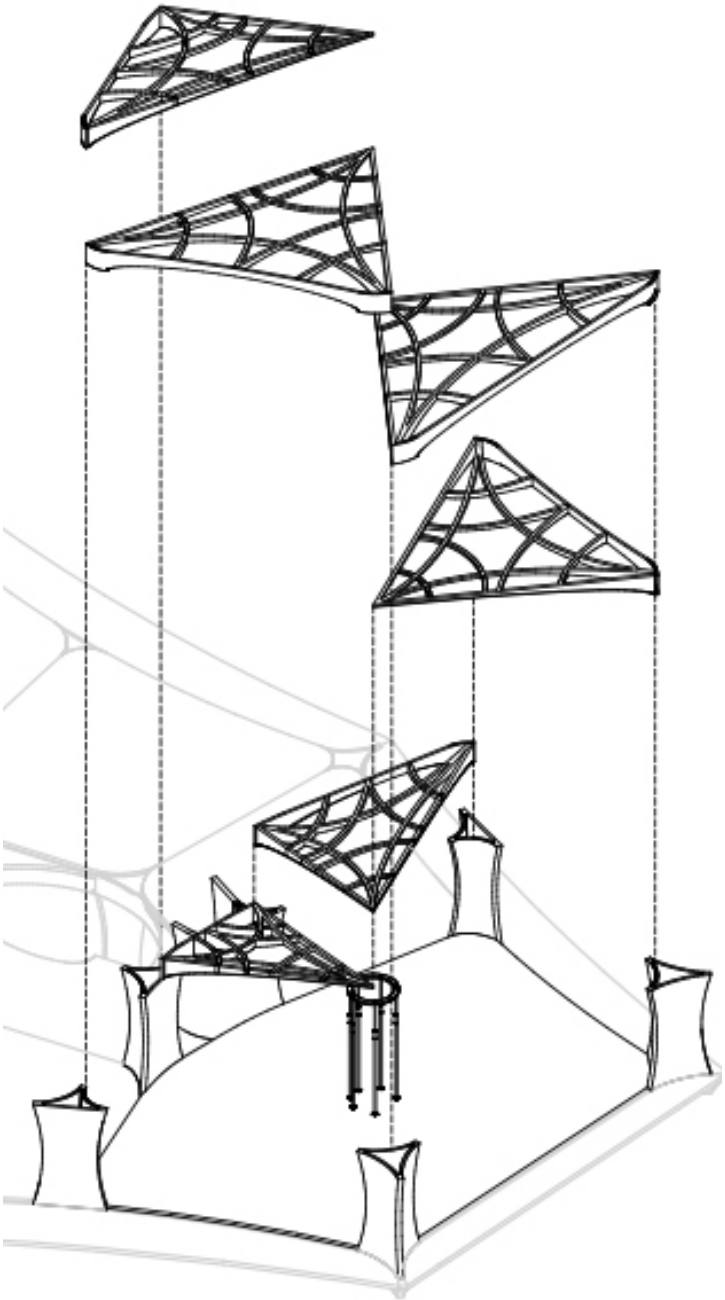


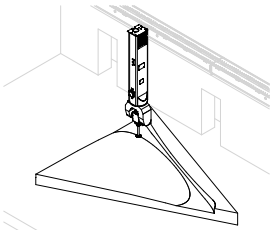
[SHELLTECTONICS]

Leon Kremer & Thilo Schlinker / TU Braunschweig

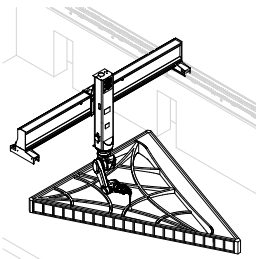
A05

Starting point of our design proposal was the shell and its material-efficient way of transferring loads to the ground. Therefore we used vaulted ceilings and columns that consist of three shells that also brace themselves. The parts are prefabricated in a controlled environment and then assembled on site with dry joints, creating a super-light load-bearing structure. The plan is completely free for an unlimited number of configurations. Lightweight wooden structures separate rooms and complete the façade.

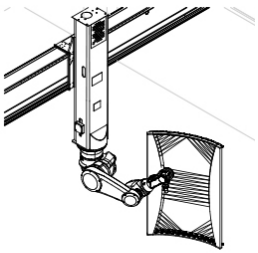




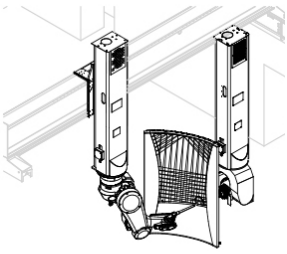
S1 milling of wax-formwork



S4 rib shotcreting



D2 winding first layer

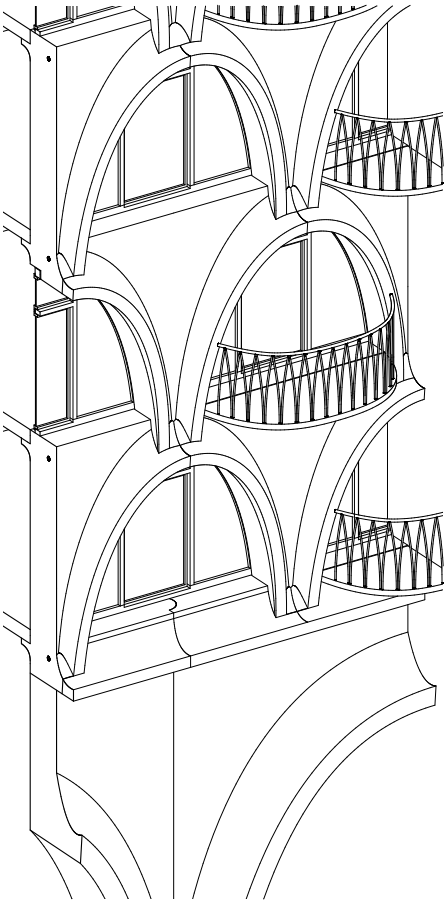


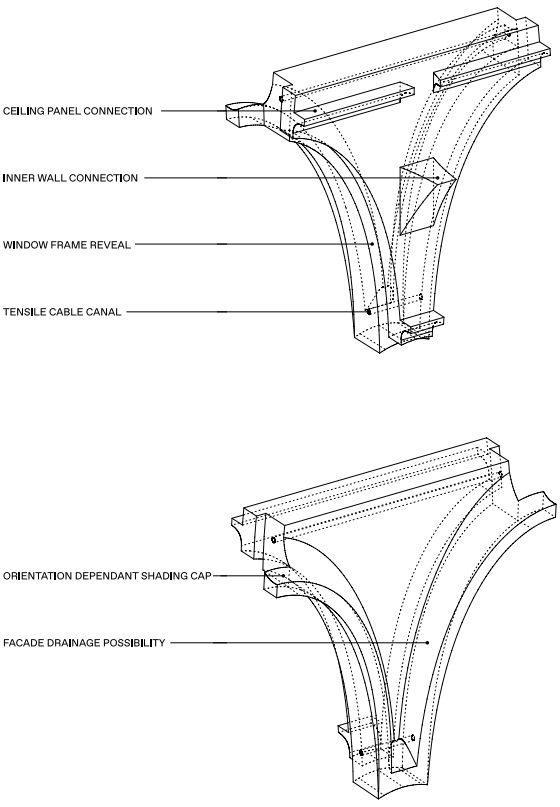
D4 shield printing

[THE RENEWED POTENTIAL OF A FORMAL LANGUAGE]

Philip Nünning / TU Braunschweig

LP3DCP is chosen to be the AM method for this project and describes a process in which shotcrete is sprayed onto and between recycled coarse aggregate coming from demolished buildings. As the process takes place inside a particle bed there are nearly no limits to the printed elements' formal expression. The building design focusses on resource optimized elements with a minimized usage of reinforcement by reducing most of the static structure to compressive forces taken up by the arched, monolithic facade elements. The aim is to combine an aesthetic approach with the various formal possibilities of AM technologies whilst creating simple monolithic elements that host different functions such as orientation dependent shading, insulation and drainage functions. Being printed ex situ, the single building parts get transported to the site and are being assemble with the help of a traditional crane. The elements of each floor are post tensioned after being assembled with the help of tensile ring beams.



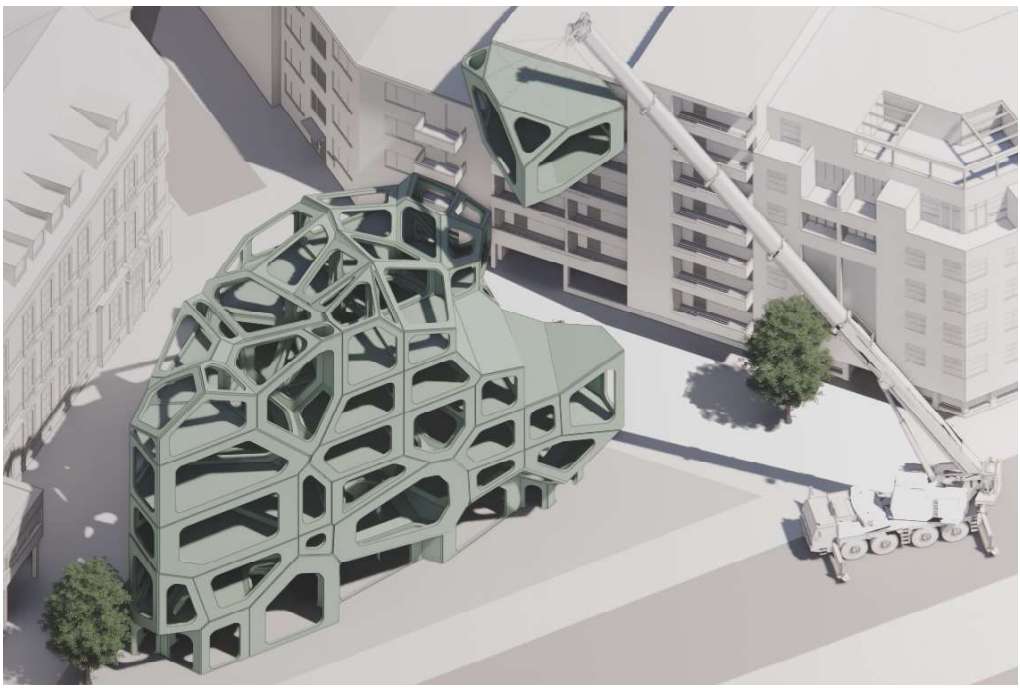

CEILING PANEL CONNECTION
INNER WALL CONNECTION
WINDOW FRAME REVEAL
TENSILE CABLE CANAL
ORIENTATION DEPENDANT SHADING CAP
FACADE DRAINAGE POSSIBILITY

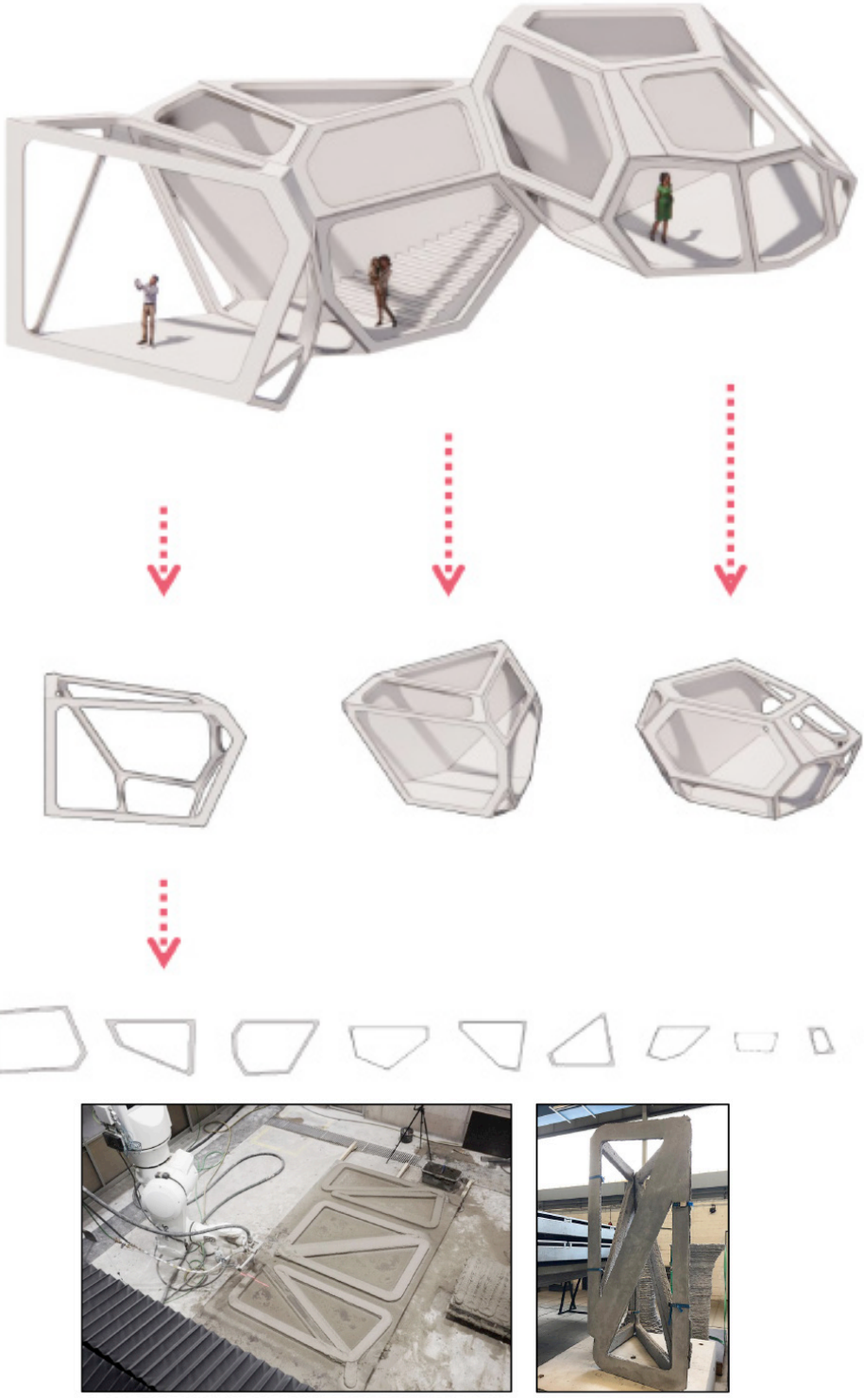
[VORONOI STACKING]

Cong Zhou / TU Braunschweig

A04

The project aims to develop a flexible yet modularized structure based on the technic of shotcrete 3D printing. The voronois are printed in separate parts, optimizied for their future function and the stacking assembly. By parametric design und optimization throughout the printing process, material is efficently used only for relevant, load bearing and stiffening building parts. The structure is solid and stiff by the combination of the varying voronoi forms, it can adapt to changing circumstances of different sites and it is expandable as well as easily removeable.





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July 2022