Earth Printing

Compact Design Studio

Institute of Structural Design
Winter 2023/2024

The Earth Printing compact design course led by Prof. Norman Hack and Noor Khader from the Institute of structural design (ITE), explored the ways in which advanced technology, specifically 3D Ceramic Printing, has transformed the world of design and fabrication nowadays. The use of advanced technologies and parametric modeling has enabled designers and architects to develop intricate and complex designs informed by variable parameters. This has opened up new possibilities for a novel design expression, highly detailed patterns and textures, and visually striking objects that are both functional and beautiful.

The students developed in 6 weeks a section of a Façade Wall that is segmented into parts and informed by the investigated experimental process such as parametric design, assembly and disassembly, fabrication limitations, interface connection and functional integration. Through series of lectures, digital modeling workshops, and mainly hands-on 3D printing sessions, students have learned fundamental principles of 3D digital modeling, the technical aspects of 3D ceramic printing, and the creative possibilities and pronounced aesthetics enabled by this technology.

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Printed Explorations

Prismo Bricktiles

Eitan A. Guzmán, Hagen Siedler & Mwaala Amadhila

Prismo Bricktiles

The hanging scales

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1 Facade visaulisation of the Prismo Bricktile

Preface

In the ever-evolving landscape of architecture, cutting-edge technologies played a pivotal role in tackling the dual challenges of sustainability and aesthetic innovation. The integration of digital fabrication and 3D printing technologies into building facades provided a unique opportunity to meet these challenges by enabling intricate, customizable designs that were efficiently fabricated using various materials.

The Prismo Bricktile

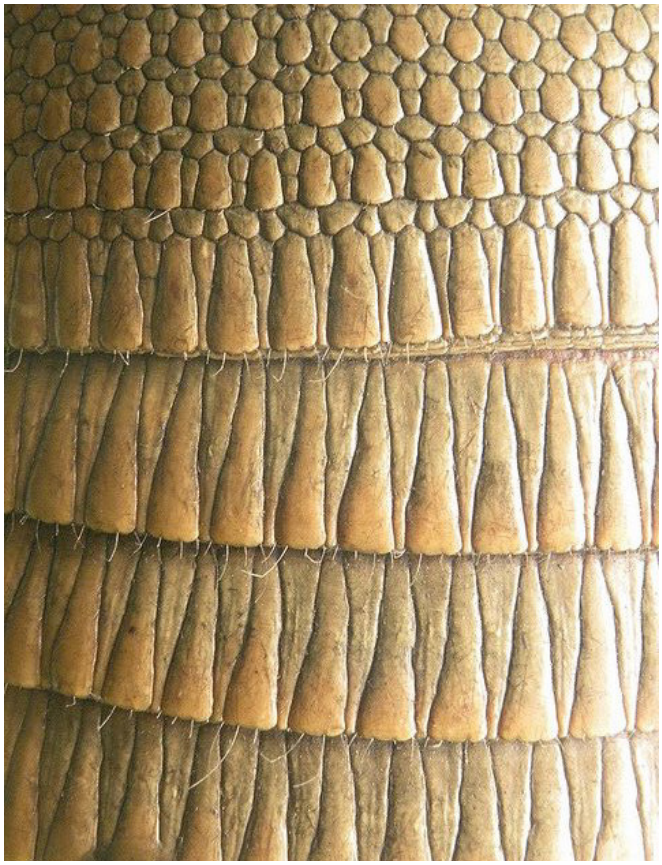
Prismo Bricktile was an exploratory research project that addressed various factors present in architectural design and construction, with sustainability and efficiency being of utmost importance. Until then, the environmental impact of traditional construction methods had prompted a paradigm shift toward sustainable practices. On the one hand, digital fabrication and 3D printing technology, when applied to facade design, offered the potential for reduced material waste, efficient use of resources, and a lower carbon footprint compared to conventional construction methods. On the other hand, it allowed for unprecedented design freedom. By incorporating organic forms, it was possible to create visually stunning facades that not only

enhanced the aesthetic appeal of buildings but also contributed to improved functionality. This level of customization enabled a unique blend of art and technology in architectural design.

Design inspiration

The project's ethos was rooted in the resilient and intriguing armadillo. With their unique protective shells made up of overlapping plates, they had evolved over millions of years to provide an effective defense mechanism against external threats. In the context of a brick tile facade, the armadillo-inspired design offered several benefits. First and foremost, the overlapping plates on an armadillo's shell created a natural form of weatherproofing, preventing water infiltration and minimizing the impact of harsh environmental conditions. By translating this concept into a brick tile facade, a structure that was inherently resistant to water damage was created, ensuring the longevity and durability of the building. The emerging layers varied depending on the building situation, in which the openings between layers were exaggerated when placed in front of windows or glass facades, while the closed, narrow layers worked as shielding for the outside walls of the building. These organic openings were formed by slightly shifting the flow of each row in relation to the next overlap to enhance the building's responsiveness to external factors, such as wind and sunlight protection. Flowing, ongoing curved lines simulated each plate of the armadillo's armor, and the separation into individual tiles emulated the pattern on each plate, following not only the animal's efficient shielding but also its astonishing texture..

From the concept and inspiration, the design evolved through extensive experimentation and testing of the reulting pieces. From simple vertical straight pieces to curved diagonals, the different geometries explored resulted in very interesting pieces, each one resulting in changes that led to the complex geometry of the Prismo Bricktile. The fabrication of this complex, prism-like structures that would be challenging to achieve through traditional construction methods, was made possible by clay 3D printing technology.



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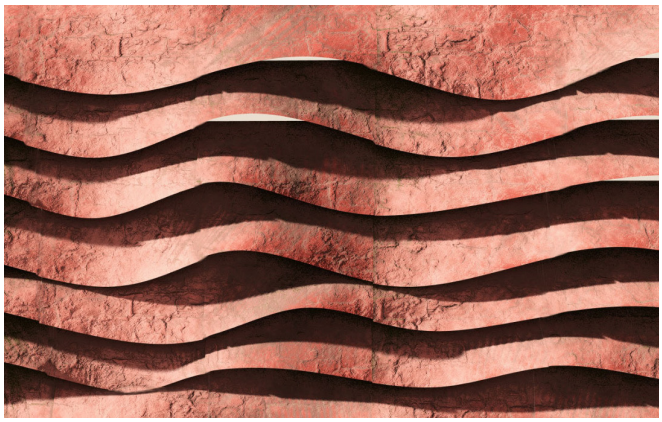

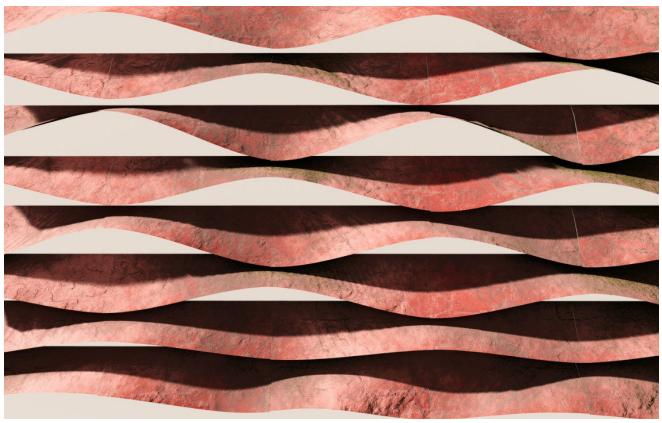

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2 Armadillo plates and patterns

3 Biomimicry design study of flowing rows and openings

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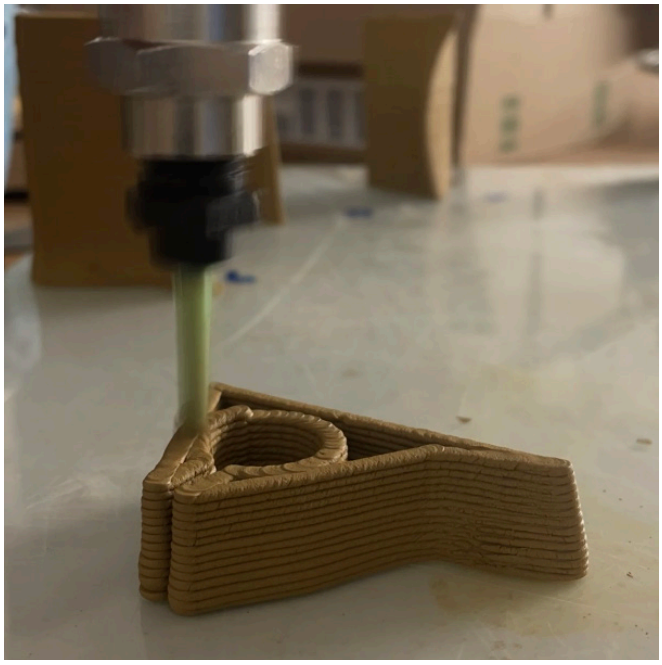

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4 Early geometry printing tests with different textures (front)

5 Early geometry printing tests with different textures (from above)

6 Process of 3D printing using specialized clay injector

Materials efficiency

Clay is a very versatile material perfect for sculpting ornamentation and togehter with the innovating process of 3D printing exceeds the limits of regular sculpting with innovative, organic and parametric designs and unravels new opportunities for modern architectural solutions.

Through this innovation, the Prismo Bricktile promoted resource efficiency by considering many of the material's characteristics and applying them to the design. It also reduced material waste by using only the amount of material necessary for the pieces to be strong enough. In addition, Prismo Bricktiles tackled the ability to customize each tile for optimal performance. Furthermore, the geometry of the tiles set up organic openings, which created an aesthetic play of light and shadow, resulting in a dynamic facade that changed throughout the day.

This feature not only enhanced the project's functionality and efficiency but also created a comfortable, visually stimulating, and harmonious indoor and outdoor environment, improving the overall well-being of building inhabitants and users..

Assembly system

The prism geometry functioned as the stabilizer of the piece, forming an opening into which a metal rod slid into place. The triangular sides made the body less fragile while using less material. This part was key in every piece for assembly. The front side was the only variable, extruded differently in each print.

Using Kengo Kuma's hanging brick structure design, developed for a hall in Shanghai, China, as a reference, the project implemented clay as a filigree facade material rather than the traditionally solid, load-bearing brick construction. This was achieved by using tension cables anchored from the ground to the top of the building as the facade structure. The tiles were then suspended by custom steel clamps that pressed the cable while connecting the metal rods to fix the tiles in place.

The virtually levitating pieces defied the conventional installation methods of regular brick facade construction and conformed to an adaptive system with many variations.

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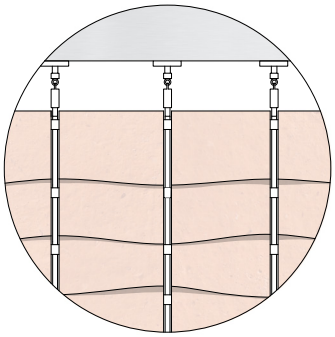

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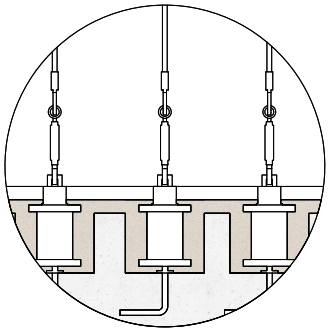

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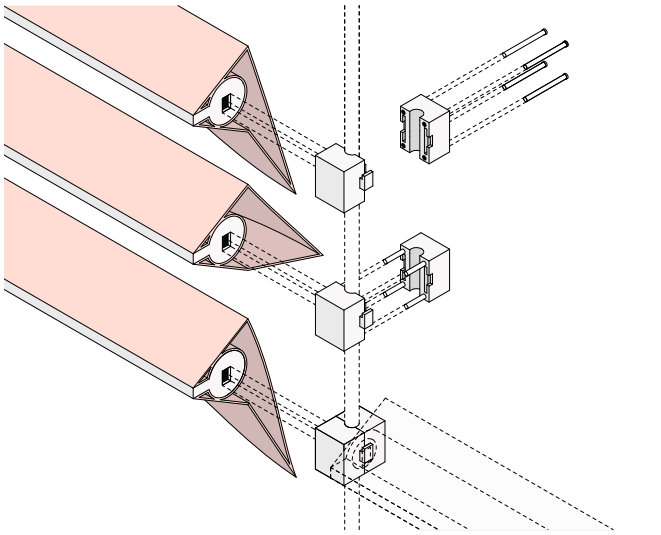

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7 Physical reconstruction of the Prismo Bricktiles supended on steel cables

8 Ilustration of the structure anchoring to the top of the building

9 Ilustration of the structure anchoring to the ground

10 Ilustration of the structure's assembly using specialized clamps

11 3D printing test showcasing the curvature flow on the pieces

13 3D printing test showcasing the curvature flow on the pieces

15

15 Visualization of the exterior atmosphere created by the Prismo Bricktile facade

16

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16 Visualization of the interior atmosphere created by the Prismo Bricktile facade

17 Physical reconstruction of the assembly system

Culture Drapes

Intisar Ahmed Fadel, Farah Chikh Torab

Culture Drapes

Unveiling the cultural charm:
Elegance in bricks inspired by curtains

1

1 Photo of the final demonstrator of a section of the facade in a 1:5 scale, presented during the final presentation

Preface

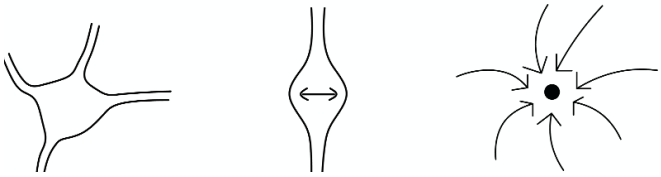
The project drew inspiration from the vibrant flow of culture within the city, ingeniously employing parametric design to craft a facade that served as a dynamic cultural meeting point. The primary objective of the course centered on the development of a facade within the urban landscape of Braunschweig, utilizing printed clay material. Throughout the project, various innovative techniques and software applications were embraced and mastered to enhance capabilities. The incorporation of these advanced methods became instrumental in the commitment to crafting a facade that seamlessly integrated with its environment, contributing to a dynamic and aesthetically pleasing image for the city.

The approach involved a thorough analysis of the surroundings, focusing on identifying key elements within the city that could serve as inspiration for the project. Multiple on-site visits were conducted during the analytical and research phase, involving precise measurements of the existing facade and a comprehensive examination of the adjacent buildings. The overarching objective was to harmonize the new facade with its surroundings, fostering a space that promoted cultural exchange and interaction among individuals from diverse backgrounds.

Initial Idea

The facade was situated in the heart of Braunschweig, nestled amidst a backdrop of historic buildings. Notably, the existing facade featured a blank surface, surrounded by the symmetry of the neighboring historical facades and statues. The site's uniqueness was deeply rooted in its historical evolution, with the passing years leaving an indelible mark.

What particularly captured attention were the narrow, winding streets that suddenly opened up into large, open spaces, as shown in Fig. 2. This interplay between tight urban confines and spacious pockets not only offered a sense of orientation but also wove an engaging and captivating urban tapestry.



Design Process

The design was primarily created using Grasshopper, with Rhino used solely for minor adjustments to refine the form.

The facade was divided into vertical strands. Attractor points were manually placed to generate windows and the entrance door, ensuring that the windows varied in size and the entrance door made a bold statement. Along the vertical structure, hand-drawn curves were extruded to mimic the irregular folds of a curtain. To enhance the simulation of a falling curtain, the extruded strands were deformed, causing the folds to vary in size through vertical extrusion. Subsequently, the strands were given a woven surface to replicate the texture of a curtain.
Finally, a vertical grid was applied to divide the facade into brick-like sections.

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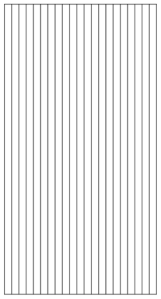
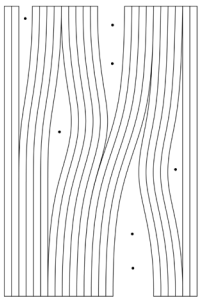
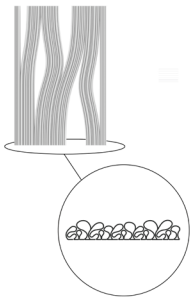


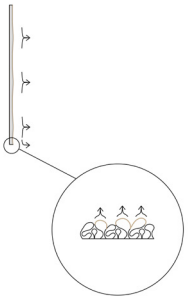
Dividing surface into strands



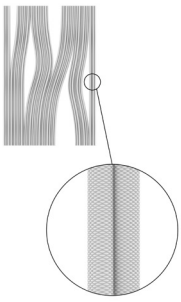
Placing attractor points to generate openings



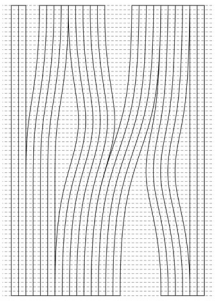
Extruding curves along curves



Deforming strands



Weaving surface



Segmenting strands into bricks

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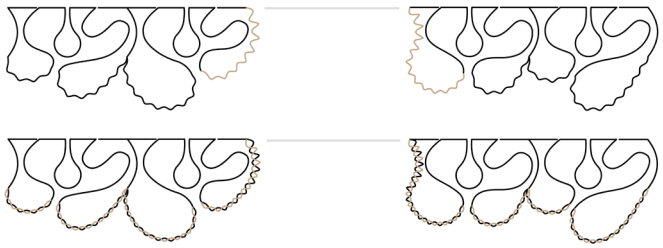
2 Aerial view of the site and pictures of the open spaces in its environment.

3 Diagrammatic representation of the individual steps in the design process.



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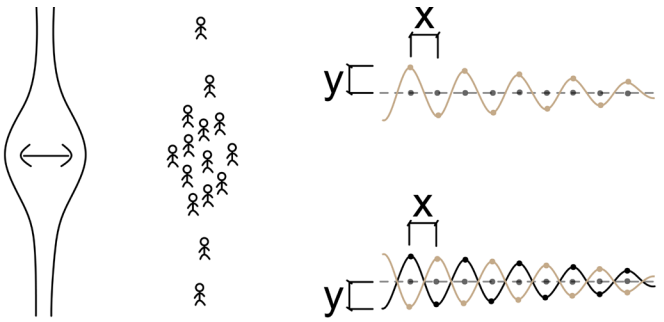

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4 The printing path generated by the point displacement at the window openings, as well as the alternating printing paths above and below them.

5 The displacement of the points with a spacing of x from each other in the changing amplitude size of y.

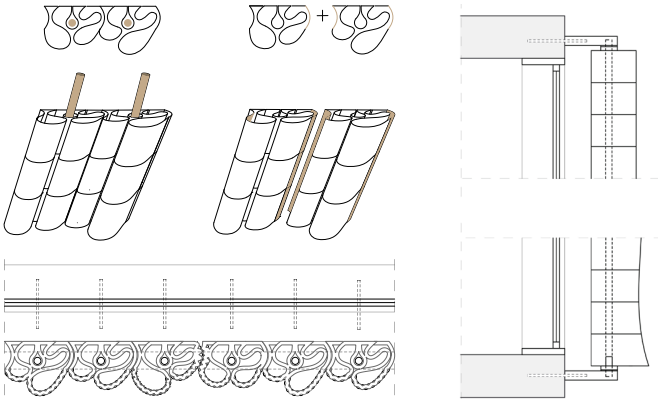
Surface Pattern

The pattern on the brick surface was designed to densify near the windows, mirroring the pedestrian density in the public spaces of the city.

This was achieved by dividing the curve into points, with every second point alternately shifted inward and outward. To create an offset in the pattern, the displacement in the subsequent layer was mirrored. The density of the pattern depended on the number of points and the size of the amplitude, resulting in an increase in amplitude at the window openings.

Infill and Connection

he infill design meticulously corresponded to the brick's form, serving a dual purpose of enhancing aesthetic cohesion and reinforcing the structural stability of the brickwork. In its execution, the design incorporated a strategically positioned aperture within each brick, facilitating the insertion of steel rods that provided essential vertical support, as shown in Fig. 6. Each strand was reinforced by the insertion of a steel rod, ensuring a robust structural framework.



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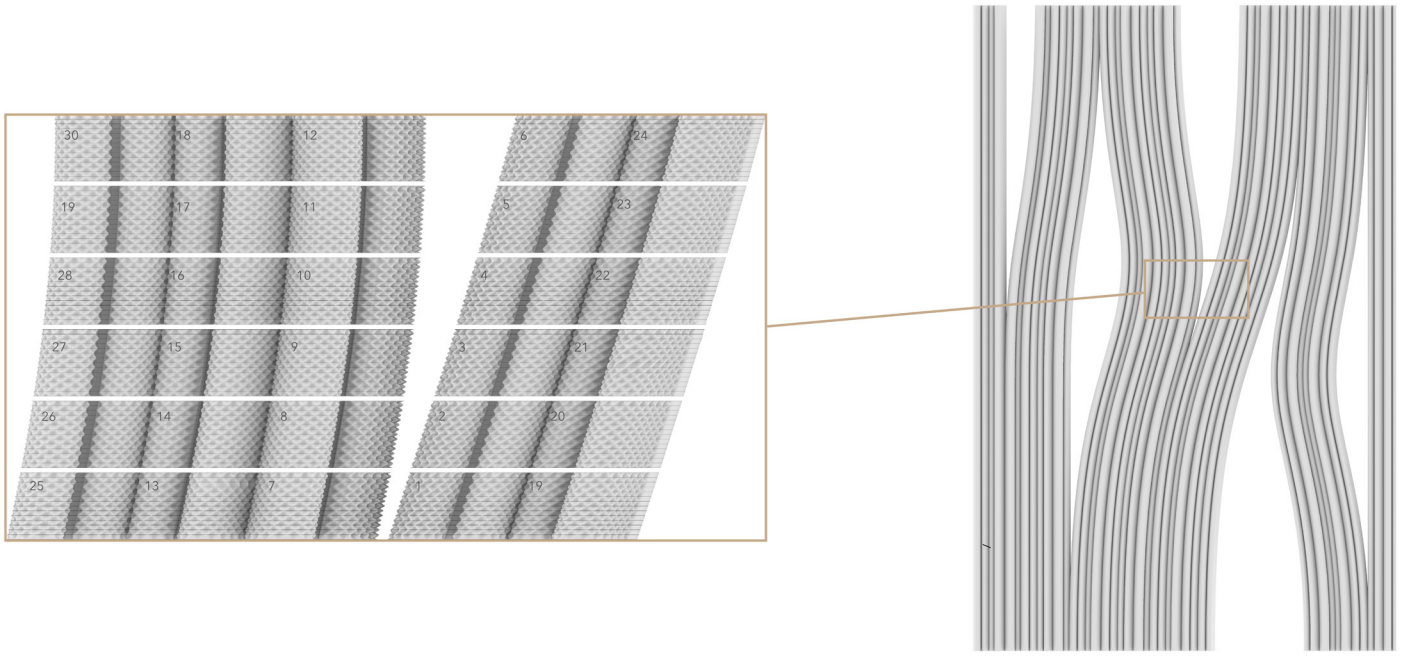
6 Demonstration of the vertical and horizontal connection through sections taken from the facade.

7 The form as a structural self-support.

A secure horizontal connection was established through a straightforward yet effective female-male connection mechanism. The precision of the brick dimensions guaranteed a seamless fit between adjacent bricks, contributing to the overall structural integrity and visual uniformity of the facade. In instances where openings existed within the facade, the adjacent bricks maintained a straight alignment, ensuring a cohesive and visually appealing integration.

Notably, the brick facade was seamlessly linked to a glass facade at both the base and summit of the building, creating a holistic architectural composition. Behind each opening in the brick facade, strategically positioned windows offered dual functionality. Beyond their aesthetic contribution, these windows were designed to promote air circulation within the building, adding a practical element to the architectural design while maintaining a harmonious connection between the interior and exterior spaces.



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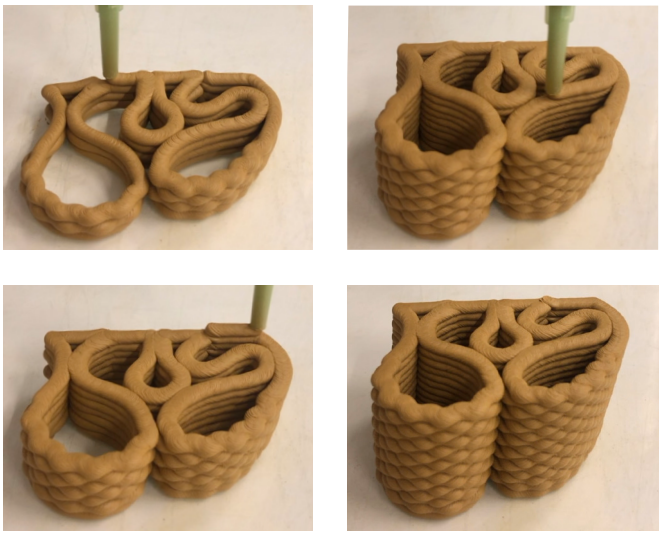

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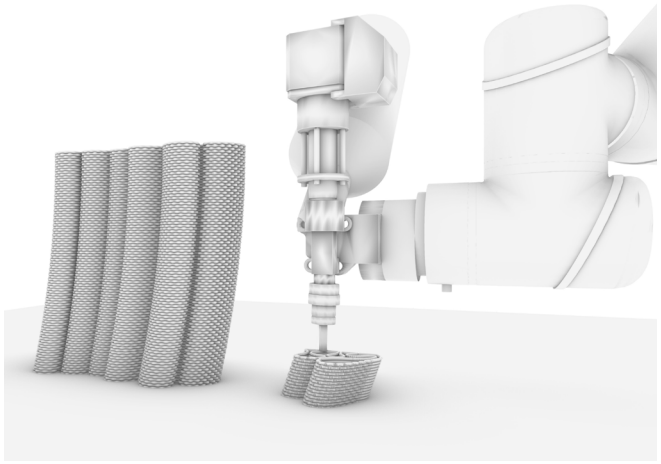

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The Final Demonstrator

When choosing the final model, a 1:5 scale section was selected. This section displayed five strands, representing the lower part of a window opening. The altered surface of the bricks within the openings could be observed. The cutout included a total of 30 bricks, as indicated by the numbered sequence in Fig. 8, which represented the printing order.

For printing, a 3.8mm nozzle was utilized with an air pressure of 4 bars, and the speed was set to 12mm/s. The layer height was 2mm. The printing process for each brick took approximately 5 minutes.

8 Display of the bricks chosen from the complete facade in a sequentially numbered printing order for the final demonstrator model.

9 Film stills captured from a video demonstrating the printing of a brick.

10 Simulation of the robotic printing of the final demonstartor.

11 The printed model while it is not yet fully dried.

12 The staged facade.

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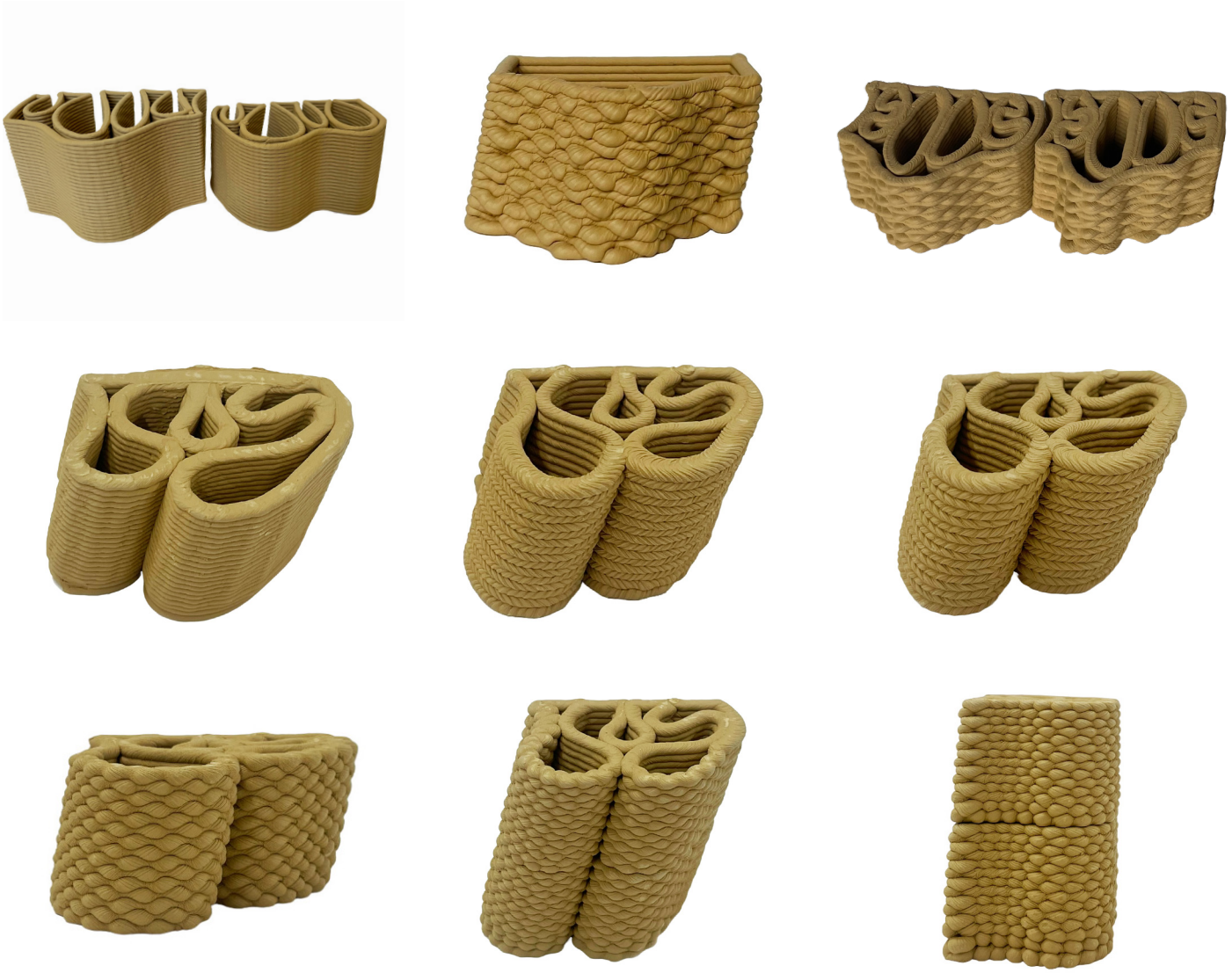

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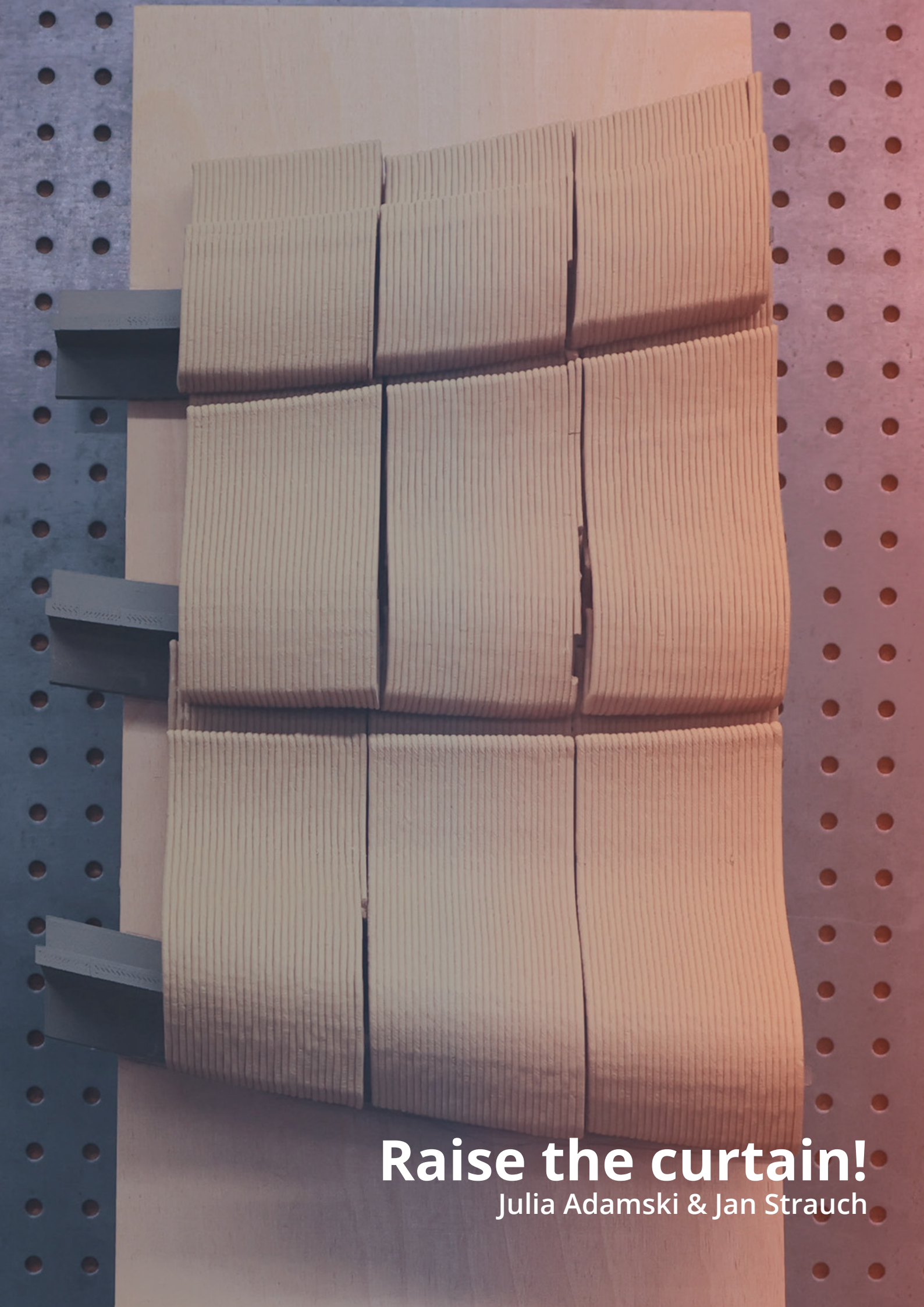
13 Working lab shots

14 The evolution of the design in photos.

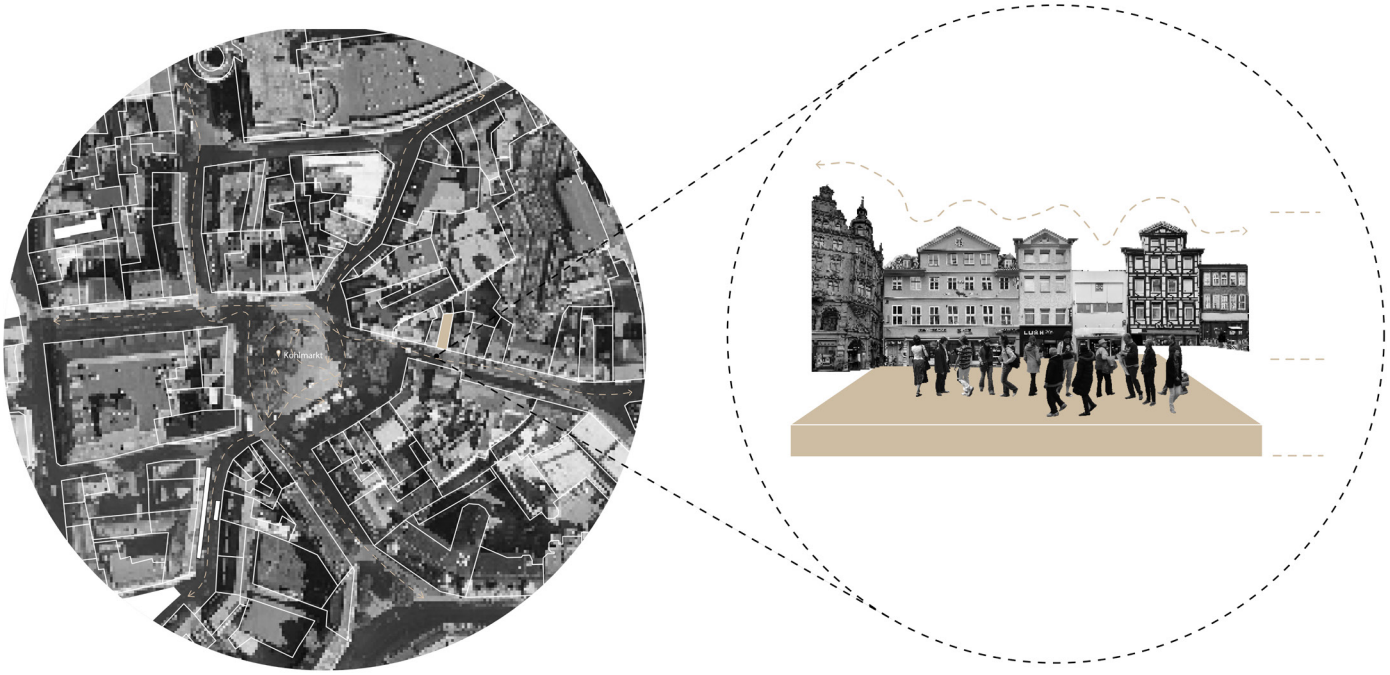


Raise the curtain!

Julia Adamski & Jan Strauch

Raise the curtain!

Unveiling Urban Rhythms



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1 Background analysis with collage of concept “stage of people´s life”

Prolog

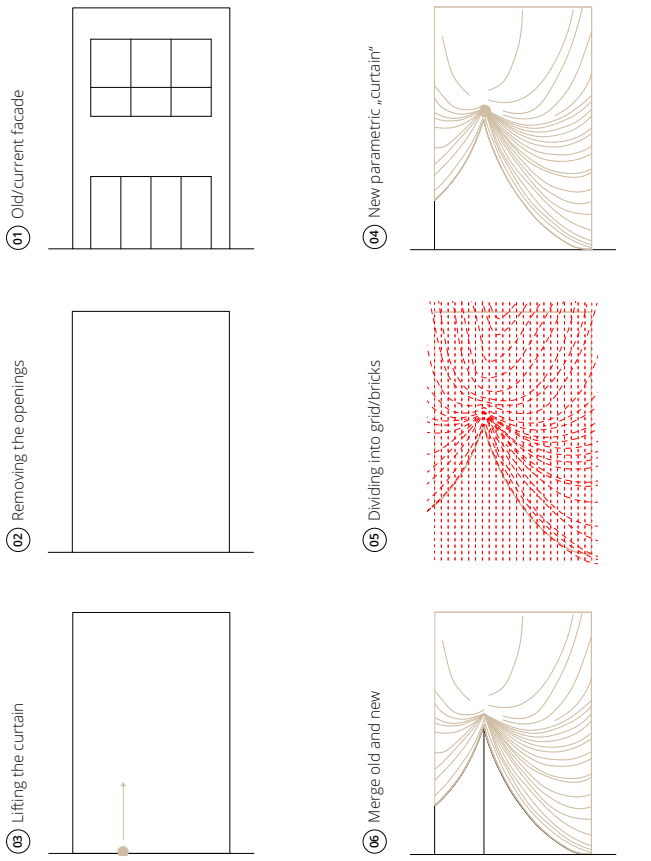
The city center of Braunschweig, a vibrant urban space, is both the location and the source of inspiration for this design. The lively atmosphere thrives from the diverse array of shops, cafés, and restaurants, as well as the people living in this city. Contributing to this lively atmosphere is the dynamically evolved city with various architectural styles, heights, proportions, history, and materials.

For such a lively place, we chose the metaphor of urban places being the stage of people’s lives. In this metaphor, the facades serve as the backdrop for the play.

Our conceptual theme revolves around the idea of an opened curtain, celebrating the tension between the inside and outside. The choice of a curtain is metaphorical. The facade, lacking openings, is likened to a closed curtain that needs to be raised. Like a curtain, the new design is intended to capture the audience’s gaze, direct attention to the hidden spectacle, hide and arouse curiosity at the same time, and create a sense of mystery. Additionally, it serves as a haven of peace or shield.

Concept

The idea began with the old rituals facade, which was a basic design featuring one large window in the upper half and a generous entrance opening on the ground level. Both openings were removed, resulting in a flat, white wall, reminiscent of a closed curtain. The plan was then to open it. To achieve this, the curtain was "picked up" at one point on the bottom and lifted upwards. This process created a new opening on one side and generated numerous folds on the other, shaping the final look of the new facade: the raised curtain. The opening was oriented towards the Kohlmarkt to establish a connection between the building and the lively city square. The final step involved dividing the facade into a grid so that it could be assembled with individual bricks. It was divided vertically from top to bottom and horizontally by following the lines of the folds, maintaining the lightness of a curtain.



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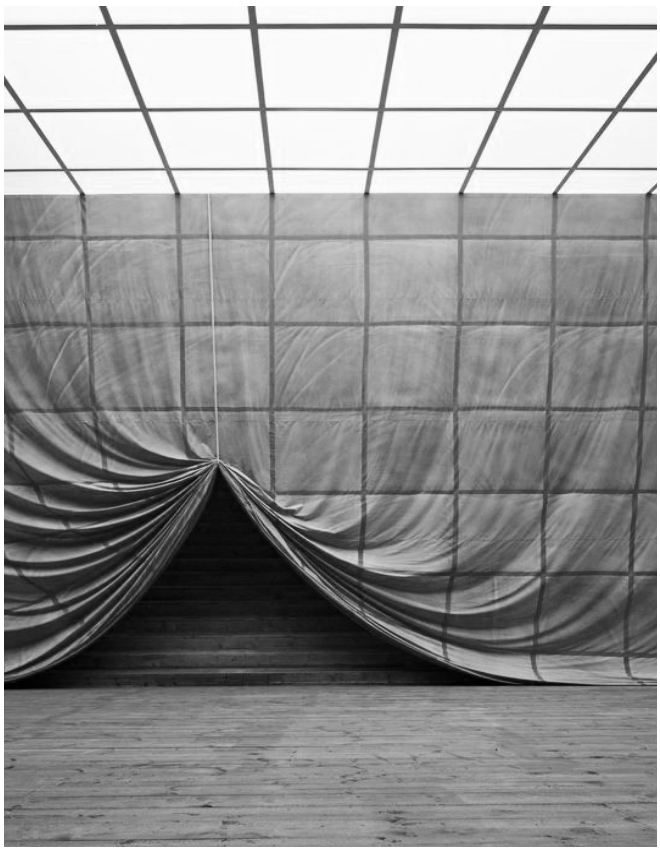
Inspiration

Besides the graphic inspiration of the picture, the artist Ulla von Brandenburg inspired the project through her exhibitions and art installations. Her work addressed the world of theatre and the relationship between fiction and reality, actors and audience. In this particular exhibition, named Secession (Vienna, 19.9. - 10.11), the heavy and old theatre curtain served as an entrance portal for visitors. Passing through the curtain meant entering a new world of imagination and dreams. Behind the curtain, a video installation awaited the visitors. The installation, called Die Straße, was described by Ulla von Brandenburg herself: "He enters another world and tries to understand the various goings-on that strike him as foreign. It's as if he were time-travelling, although it's not quite clear what sort of temporal context he has landed in, and there is no real development in the sequence of events." (Ulla von Brandenburg, interview with Nina Möntmann). The film played with the confusion of a man and the combination of familiar and unfamiliar objects and situations. This emotion was also intended to be experienced by the viewer through the art installation.



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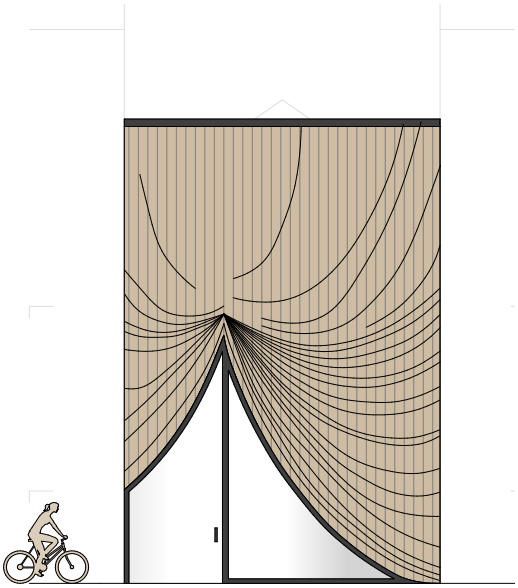
2 pictogramms concept

3 Ulla von Brandenburg, Innen ist nicht Aussen, 2013



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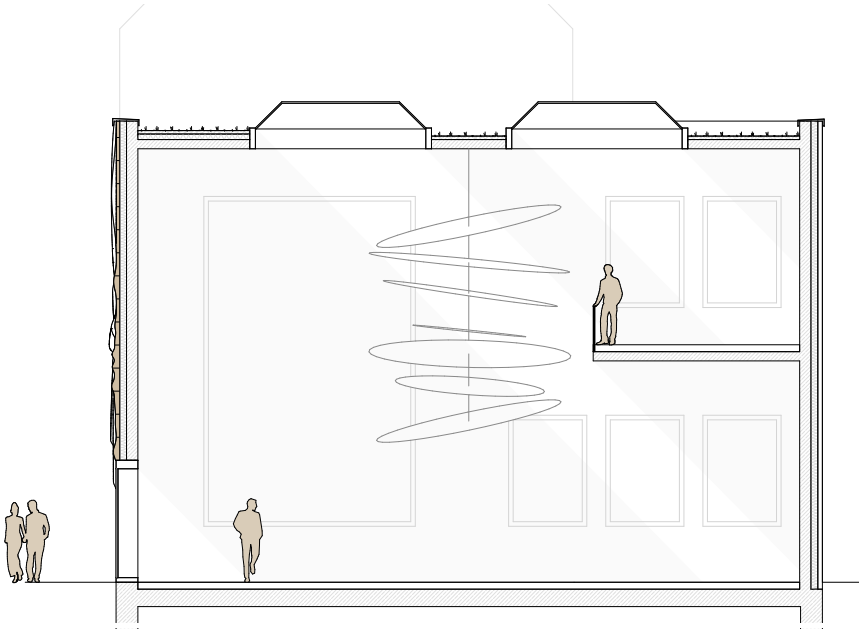

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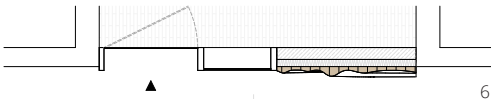

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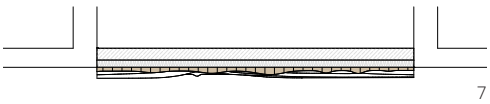

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4 Front view of final facade

5 Cross section exhibition room with hanging art piece and murals

6 Horizontal section entrance +2,00m

7 Horizontal section +6,50m

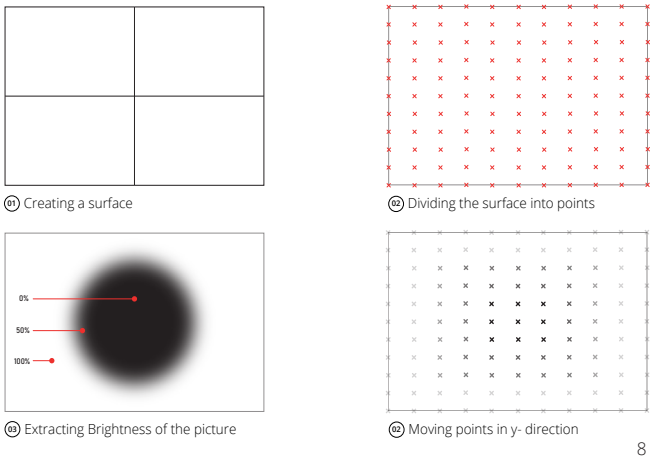
Interior

Another part of the idea focused on what happened inside the building. By removing the old openings and creating the new extravagant entrance, a new usage needed to be identified. Keeping a retail store inside no longer seemed fitting, but a single, predetermined usage was also not deemed desirable. Instead, the goal was to maintain versatility. To achieve this, most of the first floor was removed, creating one large room with a small gallery at the back. This redesign allowed the building to serve multiple purposes, such as hosting exhibitions of various kinds, meetings, showrooms, concerts, and pop-up stores.

Experiments in Grasshopper

To achieve the desired appearance of the facade, the process began with experimenting and researching methods that provided the best results and aligned with the design process. After testing various scripts and tutorials found online, a script using the image sampler was chosen. The image sampler extracted the brightness of the uploaded picture. Subsequently, these points were moved in the y-direction based on the brightness factor, and a new surface was generated from these modified points.

To prepare the picture for the script, a black-and-white drawing of one of the inspirations was created and manipulated with varying degrees of a Gaussian blur filter. Through further experimentation with different openings, fold depths, and levels of blur for added smoothness, the final design was achieved.



01 Creating a surface

02 Dividing the surface into points

03 Extracting Brightness of the picture

02 Moving points in y- direction

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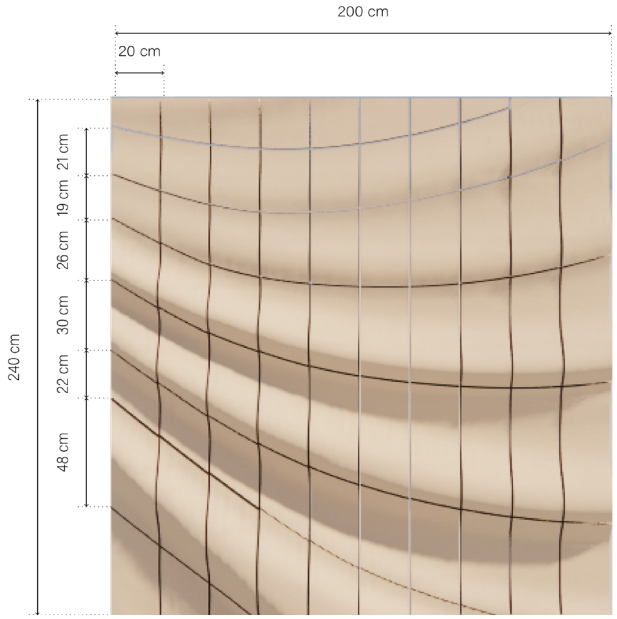

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Grid and Construction

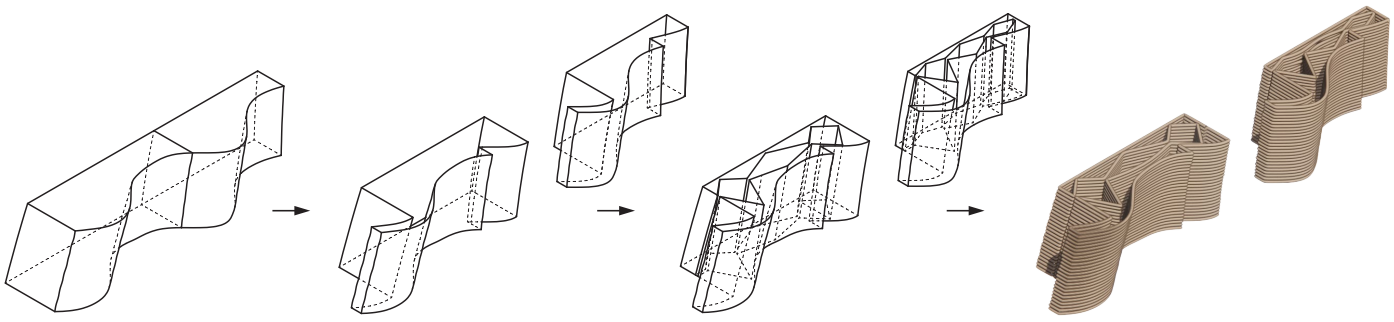
Specially made rails served as the construction between which the individual stones were inserted. To avoid destroying the image of the curtain, the rails were hidden. These were simply attached to the load-bearing external wall. Starting from the bottom, a row of stones was placed on a rail. On top of this, the next rail was added with the next row of stones, and so on. Due to the overlapping of the stones in a vertical plane and the slight tilting of the rail, each row kept the row below it in place.

8 Pictogramms explaning how the script works

9 Rendering of final facade in context

10 Section 200cm x 220cm

11 Construction Detail



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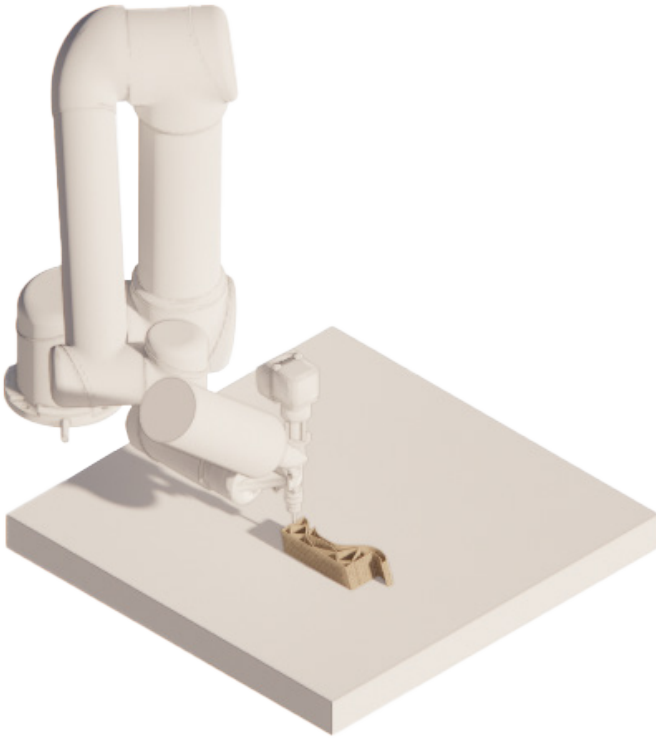

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12 Piktogramm of brick design process

13 Simulation of robotic arm while printing

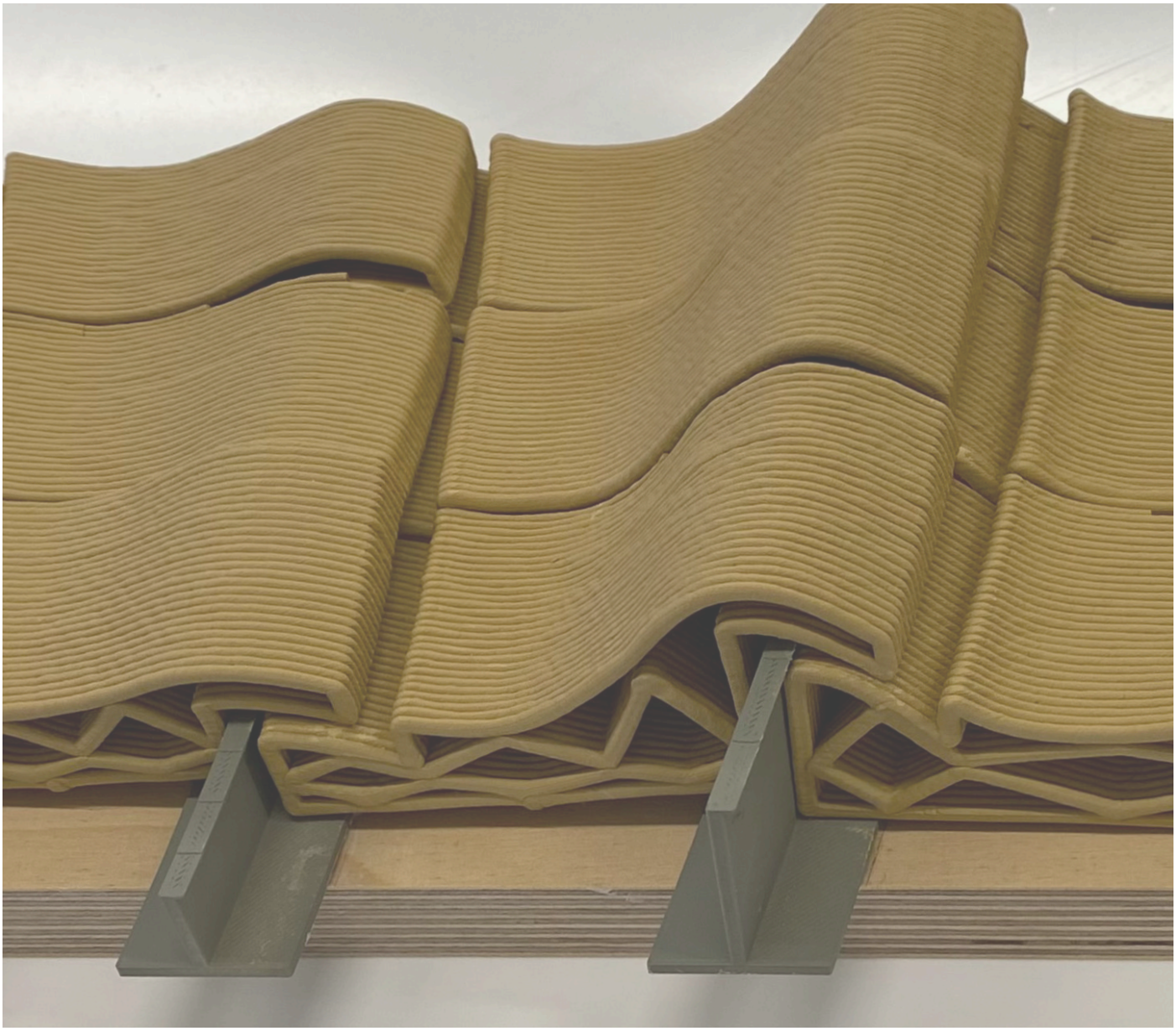
14 Construction detail in final model

Brick Design

After slicing the facade into its individual unique bricks and extracting the bricks, the connection was modeled to intertwine the bricks vertically. In this step, the stability was improved, and a more woven-together appearance of the overall facade was achieved. The connection area of two bricks also served as a covering for the construction behind them. Subsequently, individual infill, shaped like interconnected diamonds, was added to stabilize the brick itself.

Printing Process

All the designed bricks were printed while being rotated by 90 degrees. By this method, the vertical orientation of the printed paths was also achieved, which underlined the flowing structure of the lifted curtain. For assembly, the brick was turned over and placed on the steel rails. After experimenting with different speed settings, the final prints were achieved at a speed of 14m/s. The nozzle used was the 3.8mm nozzle, and the layer height was 1.8mm.



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15 Photo

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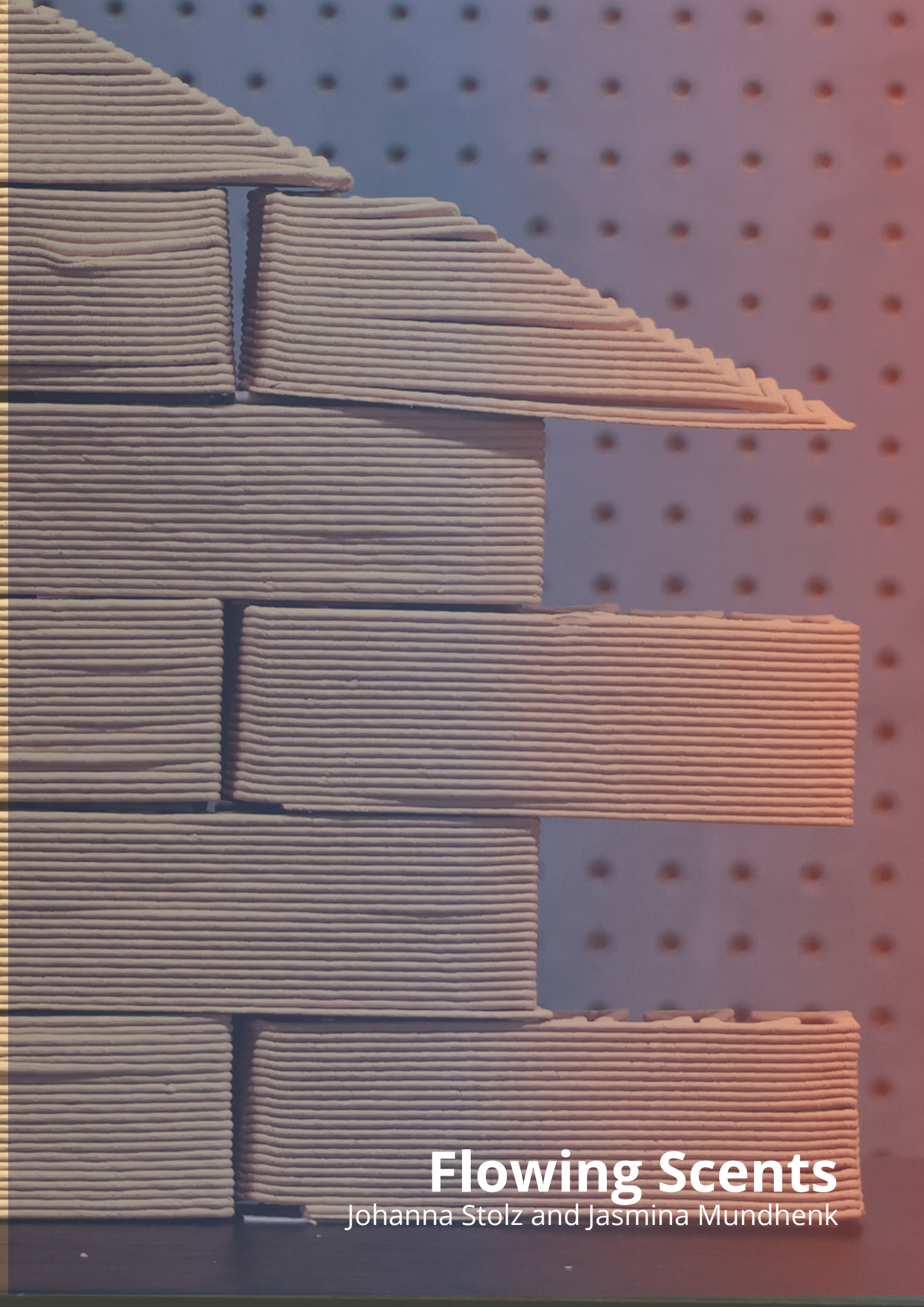
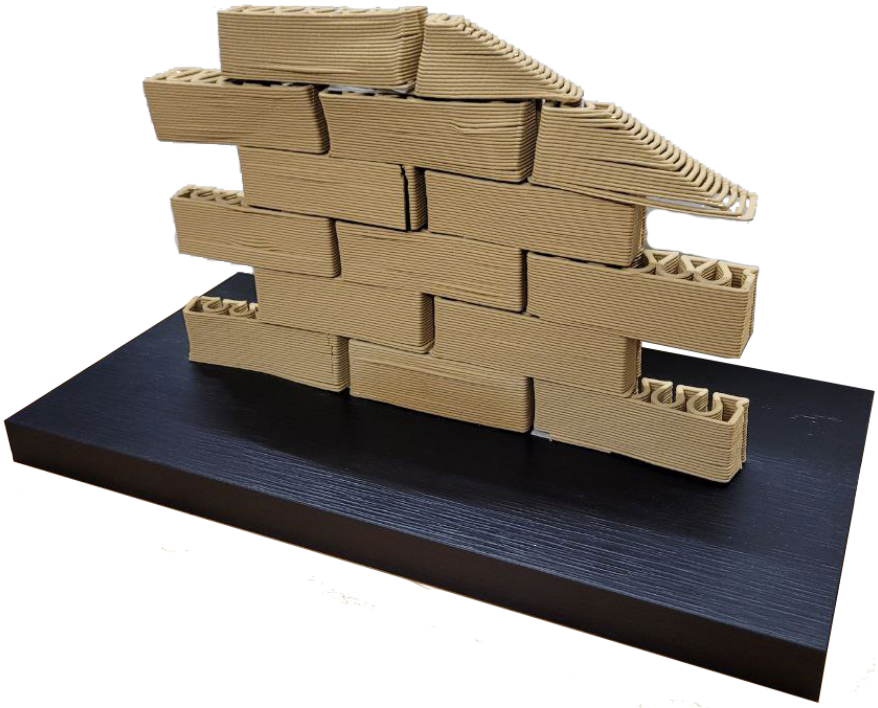


Flowing Scents

Johanna Stolz and Jasmina Mundhenk

Flowing Scents



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1 picture of the entire model section

Preface

The design was inspired by the scents that moved through the city and could be smelled in the surrounding area. Year-round food markets on Kohlmarkt and nearby perfume stores created distinct aromas that were noticeable as people moved through the city and passed the shops.

This strong sensory presence inspired the idea of translating the movement of these scents into the facade, creating a soft, wave-like surface to represent the flowing scents moving through the streets.

To achieve this wavy surface, MidJourney was used to generate new curve patterns. Carefully crafted prompts ensured the generated images matched the design vision and had the same dimensions as the existing facade. The image was then cropped and edited in Photoshop to reduce sharpness, making the curves appear smoother. Finally, it was transferred into the Image Sampler in Grasshopper, which used the varying pixel brightness to extrude different heights and create the surface.

The Openings

The openings were placed to align with the movements in the pattern. The concept was to ensure that the old facade was not entirely concealed, but instead lightly covered by the new facade, resembling a waft of scent. This approach better represented the idea of a scent flowing through the city.

The individual bricks

The wavy surface of the facade was ultimately achieved by varying the depth of the bricks. It was determined that the flattest brick could have a maximum depth of 5 cm to ensure stability. The generated surface, with a depth variation of 15 cm, was then applied. As a result, the depth of the bricks ranged between 5 and 20 cm.

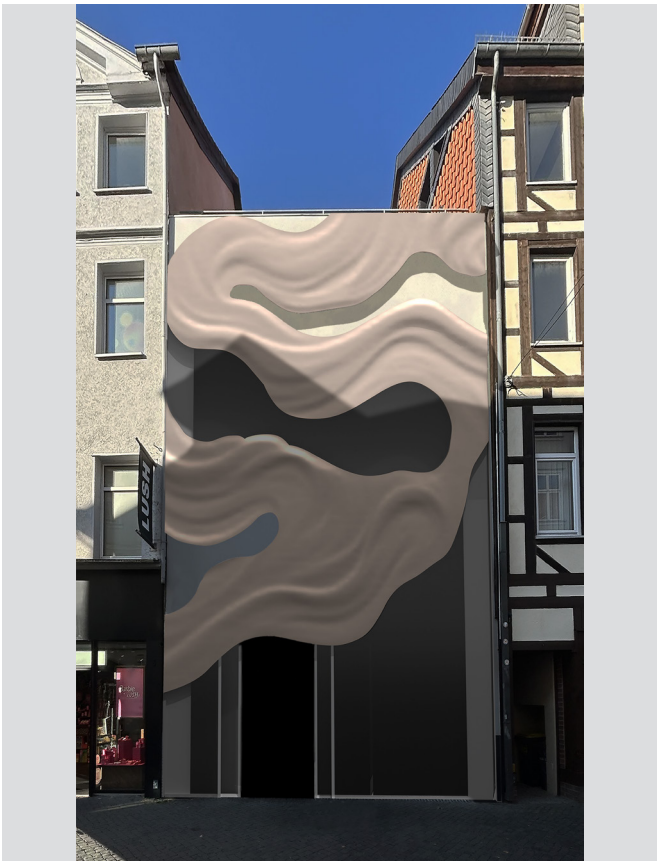
Working with Midjourney

MidJourney is an artificial intelligence program and service developed by MidJourney, Inc., an independent research lab based in San Francisco. This platform specializes in generating images from natural language descriptions, known as prompts.

Initially, the images generated in MidJourney were not optimal, as the wave pattern did not match the aspect ratio of the facade to be redesigned. Enlarging and stretching the image to fit the facade dimensions resulted in waves that were scaled too large, failing to convey the intended flowing movement.
An attempt was then made to mirror the original image before applying it to the facade. However, this approach did not align with the core concept, as the mirrored pattern introduced repetitive elements that contradicted the organic, non-repetitive nature of a scent's movement.

The solution was to revisit the prompts, refining them to emphasize a flowing motion while including the correct aspect ratio. This adjustment ensured that the generated image matched both the design intent and the facade's dimensions.

Final prompts used for the image generation:
Large irregular waves reminiscent of scents rising upwards, soft and large flowing movements that ascend upwards, fluidity, motion, movements in the air, wafts of scent, gentle billows of smoke, --no sharp edges, --no light exposure, --ar 6:10



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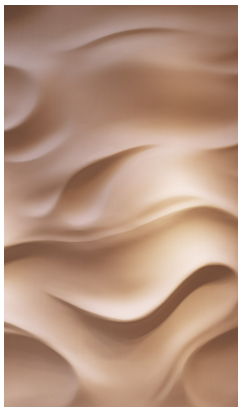

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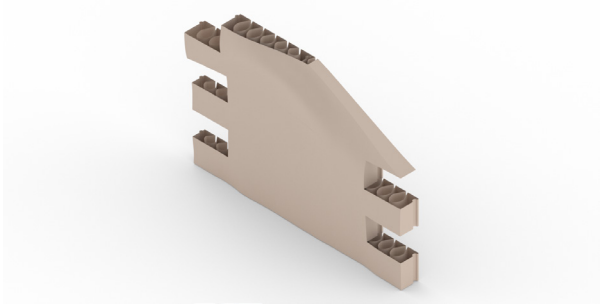
2 Overall perspective of the facade

3 First generated image in Midjourney

4 First image mirrored and edited in

5 Final generated image in Midjourney



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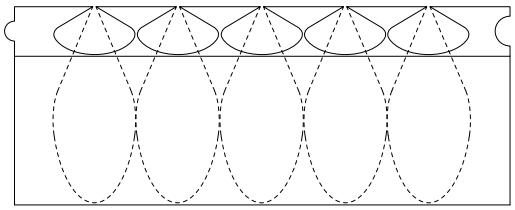

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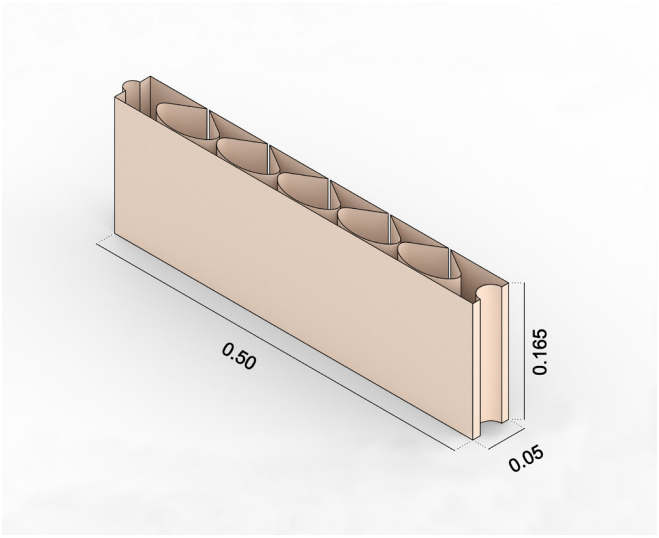

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4 Render of the final section

5 Detail of the infill of the bricks

6 Dimension of the base brick

The infill

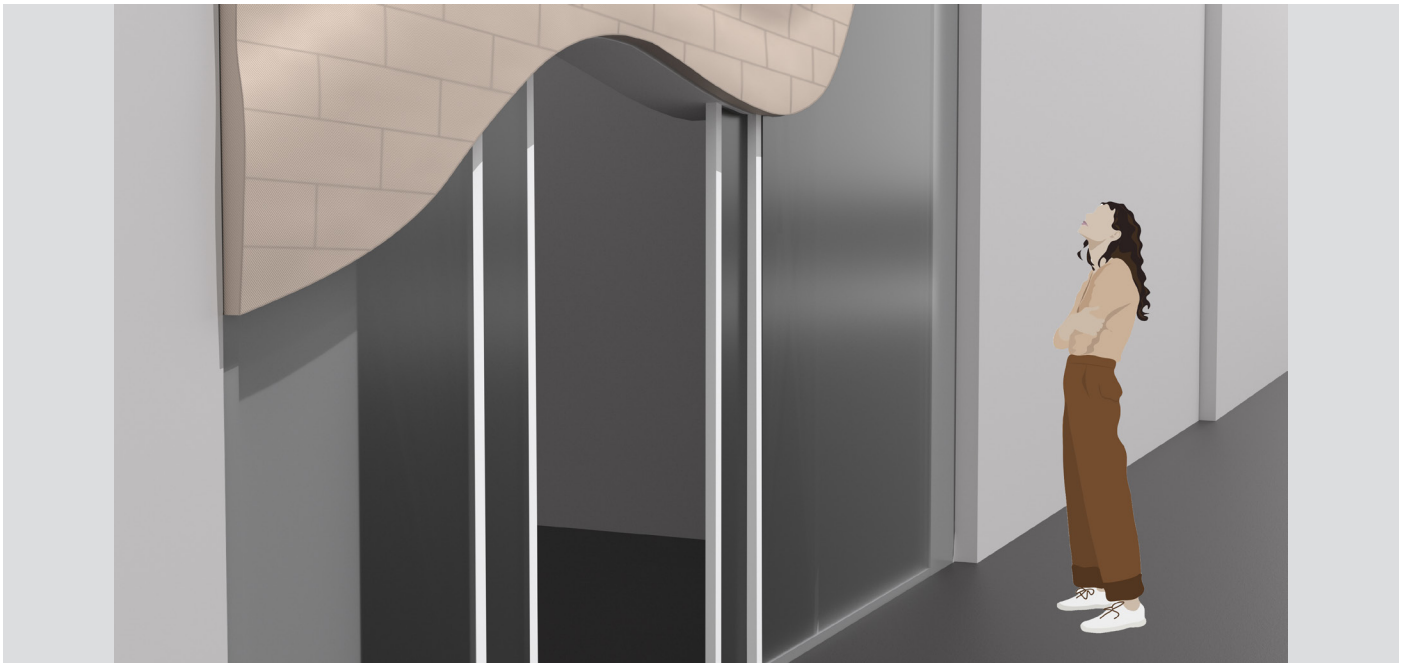
To support the bricks in the printed section, an infill was designed to connect two opposite sides of each brick, maximizing stability. The planned infill consisted of five loops originating from the back side of the brick (see Picture 5). These interconnected loops stabilized one another, enhancing the overall sturdiness of the brick. Since the bricks varied in depth, the loops were adapted to match the different depths and wave patterns of the individual bricks.

The depth of each brick ranged from 5 to 20 cm, depending on the curvature of the wave pattern at its specific location on the facade. In contrast, the length and height of the bricks were standardized at 50 cm and 16.5 cm, respectively, to maintain a traditional masonry pattern that juxtaposed the flowy waves on the facade (see Picture 6).

The connections

The bricks were connected horizontally through male-female connectors on both sides, functioning like puzzle pieces to hold the bricks in place and prevent lateral movement. To ensure the bricks remained securely in position and did not fall off the facade, hooks were used to attach each brick to the building's existing facade (see Picture 12). Each brick was individually hooked, making unauthorized removal impossible. This method also allowed for the replacement of individual bricks in case of damage, eliminating the need to dismantle the entire facade. This approach ensured both an easy repair process and straightforward construction.

The hooks could be easily removed from the existing facade if the brick facade needed to be taken down or relocated. While this technique required substantial material and a physical connection to the building, it was essential to sculpt the wave-like pattern. The individually hooked bricks allowed for large openings in the clay facade and a smooth, flowing motion across the building.



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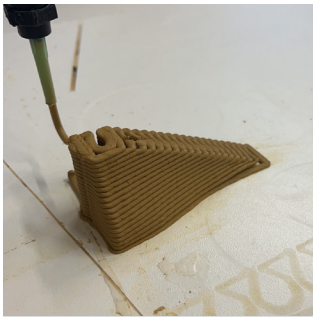

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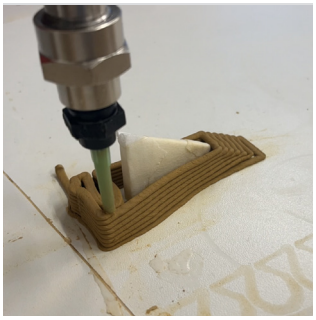

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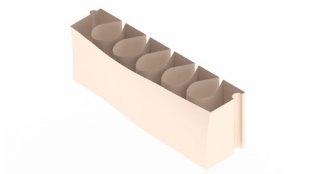

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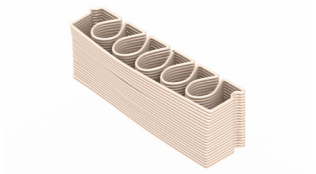

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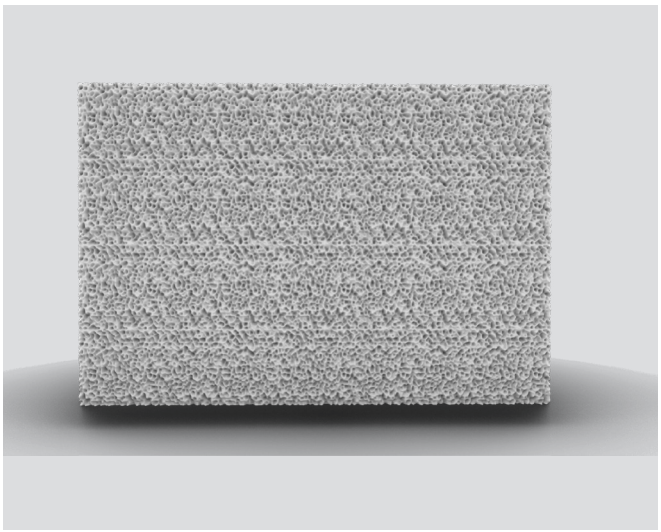

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The printing

Printing the final bricks presented several challenges, particularly with the robot and the new material. After working in the KE, it became easier to handle the clay and incorporate the newly acquired knowledge into the creative design process. While most bricks were straightforward to print, some with angled edges proved more difficult to adapt to the robot's script. Ultimately, the best solution for printing these special bricks involved cutting a styrofoam block to match the planned brick's shape, providing support for the layers during printing. The styrofoam was then easily removed afterward.

7 Visualization of the finished facade in context

8 Finished angled brick

9 Process of printing an angled brick

10 Render of an individual brick

11 Visualization of a printed brick

12 Render of the connection from individual bricks to the present facade

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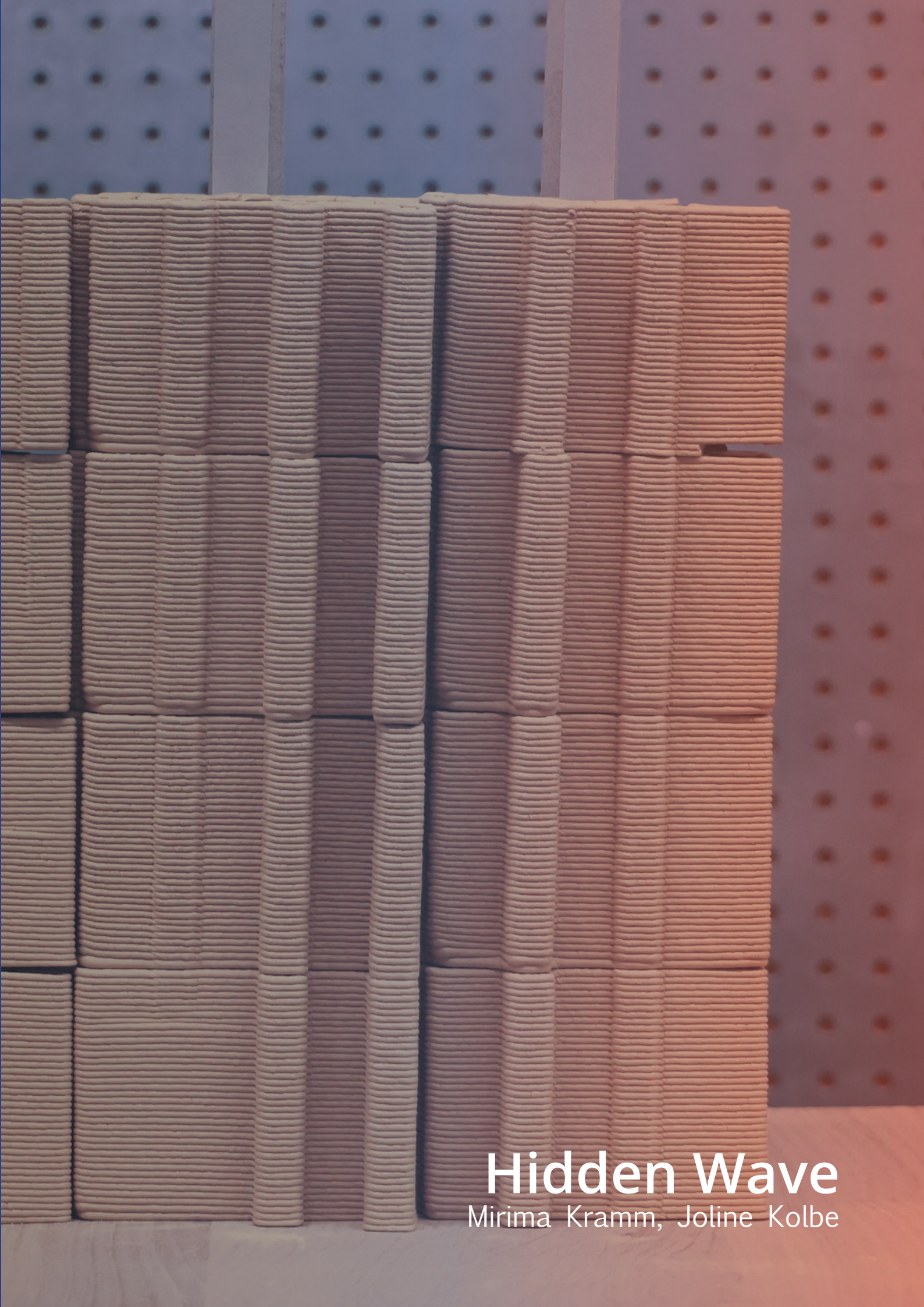


Hidden Wave

Mirima Kramm, Joline Kolbe

Hidden Waves

1 final fassade front view

Preface

Inspiration

During our visit to the site, we observed the constant flow of people passing by, each with their unique rhythm and motivations. Some moved hurriedly, while others strolled more leisurely. This diversity inspired the project, particularly a diagram of varying frequencies, which we interpreted as the different movements of pedestrians and cyclists on the street. We decided to represent these motions on the façade, adding detail through the inclusion of slats in the wall.

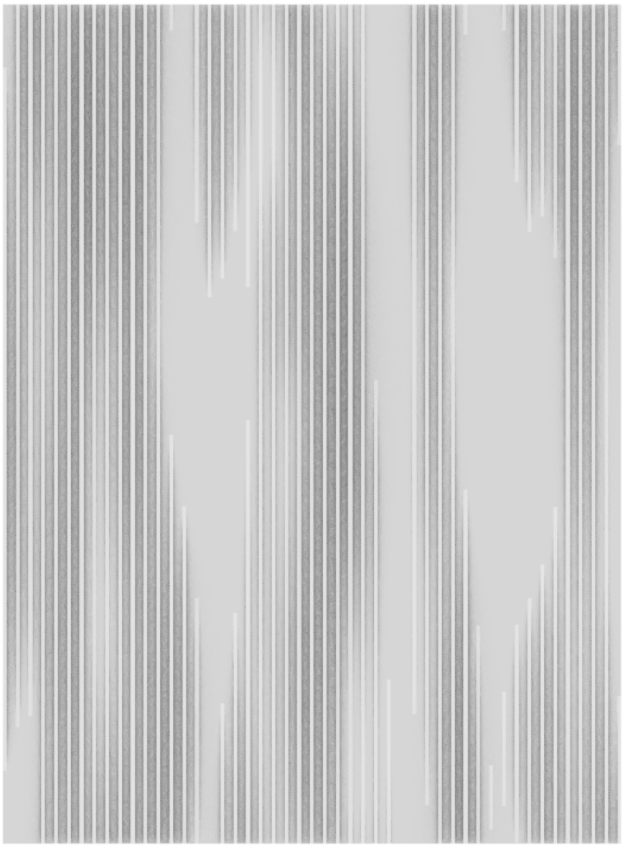
The idea for this approach was influenced by the Apical Reform Studio of Amrish Patel and Darshan Soni in Gujarat, India. Known for combining art and innovation, their studio integrates design with technology and manufacturing, with a characteristic focus on parametric design.

Design Process

After the skill-building workshop, we began implementing our idea with Grasshopper. This program allowed us to create variations of geometric shapes by adjusting parameters and rules instead of building the model from scratch. Initially, we laid a single wave across an entire wall without indentations. To explore different types of frequencies, we used variations in Grasshopper with tools like graphmapper, randomness factors, and an image sampler.

We attempted to incorporate the slats into the design with Grasshopper but struggled to make it work. As a result, we changed our approach and started searching for tutorials and scripts for walls with slats. We discovered that it was easier to create the slats first and then lay the frequencies on them using the graphmapper command. However, this left us with only slats and no full wall. We resolved this by adding the wall afterward in Rhino. By coincidence, we moved the wall too far forward, leading to the idea of the hidden wave.

Another challenge was creating the bricks with Grasshopper, which we ultimately did in Rhino due to difficulties with the script. For the horizontal connection between bricks, we used a simple but effective female/male connection method, which remains hidden from the outside. The vertical connection was more complex, but we decided to use an I-beam placed between two infill squares to maintain symmetry. Overall, the solution worked well, and we proceeded with the infill.



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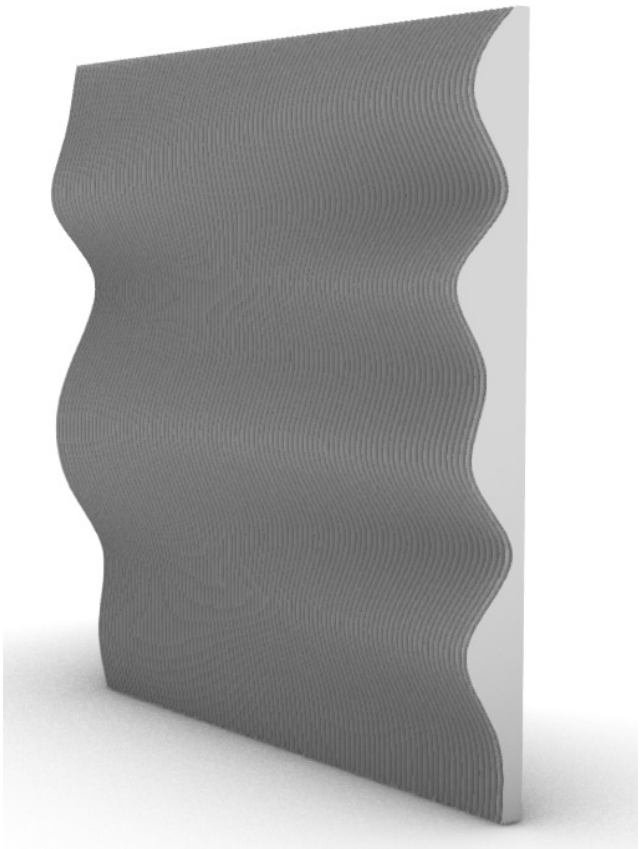

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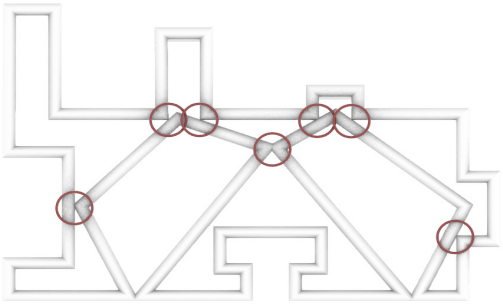
2 printed facade front view

3 early symmetrical design



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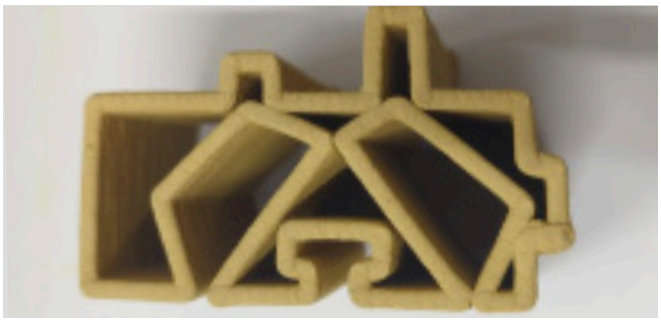

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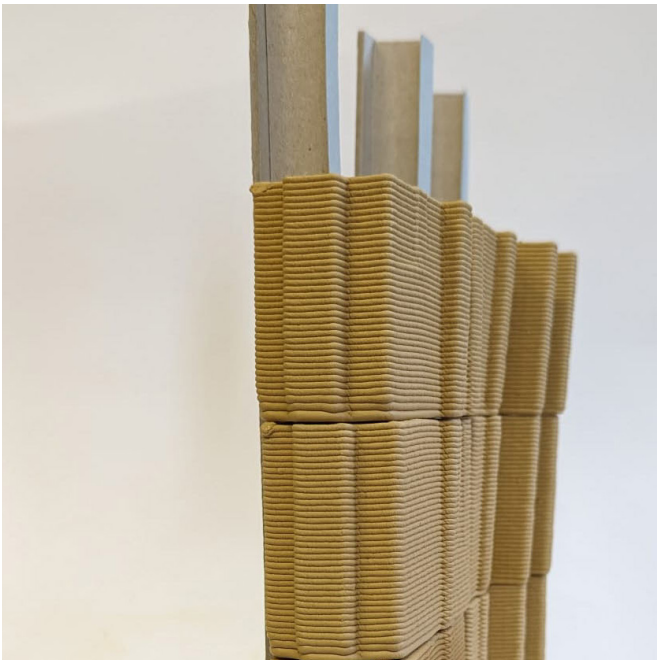

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4 critical points in our brick

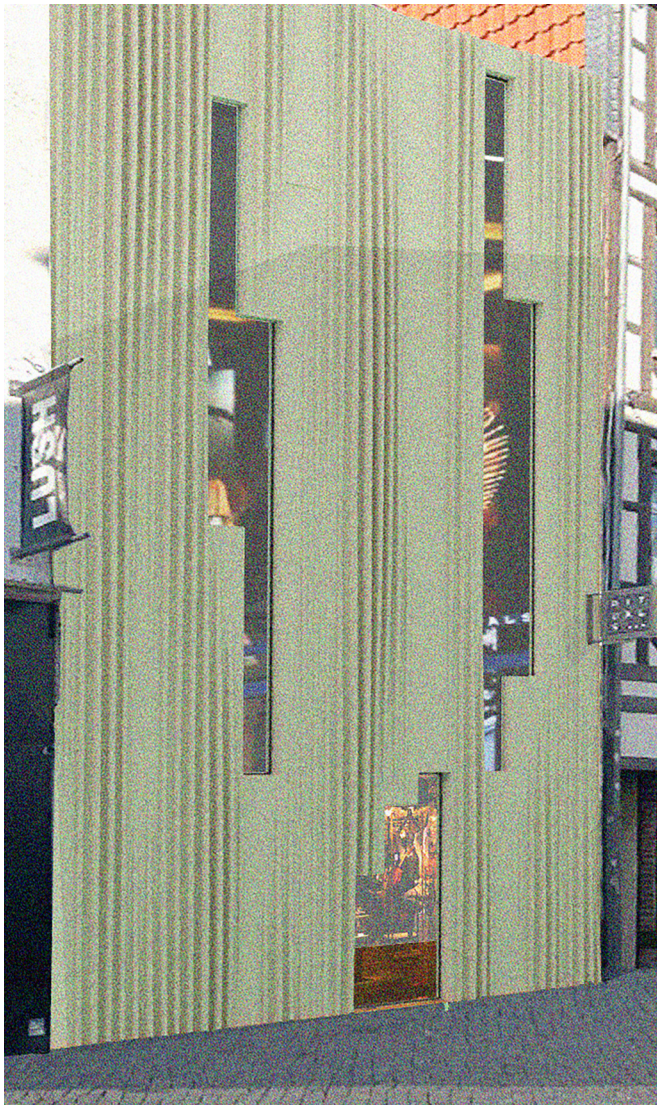
5 printed brick

6 printed facade side view

Infill

Our first idea was to create a curved infill that would touch the fragile points of the brick, supporting both the small parts between the slats and the slats themselves. The robot operated on a point-based program, meaning that more curves would require the robot to generate more points to maintain a clean line. After several test prints, we realized that a straight infill would be more practical for our project, as the infill and connection required more points than the robot could generate.

As a result, the final design featured straight edges and corners.



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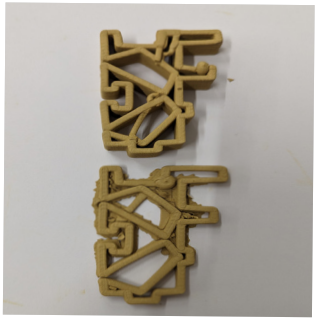

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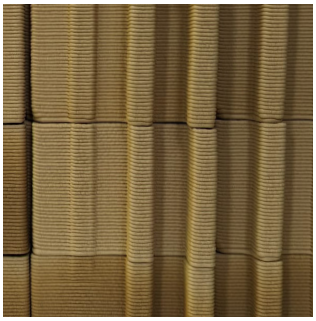

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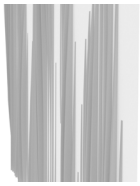

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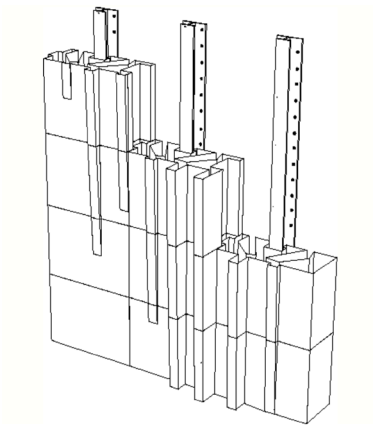

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Printing

The 3D ceramic printing was one of the most challenging yet rewarding parts of the KE. Despite facing several issues, each challenge provided valuable insights that deepened our understanding of the concept and design process. The digital earth printing was an excellent opportunity to explore parametric design and advanced 3D ceramic printing techniques. It offered hands-on experience that highlighted the advantages and individual steps involved in the digital earth printing process.

7 visualisation

8 printed facade top view

9 failed prints robot printed some layer incorrect

10 detail printed bricks showing the layers

11 detail facade to see curves

12 early infill design that had problems printing

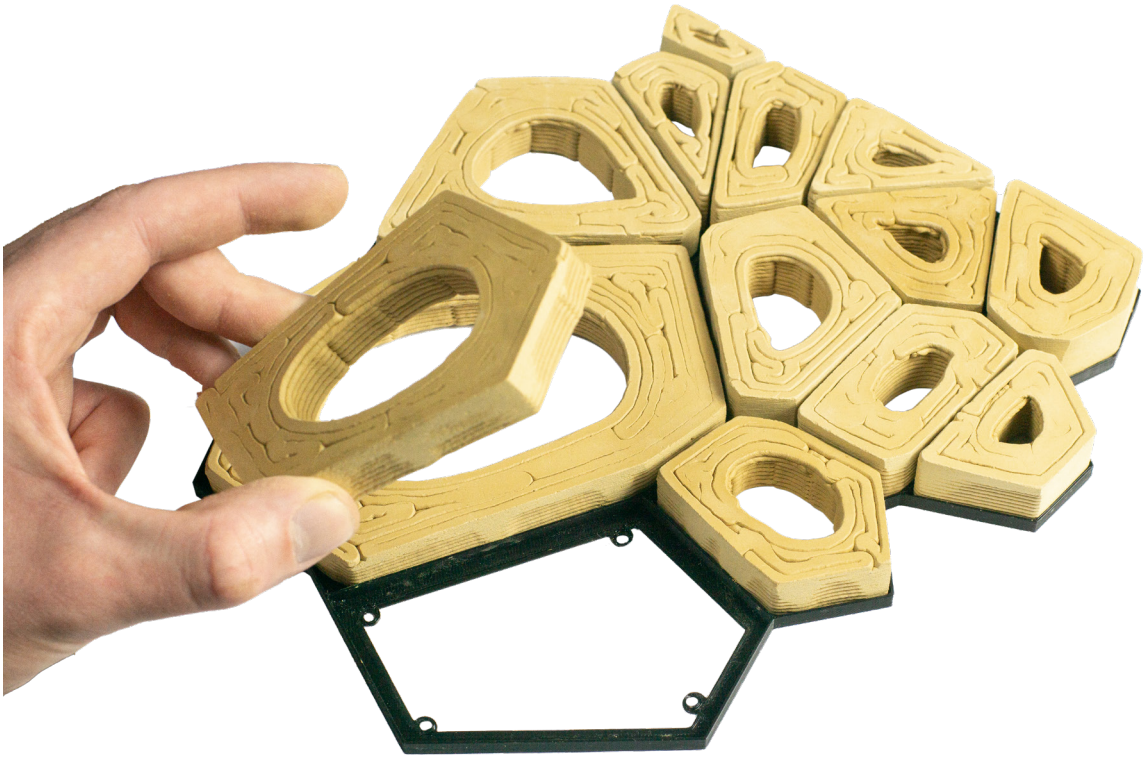
13 strucutre behind the bricks and brick connection

Organic Essence

Nico Marcinkowski

Organic Essence

The smallest in the magnifying glass



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1 Sectional model of the façade. Bricks are attached to the frame using neodymium magnets.

Preface

The technology of 3D printing had long been established in mechanical engineering and had made its way into the consumer market. In the construction industry, 3D printing was still an emerging process with tremendous potential. This innovative technology bridged two previously separate worlds: the choice between mass-producing identical components or engaging in time-consuming and costly custom production. 3D printing united these two options by enabling the mass production of complex, customized objects without additional time or cost.

During this KE, the possibilities and limitations of this cutting-edge technology were explored, providing valuable insights into its application. This article shared experiences with 3D printing and highlighted the development process and software tools utilized. The “Organic Essence” design aimed to create an organic façade for the Rituals store on Kohlmarkt in Braunschweig, enhancing its small, inconspicuous space between larger buildings. A cell motif was applied to enrich the restrained structure with a complex, organic aesthetic. Over several weeks, a fully parametric façade was developed, reinterpreting the traditional brick façade while pushing the boundaries of clay 3D printing.

Design Idea

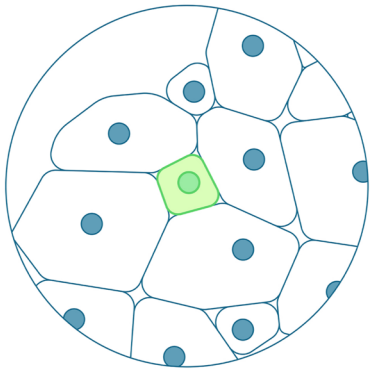
Design Idea

The redesign of the Rituals store on Kohlmarkt in Braunschweig represented an innovative approach to transforming an initially inconspicuous, two-story structure. Due to its low height and unremarkable façade, the building blended into its surroundings, appearing as a small cell between more imposing neighboring structures. The design goal was to give this cell a distinctive presence despite its modest scale.
Inspired by the metaphor of a cell, this concept was transferred to the façade design through the use of a Voronoi diagram—a mathematical method for subdividing areas into sections. Points placed within a predefined area determined the size of the resulting cells based on the distance between them. As these points expanded at a constant rate, they formed characteristic lines at their intersections, creating the distinctive cell structure of the Voronoi diagram, which became a central motif throughout the design. The parametric façade, based on the Voronoi principle, provided the Rituals store with a unique identity. The organic arrangement of the cell structure visually distinguished the building from its surroundings. This design not only resulted in an aesthetically striking façade but also redefined the perception of the store within its urban context.

First Steps

In the first weeks, the focus was on exploring the Grasshopper extension for Rhino 7 and experimenting with tools for parametric structure generation and manipulation. This included an introduction to the 3D clay printer, consisting of a Universal Robot UR5 and a Lutum Clay Extruder that transferred clay to the print bed through a nozzle using air pressure. The initial designs required manual placement of starting points in the Voronoi diagram to control cell sizes, aiming for close-meshed cells in the second-floor window area and wide-meshed cells at the entrance. However, this approach was impractical for 3D clay printing, as the entire inner surface of the brick had to be filled, making it economically inefficient. The design was revised by modifying the Voronoi-based cell structure, with wall contours tapering and angular cells becoming rounded as the height increased for a more organic appearance. Despite these adjustments, large overhangs still caused wall collapses during printing.

Store very inconspicuous among other



Let this cell stand out!

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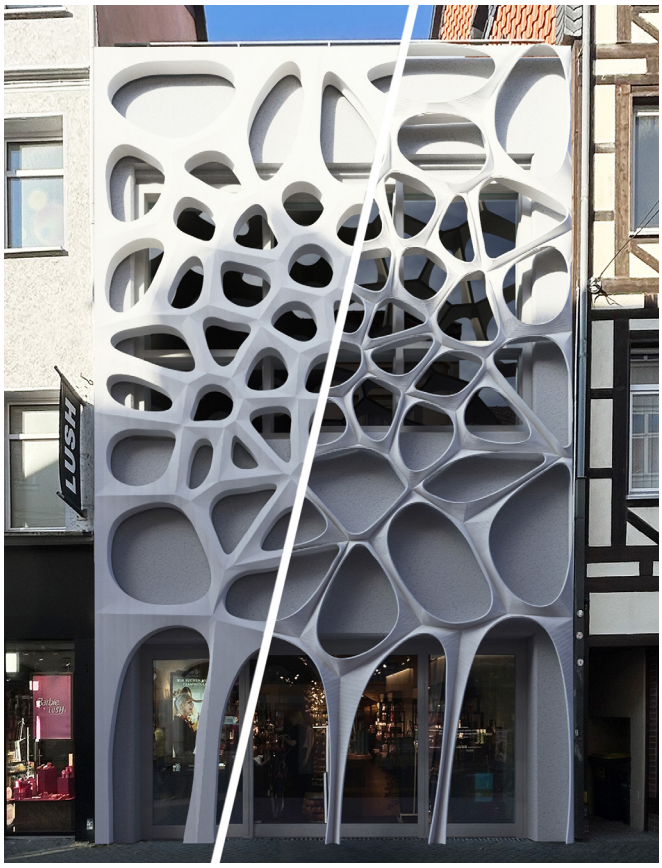

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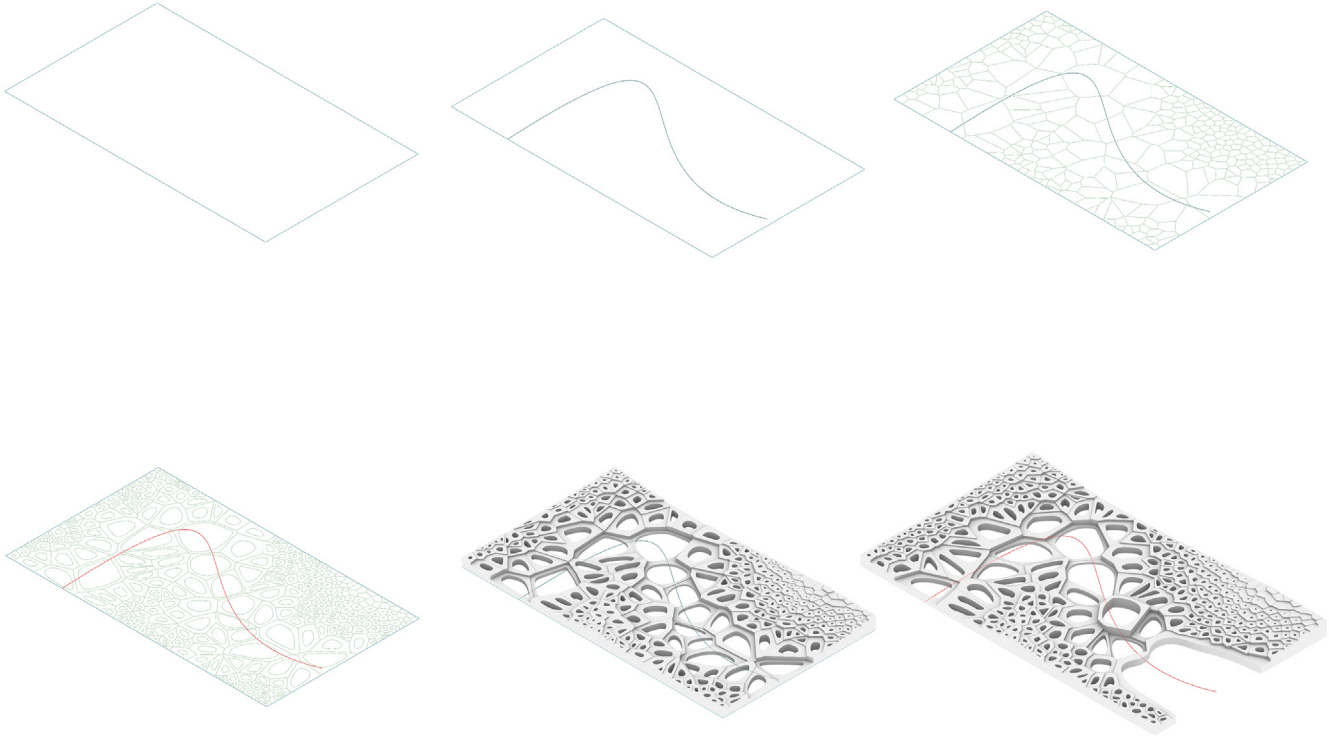
2 Concept: Transforming the ritual of loading from an inconspicuous cell to a prominent one.

3 Design evolution over several weeks from top to bottom.



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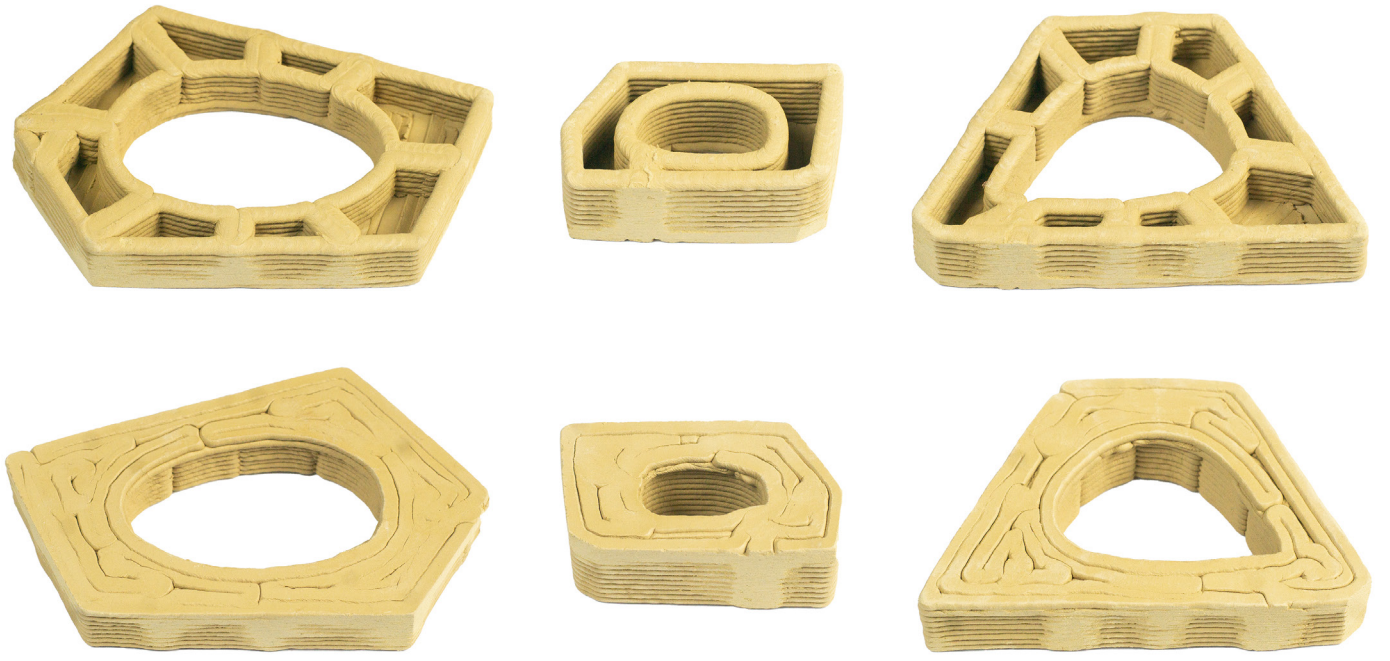
4 Creation of the façade using the attractor curve.

Parametric Implementation

In later development phases, the manipulation method of the Voronoi diagram was adapted. The starting points were no longer placed manually but were determined by a so-called attractor curve. This special curve changed the parameters of the cell structure based on the distance to it. As a result, starting points were placed at a greater distance from each other if they were closer to the attractor curve, and vice versa. This innovative approach enabled a more homogeneous and organic progression of the cells.

After the basic structure of the Voronoi diagram was created, the individual cells were processed by offsetting and applying the Grasshopper component Rebuild to create a rounded interior. This approach resulted in a more natural and organic look. The distance between the inner and outer curves was again defined by the attractor curve, with a greater distance being created as the distance from the curve increased.

In the final step, the cells were extruded based on the distance to the attractor curve. Cells at a greater distance were extruded higher than those closer to the curve. Finally, the cells in the entrance area were removed, and the resulting contour was rounded to form the entrance. This iterative adjustment of the



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Print challenges

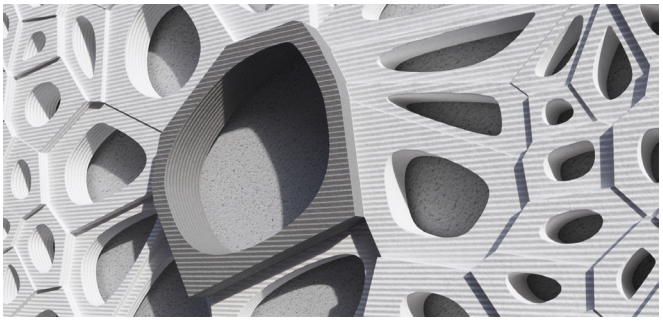
With each new design iteration, the understanding of how to use the UR5 robot arm grew. A dedicated Grasshopper script was developed specifically for the newly generated bricks, which was discussed in more detail later in the article. This script played a crucial role in converting the façade model into printable bricks for the overall model.

In the initial phase, there were complications with the stepper motor driver, which transmitted the control signals to the extruder's stepper motor. Occasionally, the communication with the stepper motor broke down, resulting in uneven clay extrusion during printing. This problem was resolved by repairing the cable connection. Irregularities also occurred in the Grasshopper

5 Photos of the final bricks: They have been sanded on the walls..

6 Problem in the script led to the printing of crooked lines.

7 Spacing of lines for first layer not yet correct.



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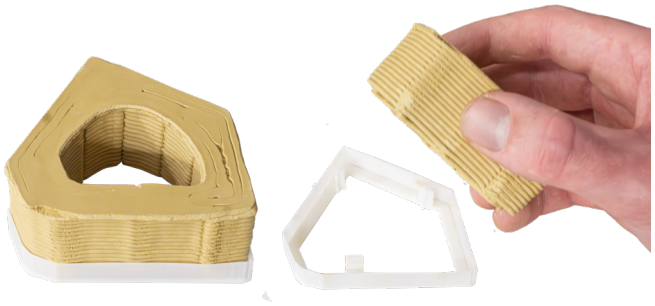

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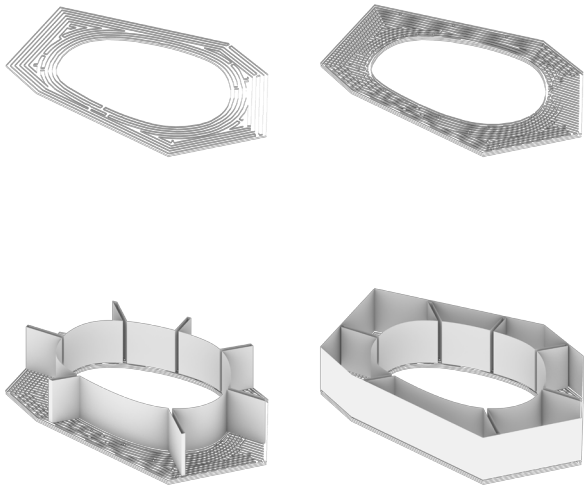

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8 Dark cell following concept.

9 Original PLA frame design with clamps.

10 Grasshopper script creates toolpaths for first two layers and generates infill and walls.

Final Design

The final design of the façade for the Rituals store was developed using the Attractor Curve. This curve's organic progression created the impression of natural growth within the cells of the façade. Larger cells were strategically placed in the window and entrance areas to allow sufficient light into the upper floor and to optimize the visibility of the shop windows on the first floor for passers-by.

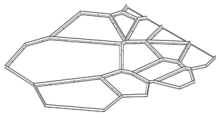
A protruding cell above the entrance was intentionally highlighted with a dark color and a greater extrusion height than the others. This design choice symbolized the transformation from a small, inconspicuous cell into a prominent structure that stood out among the rest.

The reinterpretation of the façade gained an additional dimension through the Attractor Curve, whose influence on size, offset, and extrusion height could be observed in all three spatial directions.

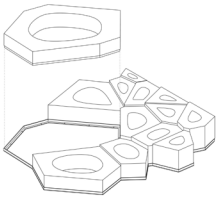
For the clay cut-out model, various designs were initially produced from polylactic acid (PLA) using an FDM 3D printer. However, the originally planned printed clips with barbs, intended to secure the bricks, proved to be prone to wear and tear. As a result, neodymium magnets were incorporated into the frame and the underside of the bricks in the final model to ensure a secure and reliable hold.

Bottom Layer & Infill Study

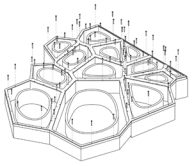
A Grasshopper script was developed to apply various infill patterns to the front faces of the bricks. Each brick was rotated 90° to position the front face downward, and the outlines were imported into the script. Using the "Nautilus" plugin, continuous infill patterns were generated, with an offset pattern in the first layer for a seamless transition between the square outer and rounded inner contours. An additional tern pattern layer was added for stability, and the lines were extruded to the required height. For the infill between the inner and outer walls, a continuous radial line was created, running through the brick. Together with the outer wall, this infill was extruded to the specified height. The extrusions were transferred to a slicer, which divided them into layers and toolpaths, converting them into commands for the robotic arm.



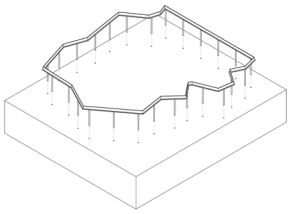
T-Beams form inner frame



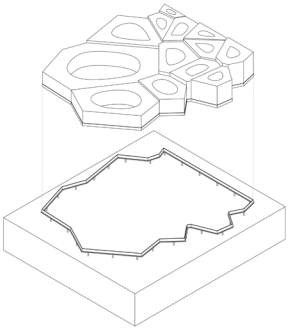
Bricks are placed in inner frame



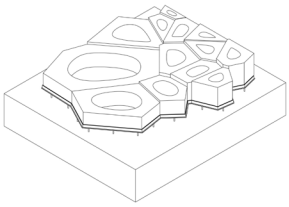
Concrete screws secure bricks to frame



Outer frame is anchored to wall



Inner frame gets placed in outer frame



Spring steel snap latches snap into recess holes connecting inner and outer frame

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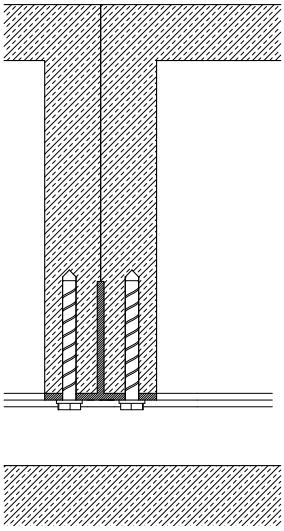

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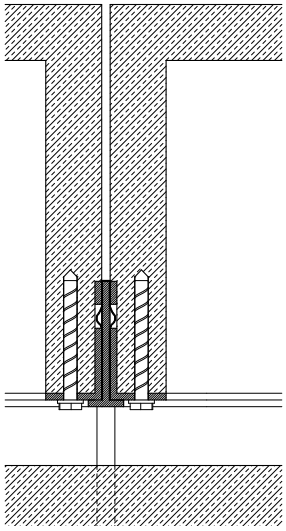

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14

Brick Connection

To connect the bricks to each other and the Rituals store façade, a steel frame system was designed with two main components. Bricks were grouped into clusters of 8 to 10 pieces and mounted onto a steel frame made of T-profiles, secured with concrete screws from underneath. A second frame, anchored within the store's wall, featured spring steel clips. The brick-mounted frames were inserted into this wall-mounted frame, where the clips engaged with recesses in the brick-frame to prevent horizontal displacement. This system allowed easy replacement of individual bricks in case of damage without requiring rear access to the façade.

11 Steel frame system for attaching the bricks to the wall.

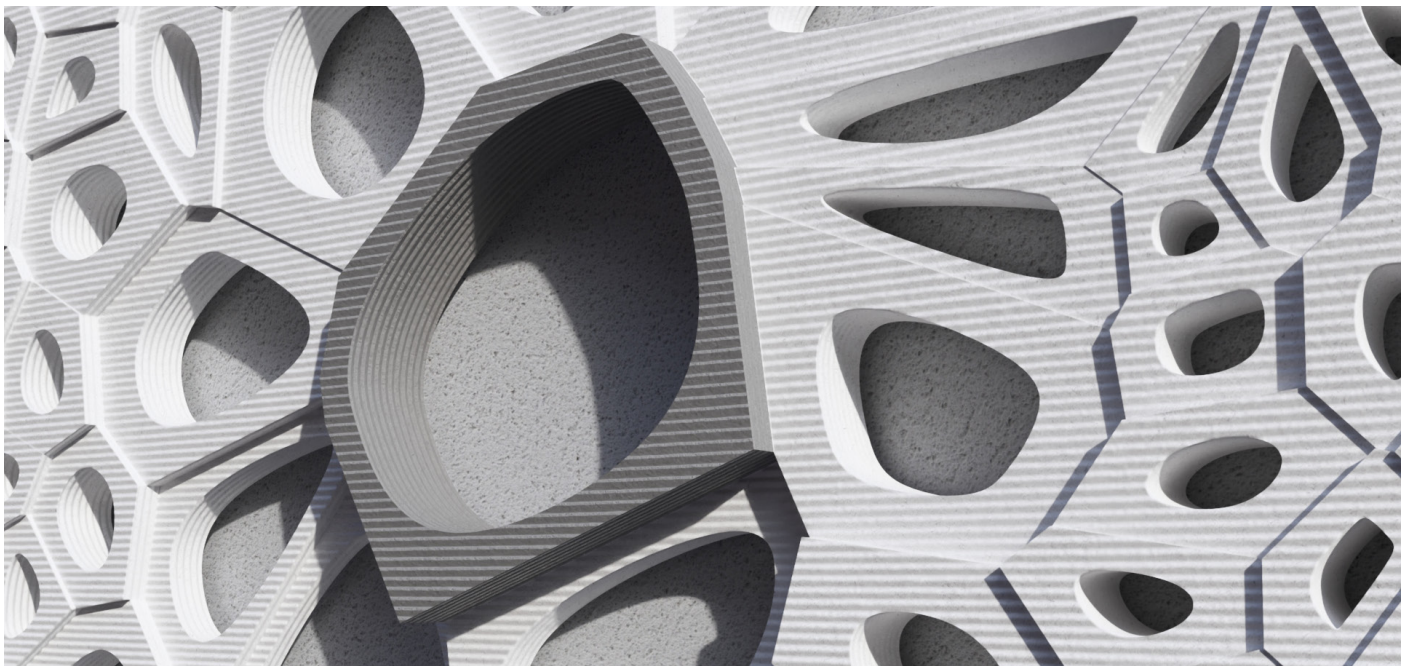
12 Sectional view of the brick-frame connection.

13 Sectional view of the frame-frame connection.

14 Model photo: Bricks are secured by neodymium magnets.

15

15 Rendered view of the entire façade design.



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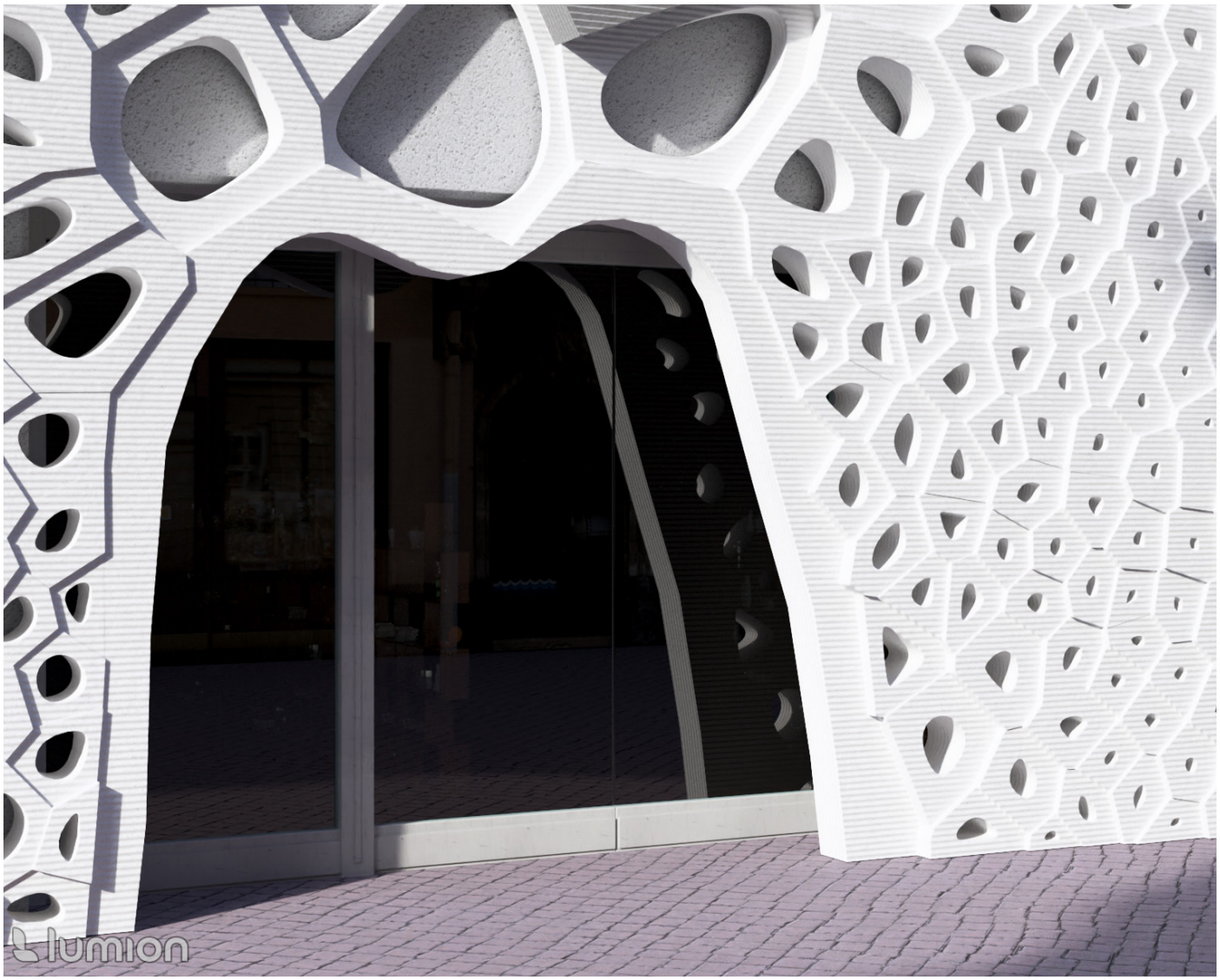

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16 Dark-colored cell as a reference to the design concept.

17 The entrance area blends in harmoniously with the rest of the façade.

Habibrick

Till Maruschek

Habi Brick

A habitat for birds and insects

1

1 200 x 200 (mm) Modul

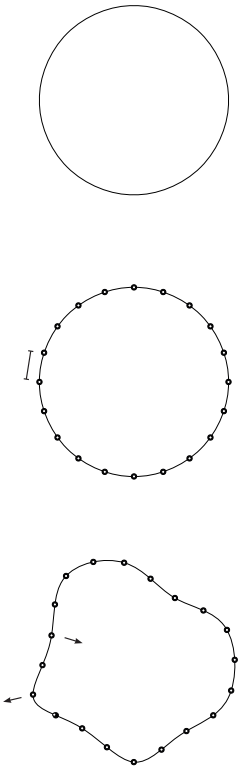
Preface

As cities expanded and urbanized, the natural habitats of birds and insects were increasingly threatened, leading to their displacement and, in some cases, eviction. This phenomenon raised concerns about the impact on biodiversity, ecological balance, and the overall well-being of urban ecosystems.

The rapid growth of cities often resulted in the conversion of natural landscapes into concrete jungles, leaving little room for the diverse ecosystems that once thrived. Trees were cut down, green spaces replaced by buildings, and water bodies altered or eliminated. These changes directly affected the habitats of birds and insects, forcing them to seek refuge elsewhere. The project was an attempt to balance the process of extinction and preserve natural habitats.

Line growth

1. At first we have a basic line-geometry.
2. In the next step we devide the line into a certain amount of segments with a certain amount of distance between them.
3. As we now increase the distance, the points begin to expand and dodge each other.



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Design explorations

In the first printing sessions, I focused on determining the appropriate scale and settings, such as layer height, speed, and the number of points.

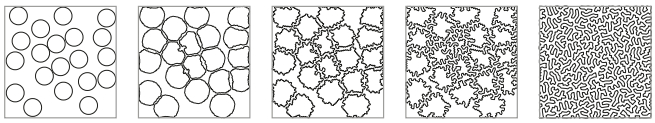
The first successful model printed was a Keith Haring-style figure, approximately 150mm x 150mm in scale. A tight layer height was used, which resulted in the clay almost being squeezed onto itself. Due to its size, the pathway points had to be reduced, causing the rounded corners to develop slight edges. Overall, this approach created a solid structure thanks to the thick layers.

In the bottom-right picture, smaller design explorations can be seen, which lacked stability.

3

2 Line growth

3 Design explorations



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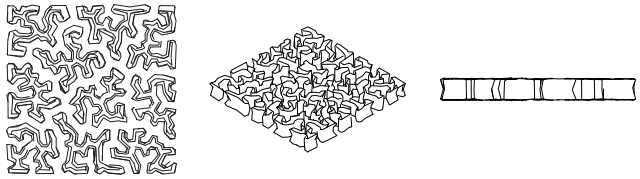

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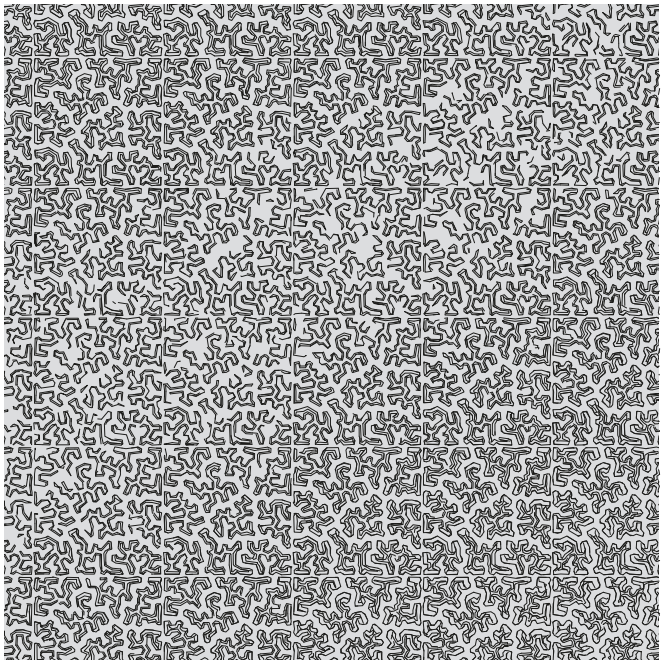

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4 Design process 500mm x 500mm.

5 Top, isometric and sideview of the tile

6 Tiles set together with attractorcurve

Script

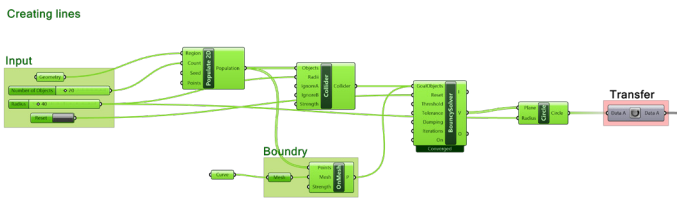
At the top, the different phases of development can be seen. The lines grow into each other until they completely fill out the frame.

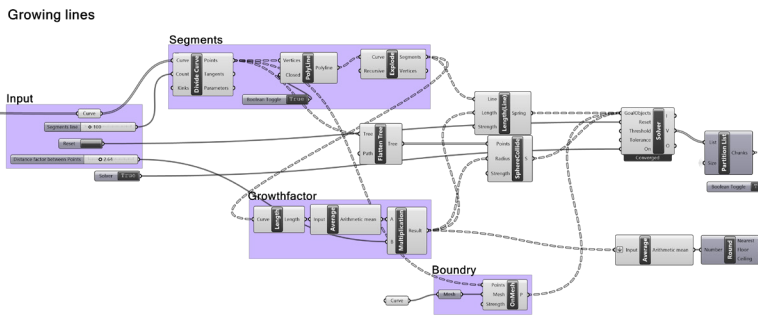
The script is seperated in four sections:

1. Creating lines - here you can set a number and size of the geometry, in this case a circle.
2. Growing lines - here you can set the amount of segments and the factor for the distance.
3. Loft lines - the script shrinks and thickens the mesh for the vizualisation.

Pattern

The pattern repeated tile by tile, with each individual brick being shaped by an attractor curve





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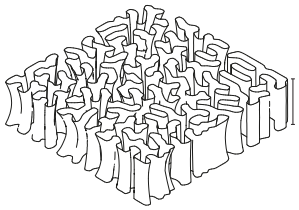

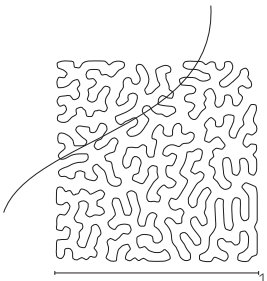

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11

Sample modul

The built model measured 200 mm x 200 mm. The stones sat in the frame, interlocked with each other, and were glued to the back face.

7 Sample modul 200mm x 200mm

8 Max. schrinked brick

9 Normal brick

10 3D model of tile

11 Vizualisation