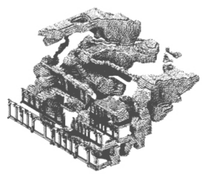

Symbiotic Amman

Project Degree in Architecture, 2022
Lund University

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&
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LUNDS UNIVERSITET
Lunds Tekniska Högskola

AAHM01 | Degree project in Architecture

Symbiotic Amman

A non-human
centerd architecture in the City of Amman

Lund University

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Year: 2022

Abstract

In this thesis project, we introduce an inclusive, environmentally friendly structure to the city of Amman, where both humans and non-humans can co-exist and share spaces within the same boundary.

We investigated various design approaches and incorporated generative design and Machine Learning in the form-finding phase of different architectural elements.

We used the generative design approach in the form-finding of the main structure. At the same time, we needed to consider how our design relates to the city and context. We bring Machine learning into our design process as a tool where we contextualize our design through the design of the facade elements. With AI-generated Images and a human-machine design-based methodology, we developed 3d-facades that resemble the city of Amman, which we integrated into our final design.

We also provided manufacturing methods for constructing our building using hempcrete as an environmental substitute for concrete.

Index

Introduction

The era of the Anthropocene, where focus on human needs became a main driving parameter for the architectural design processes, has brought many consequences to our nature. Amman is one of many cities that lost much of its biodiversity due to excessive human activities.

After being in Amman last summer, we immediately noticed the polluted air. When we headed from the airport to the city center, we felt a powerful smell of exhaust gases released from the tremendous number of vehicles dominating Amman's narrow streets. Every one in six owns a car in Jordan (Weladli, 2021). There is a considerable loss in biodiversity and a lack of inclusive spaces where other forms of life could use to propagate and thrive (A. Abboud, 2019).

We aim in this project to introduce an architecture where the barrier between the human and nature dissolves and make the relationship between the two more explicit and interactive. We are trying in our thesis to provide an example of a symbiosis-driven design, where two or more parts are actively included as main space design parameters.

With hemp as a building material, we think that when long-lasting conditions bring seeds, nutrients, rain, and light to hemp, cliff plants will gradually grow and cover the hempcrete. after years, this place will provide a pleasant space for many potential inhabitants.

We also believe that having this new notion in the city might be problematic when considering the city's context and culture. We saw potential in using Machine learning, specifically StyleGan Algorithms, to help us contextualize our design and adapt it to the surrounding. We investigated much time in the AI part where we traveled to Amman and collected facade Images, then came back home and did many experimentations regarding transforming the AI-produced images from 2d to 3d.

Our building function is mainly to be an open-air farmers market and art holding place where people can be creative with the use of spaces.

Question

How can we create a non-human-centered architectural design where humans and non-humans co-exist within the same boundary? And how can we anchor this design in the city context?

Purpose

Our main objective is to provide a novel design methodology and a novel way to rethink the built environment and consider solutions where both fauna and flora can thrive.

Methodology

Our design method divides into two main parts. The making of the hemp Structure using generative design, and the second part is the facade design where we use Machine Learning as a design collaborating tool.

We use Volume Noise in the generative design part, and we manipulate it through several parameters in our code.

For the facade, we used Machine learning. The AI Algorithm we used is called StyleGan-ADA-PyTorch.

The AI part was done by traveling to Amman and collecting a relatively large amount of facade Images. After that, we trained our set of images using the Stylegan algorithm, which generated many new facade images. We used these images as a base for developing the facade design.

For Manufacturing part we did a brick based system using delaunay lofts .

Symbiosis & Biophilia

Symbiosis in biology indicates a close and often long-term interaction between two or more different biological species. We were interested in creating that kind of natural interaction between humans and non-humans in the city of Amman.

Because one of the main parts we are working with is nature. Biophilia is also vital to unfold as our thesis design introduces connection to nature as one of the leading design parameters.

"Biophilia is a term coined by Edward O. Wilson in his 1984 book. He states that humans have an intrinsic affiliation with the natural world and that our survival on this planet relies on it. We are physiologically and psychologically nourished by the natural world as these are the environments humans evolved in over many millennia (Kellert 2005; Salingaros and Masden 2008; Ulrich 2000).

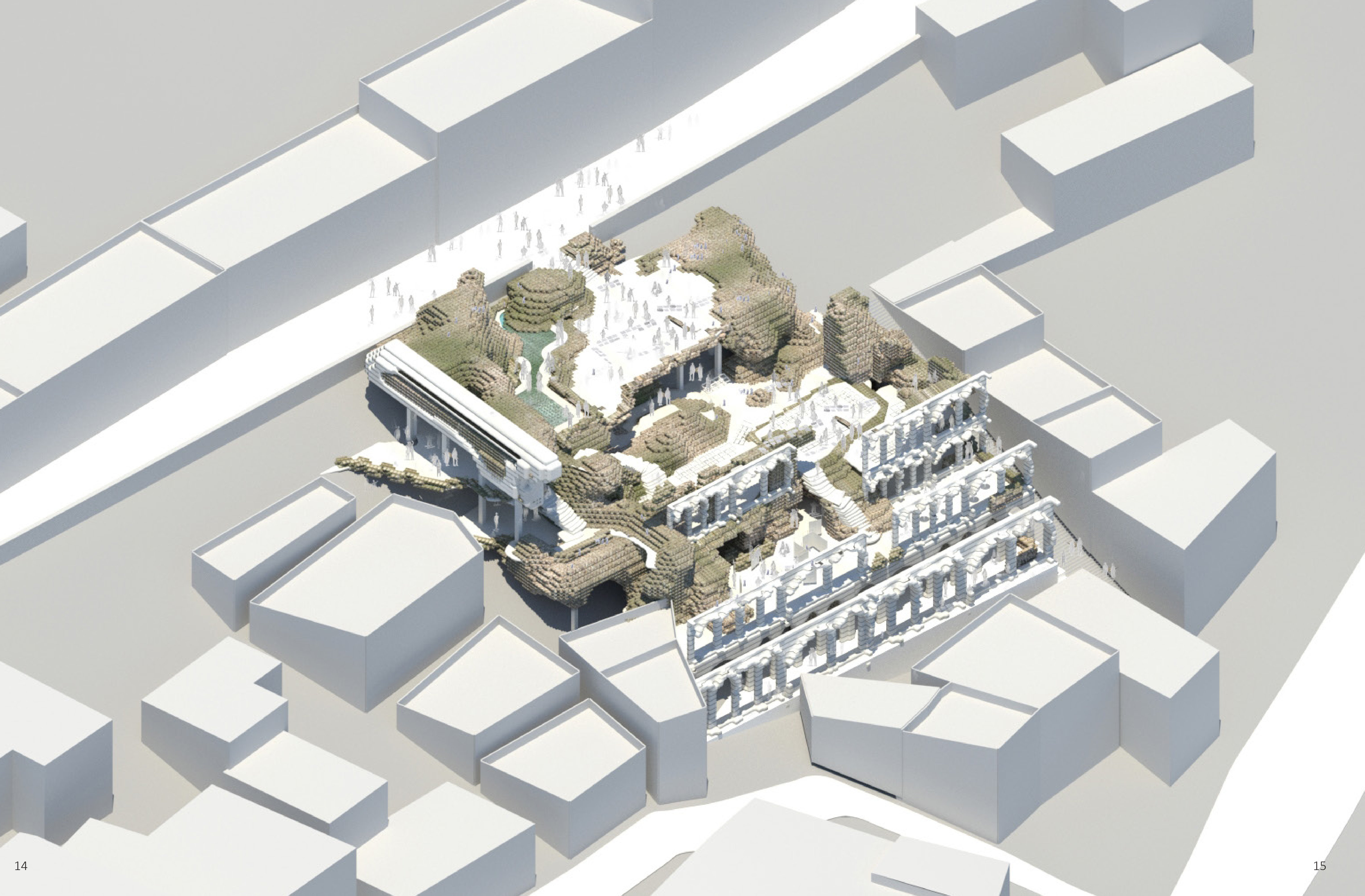
Generally, our contemporary built environment has suffered dramatically from the minimalist and modernist movements to the construction of our cities, moving from individuals to for-profit corporations. The result is sensory deprived architecture and spaces that lack the visual complexity of the natural world." (Krull. Suchomel. Bechtel,2015)

"Most contemporary research and practice into biophilia focuses on only the direct experience of nature. This is problematic as the same spaces with potted vegetation or a singular green wall do not deliver the visual complexity of the natural world and thus deliver underwhelming neurological nourishment" (Salingros. Madsen, 2008)

Amman's Flora overview

Jordan is rich in plant species, having approximately 2,600 species of vascular plants. Due to pressures associated with urban sprawl, many of Jordan's plant habitats are threatened or on the verge of extinction.

From left to right below, the five Jordanian habitats, which were recreated at the Royal Gardens. Deciduous Oak Forest, Pine Forest, Jordan Valley, Juniper Forest and Freshwater Habitat. (Royal Botanic Garden,2012)



Hempcrete-structure design and generative design

In creating the Hempcrete base structure, we used generative design as a design methodology. Our initial geometrical volumes come from Rhino, where we defined the boundary of the geometry. After that, we imported these poly-surfaces into Houdini, where we developed a more complex structure.

In Houdini Vex, We used voxel-based volumes and applied noise to voxel values. We defined parameters like noise frequency in x, y, and z. In our structure, we used equal noise frequency in x and z to create a more connected structure horizontally, while we increased the noise by a little in the y-direction to create more levels where we could start introducing elements like slabs and stairs.

The generative design methodology helped us a lot in the determination of movement. We were constantly evaluating every iteration we created and trying to foresee potential and structural risks in every iteration until we decided on the iteration shown in (figure1).

Generative design is a hard-to-control tool, and the final iteration does not have to solve all the encountered problems. For this reason, we designed extra hemp elements such as railings and integrated stairs and slabs. All of these added-on features made it possible to rationalize our structure.

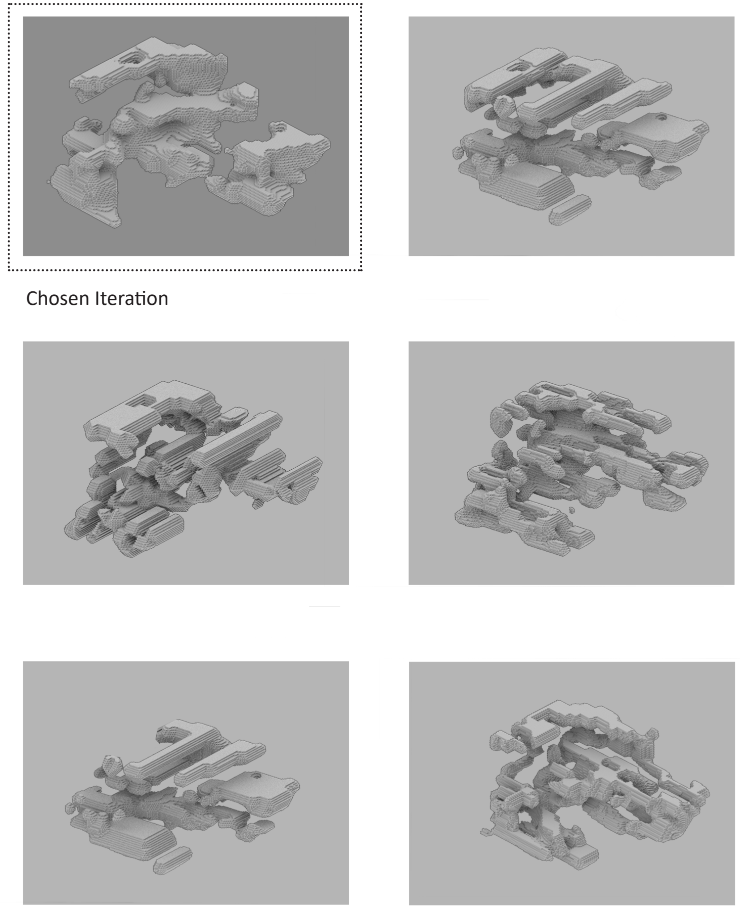


Figure 1: Iterations with different noise frequency values

Voxelizing methodology and bricks arraying:

We started by generating an equal spaced amount of points along the structure volume (figure 3). Then we used these points as centroids to array voxels (figure 4) along the volume to create a comprehensive digital structure that can be used as a base for the manufacturing phase. This structure can, later on, be divided into layers with a pre-defined bricks number.

As "spatial experiment" courses focused on the aspect of materializing and realizing our design through digital fabrication. We started looking into a brick system that can be arrayed along with the whole structure, aiming to make the building parts simple enough to be manufactured, mass-produced, and easily transported to the site.

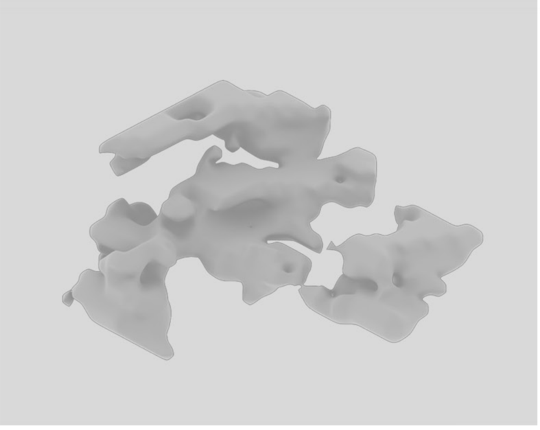


Figure 2: Mesh

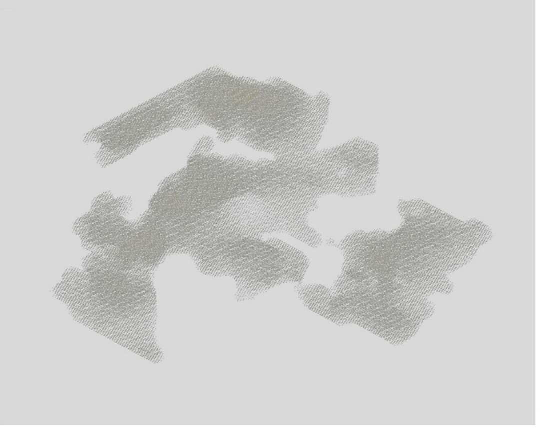


Figure 3: Points Along geometry

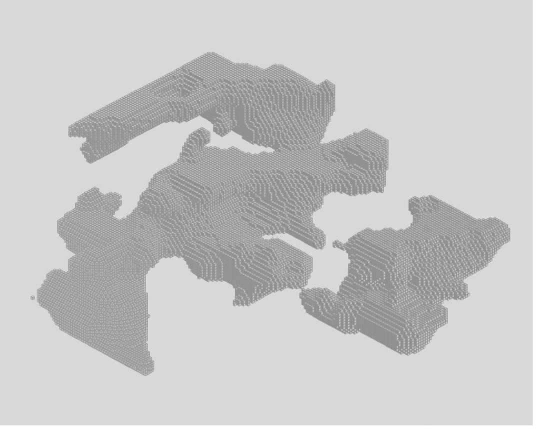


Figure 4: Voxelized geometry

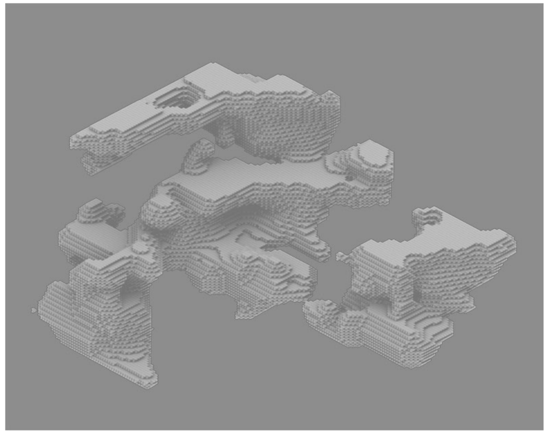


Figure 5: Brick-Based geometry

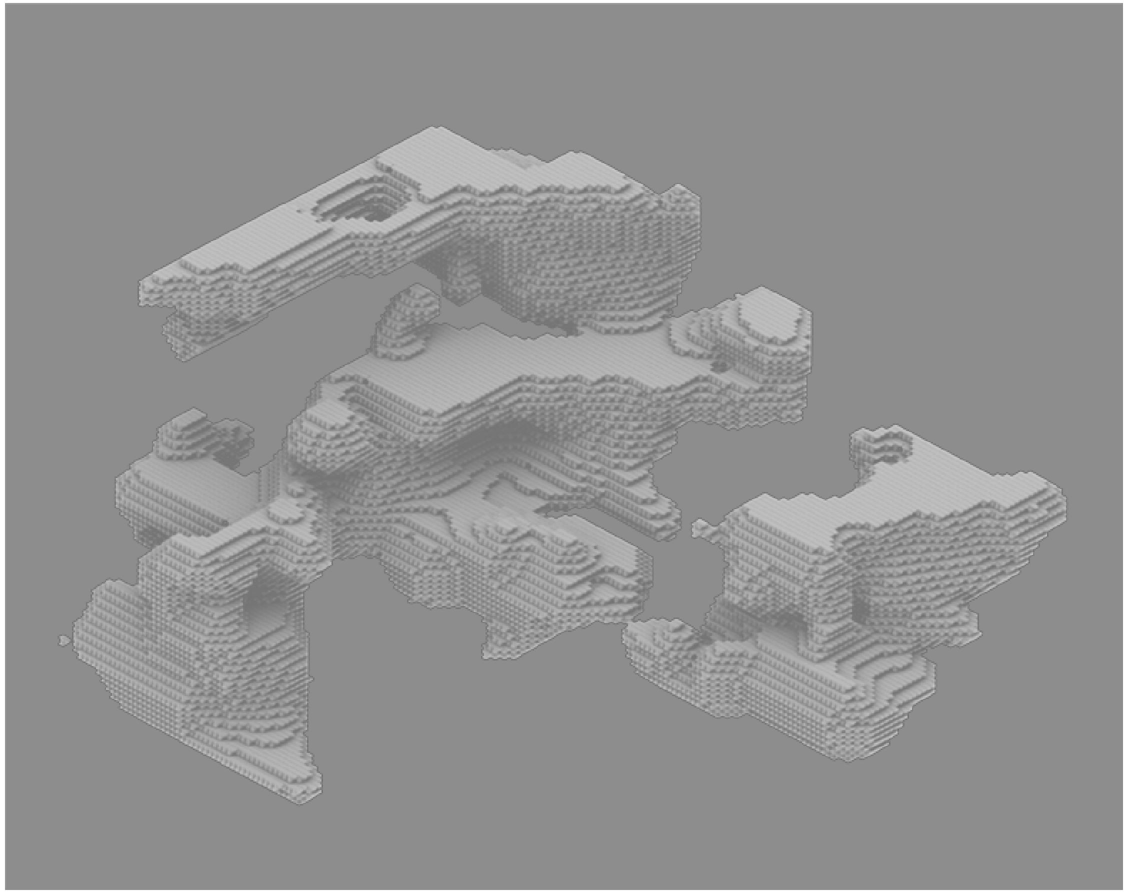
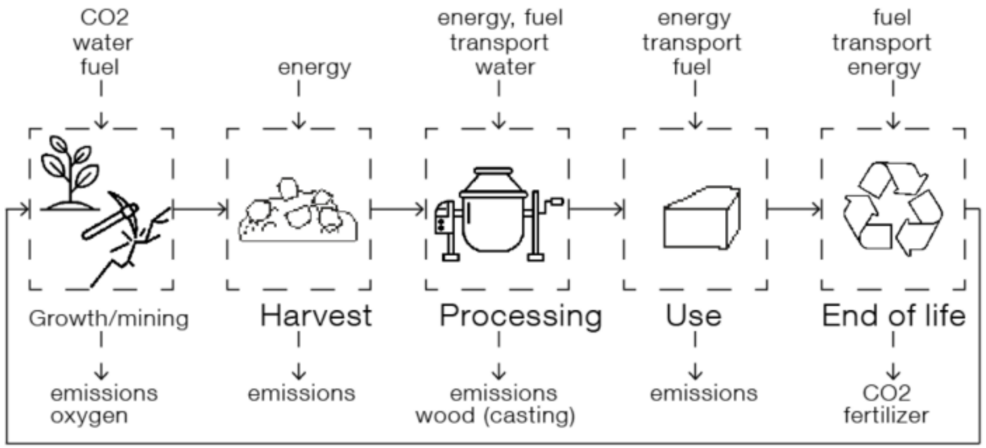


Figure 6: Hempcrete-structure

Materials

For the structure's material, we decided to use hempcrete as a substitute for concrete. Hempcrete, also known as hemp-lime, is a bio-composite building material made from the inner woody core of the hemp plant with a lime-based binder. The Hemp grows very fast, and it is carbon-negative as it absorbs Co2 from the atmosphere. Hempcrete has a good resistance against UV and is a biodegradable product (van Empelen,2018).



Life Cycle of Hempcrete (van Empelen,2018)

Making Hempcrete: Lime binder + Hemp Hurds + Water

Construction methodology

We defined several parameters for the building methodology of the main structure. First, we considered environmentally friendly materials. Second, the structure should have an easy overall manufacturing process and mass-producedable. This reflection led us to believe that the best solution in our case is to find a brick system that can fill these requirements. Then we searched for a 3d space-filling brick type that is not prism-like and structurally robust.

Delaunay Lofts:

our research on the brick landed on a paper published in 2019 by four researchers at Texas University, where they present a new approach for designing space-filling tiles in 3D space

“Our approach is inspired by scutoids — shapes that were recently reported to occur in epithelial cells due to topological changes between the extremal (apical and basal) surfaces of epithelia. Drawing from this discovery, we develop the theoretical and computational foundations leading to a generalized procedure for generating Delaunay Lofts — a new class of scutoid-like shapes. Given two extremal surfaces, both with Delaunay diagrams, Delaunay Lofts are shapes that result from Voronoi tessellation of all intermediate surfaces along the curves joining the vertices of Delaunay diagrams that define the extremal tessellations. This, combined with the use of wallpaper symmetries allows for intuitive design of complex space filling regular and semi-regular tilings in 3D space” (Subramaniana. Eng. Krishnamurthy. Akleman,2019).

“Shell and volume structures are usually composed of regular prisms (such as rectangular blocks) since they are relatively easy to manufacture and are widely available. Unfortunately, reliance on regular prisms inherently constrains our design space for obtaining reliable and robust structures” (Subramaniana. Eng. Krishnamurthy. Akleman,2019).

Figure 7: Delaunay Loft brick

The digital process:

Creation of brick in grasshopper using Voroni Component
We used grasshopper to recreate the Delaunay loft brick as the plugin already had built-in Voronoi components. We first started by understanding the nature of Voronoi and how it occurs. Mathematically, Voronoi patterns occur when boundaries centroids start to move in a particular direction, resulting in the edge collapsing and the Voronoi shapes we see. The diagram (figure 8, figure 9) shows how edge collapsing happens when every other column's sites move opposite to the other column's sites. Every time they move, we move the grid up in the z to create the Delaunay lofts at the end of the process.

The total created layers are 122. In (figure 9) you can see how the edge collapses on the selected iterations and how the grid changes its shape according to sites changing location. We increased the layers to have a highly accurate geometry when lofting all the layers.

The boundary's base shape will determine the brick's final shape. Below, we show a Delaunay loft resulting from a rectangle-rectangle grid interpolation.

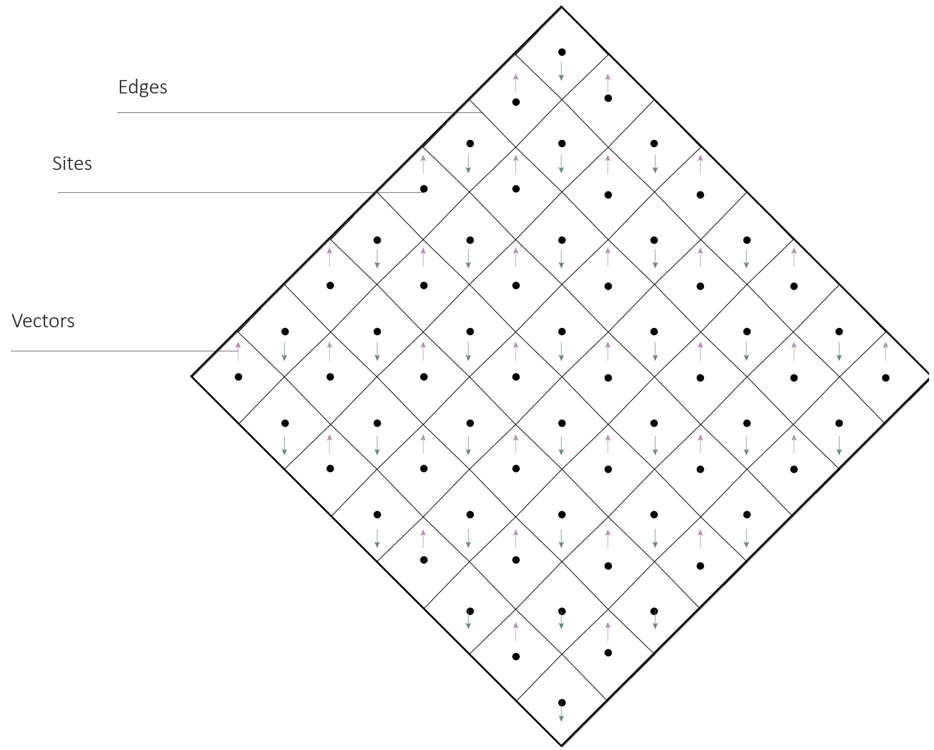


Figure 8: Grid shape and sites movement

Edge Collapsing:

Grid boundray changing shape accordingly to sites changing location.

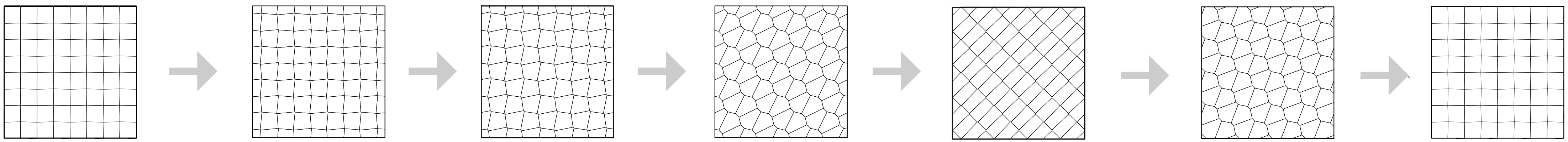


Figure 9: Delaunay Loft brick

Brick Properties/Size:

The brick has very good interlocking properties horizontally speaking. The research paper also demonstrates the load distribution along this brick type through a structural analysis, which we show in (figure 11)

The brick size is 33 cm in height and 29 cm in width. The brick scale is vital to be relatively small to increase the surface overall geometry area and provide more spaces for potential habitats such as cliff plants.

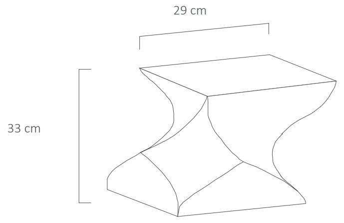


Figure 10: Dimensions

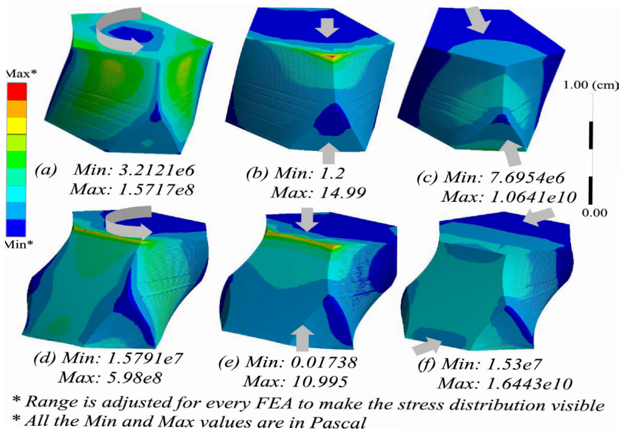


Figure 11: Stress distribution analysis. (Subramaniana. Eng. Krishnamurthy. Akleman, 2019).

Interlocking

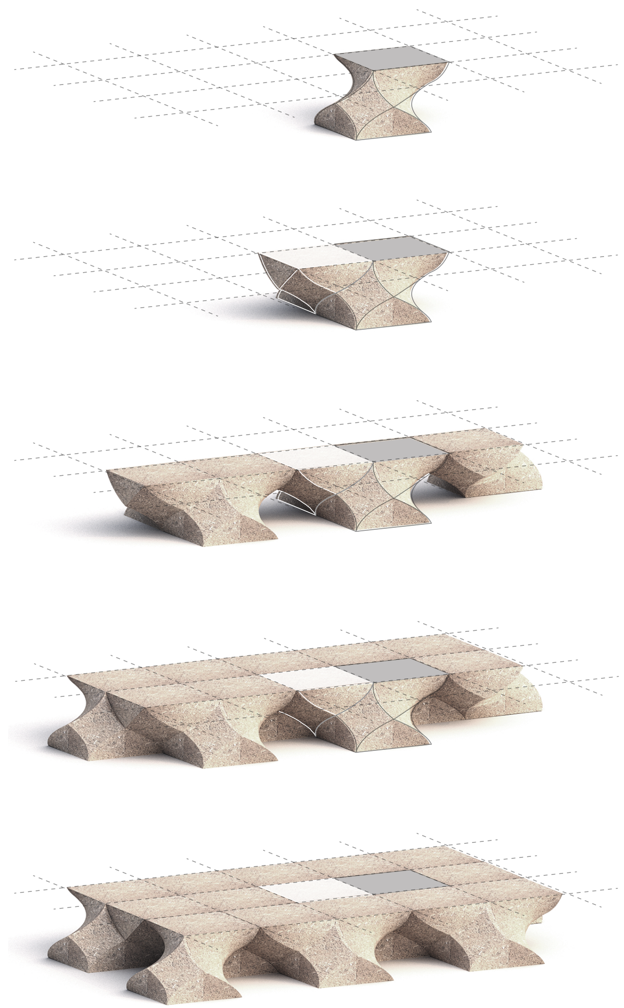


Figure 12: Brick interlocking

Brick Manufacturing Methodology:

We provide CNC milling as a manufacturing method for our brick molds. In the (figure 14, 15), we show the technique for the CNC and how we manufacture the brick. We have approximately 80 0000 bricks.

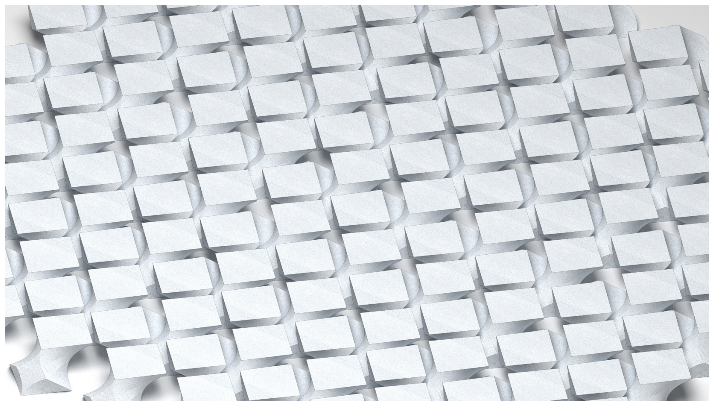
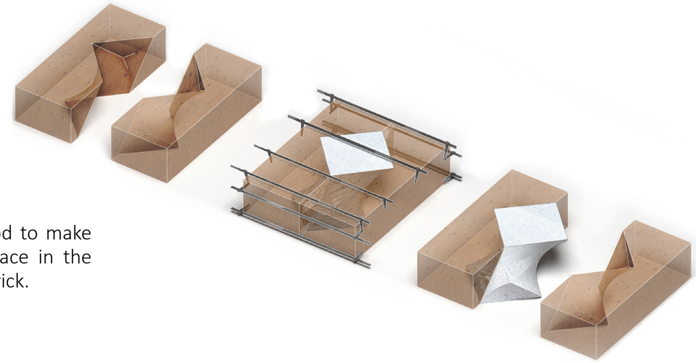


Figure 13



CNC milled wood to make the negative space in the shape of the brick.

Hempcrete Poured inside and then pressed as shown untill dry.

Brick released after drying.

Figure 14: Brick Manufacturing

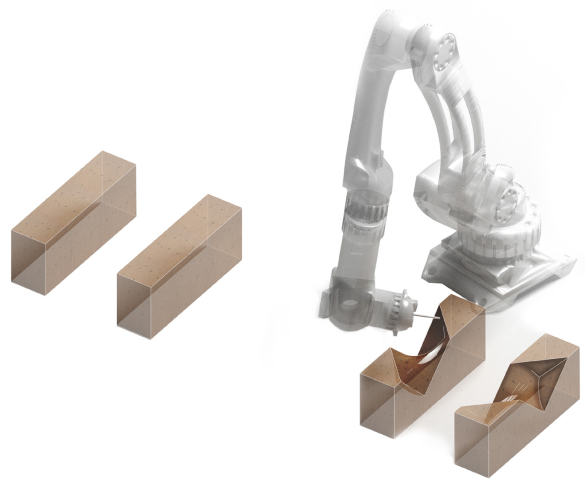


Figure 15: CNC milling

Assembly Methodology:

The brick can be repeated by replacing bricks beside each other without needing to glue them. We introduce modern slabs and columns as a foundation on which the first layer of bricks relies, and then the other layers are introduced.

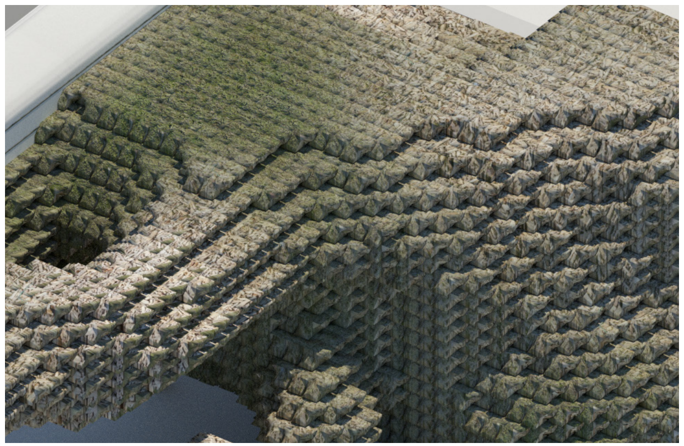
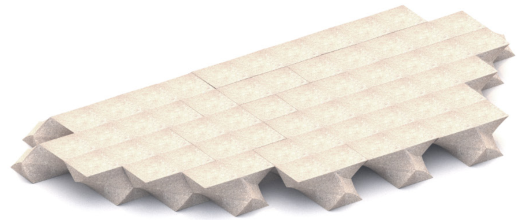
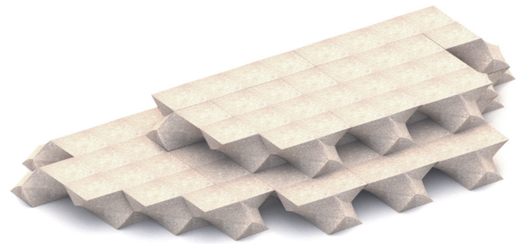


Figure 14: Final Assembley

First Layer
Relying on a slab



Second Layer



third Layer

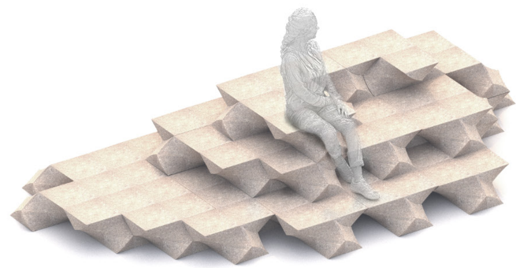


Figure 15: Layering

AI and facade creation

The Rise of AI in the last decade made it super important to ask questions like how AI can help in the architecture design process. AI is very capable of learning and can have significant potential for architecture. Feeding the AI a large amount of data will produce results that can be curated and further developed by the architect.

We used StyleGan-Pytorch Algorithm and trained our data set on Google collab. The approximate time to train was about five days.

StyleGan:
Researchers at Nvidia distributed a preprint describing StyleGAN, a GAN, for producing an unlimited number of (often convincing) portraits of fake human faces in December 2018. The StyleGAN software was able to run on commodity GPU processors from Nvidia.

Phillip Wang, an Uber engineer, created This Person Does Not Exist in February 2019, which displayed a new face each time a web page reloaded. Wang himself has expressed amazement over the fact that StyleGAN can pick apart all relevant features (of human faces) and reassemble them in a way that is coherent, despite humans having evolved to recognize and understand human faces(Peng, 2018).

The purpose of using AI is to bring the city context into our design through the design of facade elements. The StyleGan algorithm is very good at learning patterns from images and, in turn, producing thousands of iterations similar to the actual images, which means a wide range of facade designs that we can inspire from and use in our design.

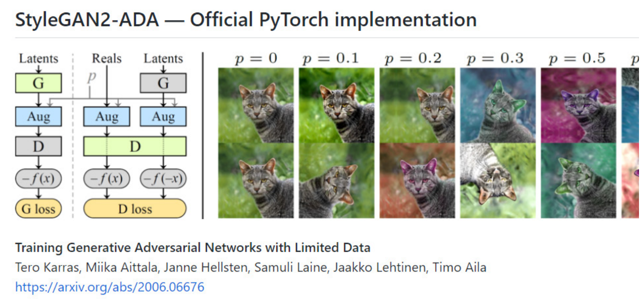


Figure 16: StyleGan-Algorithm (nurpax, 2021)

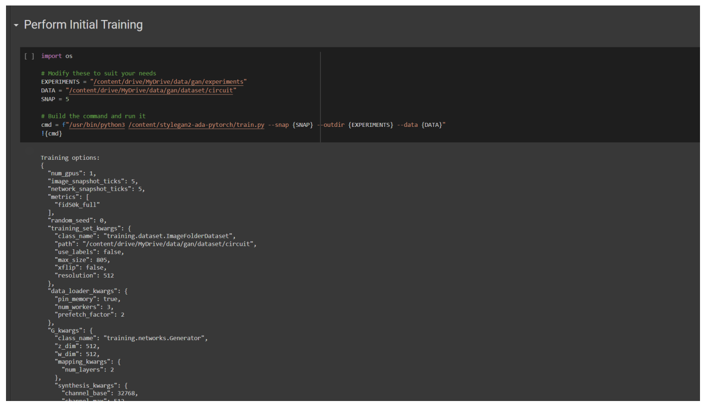


Figure 17: Google Colab

Collecting Data:

In March, we traveled to Amman to collect fasade images, and we were able to collect 1000 images from different areas in Amman.

We used one mobile camera to be sure to have similar qualities in all pictures. However, the number of pictures we took was under our estimations because we faced several challenges. Amman is a very hilly city, and the streets are narrow, which makes taking pictures of the facades very tricky, especially when only using a mobile camera.

We searched for areas on google maps, and it worked nicely. We also tried randomly asking people on the streets or taxi drivers to recommend areas where we could take pictures. It was important ask people because we wanted to know what people liked and what they considered Amman.

After spending 2 weeks in Amman, we went back to Sweden. Started training our data set and evaluating results.

Figure 18: Taking facade pictures in Amman

Collecting data is very sensitive, and since Amman is a hilly city with narrow streets, the mission of collecting data was not the easiest. Some of our pictures had more of a perspective view rather than a facade view. However, that did not affect the quality of the AI-produced images. We were interested in the actual representation of the facades and not a finished design produced by the AI. The overall quality of the images produced by AI was clear and straightforward.

Figure 19: Small batch of our collected data

The AI generated fasades

After collecting the images, we started feeding the Algorithm the pictures, and we did several training sessions. It took us about five days to achieve the results shown in figure 20.

We could keep training, but from our point of view, the images already had an excellent quality, where all facade elements were apparent.

We stopped training at this point and started looking into which images we think are interesting to develop into 3d. Our mission was to analyze those images, break them down into parts and see how we could use them to the best, where we can start manipulating and designing our facades.

Figure 20: AI Generated facades

Image Curation and transformatiom:

First, pictures are curated and adjusted in Photoshop. The adjustment had different steps, and our goal was to make the image respond better to the 3d-transformation method and to develop the expression of the facade in the direction we desired it to be. The adjustments were mainly about intensifying the colors to contrast what is open and closed, as shown in (figures 22 and 23). in addition. We did many tests with different composition approaches.

We imported our images to Houdini and created a 3d version of our 2d images through points displacement based on color. After this operation, we generated points on the surface produced by displacement mapping and replaced the surface with a voxel-based geometry.

Figure 21: Transformation - Expirement 1

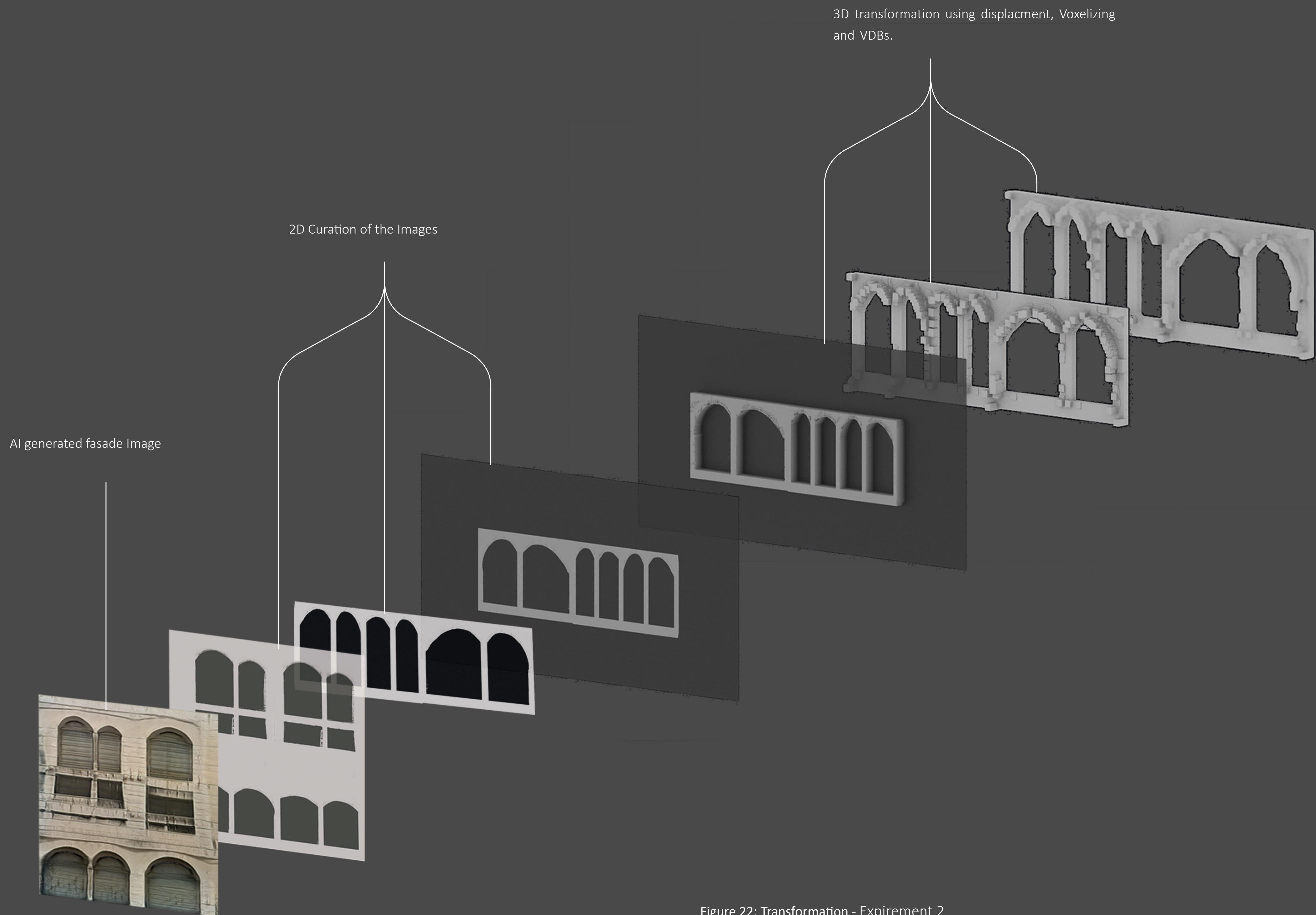


Figure 22: Transformation - Expirement 2

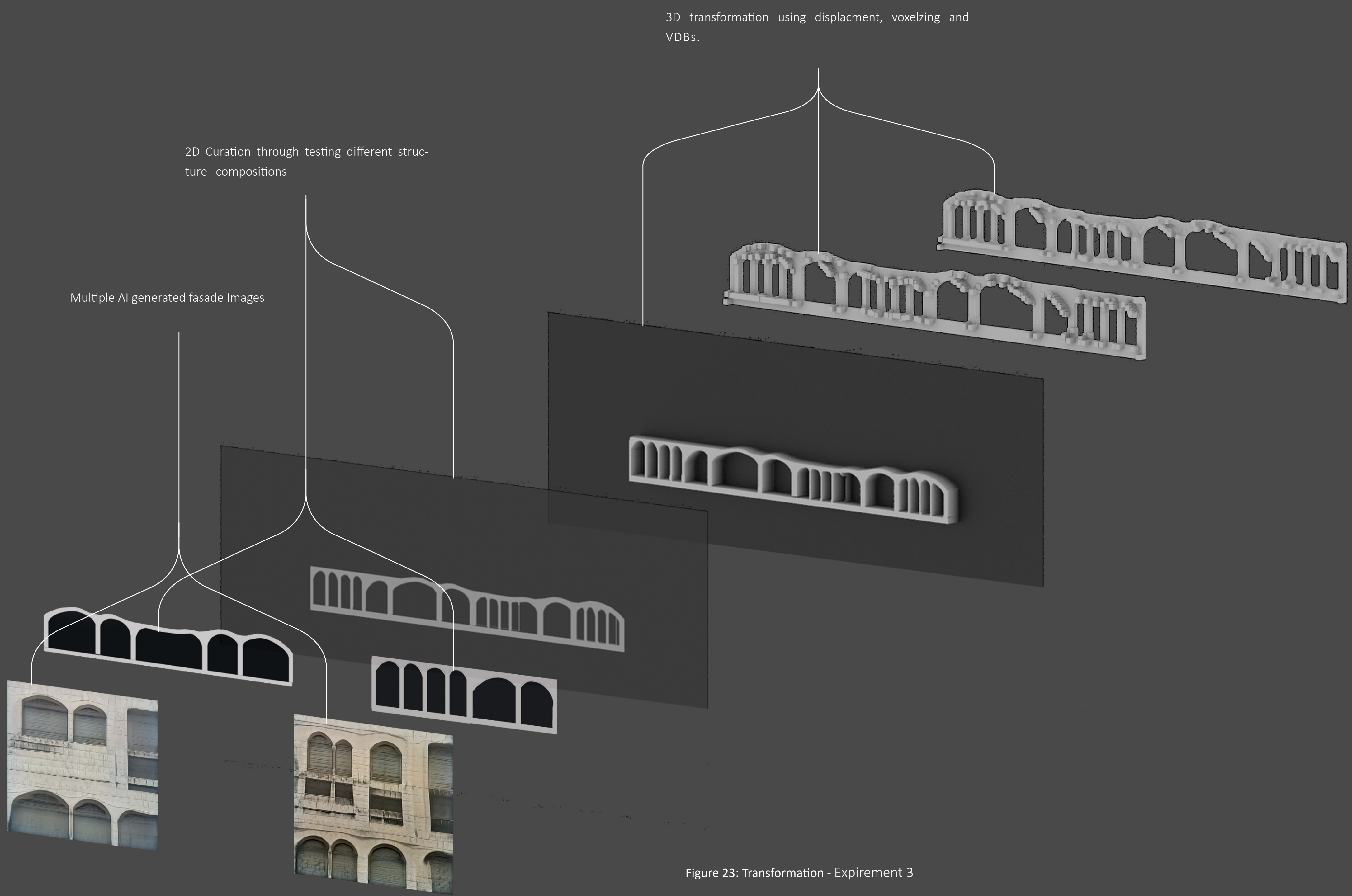


Figure 23: Transformation - Expirement 3

Fasade Fabrication method

Fasade design

Dividning the Fasade into comperhensive components for construction

Ceramic 3D printed bricks

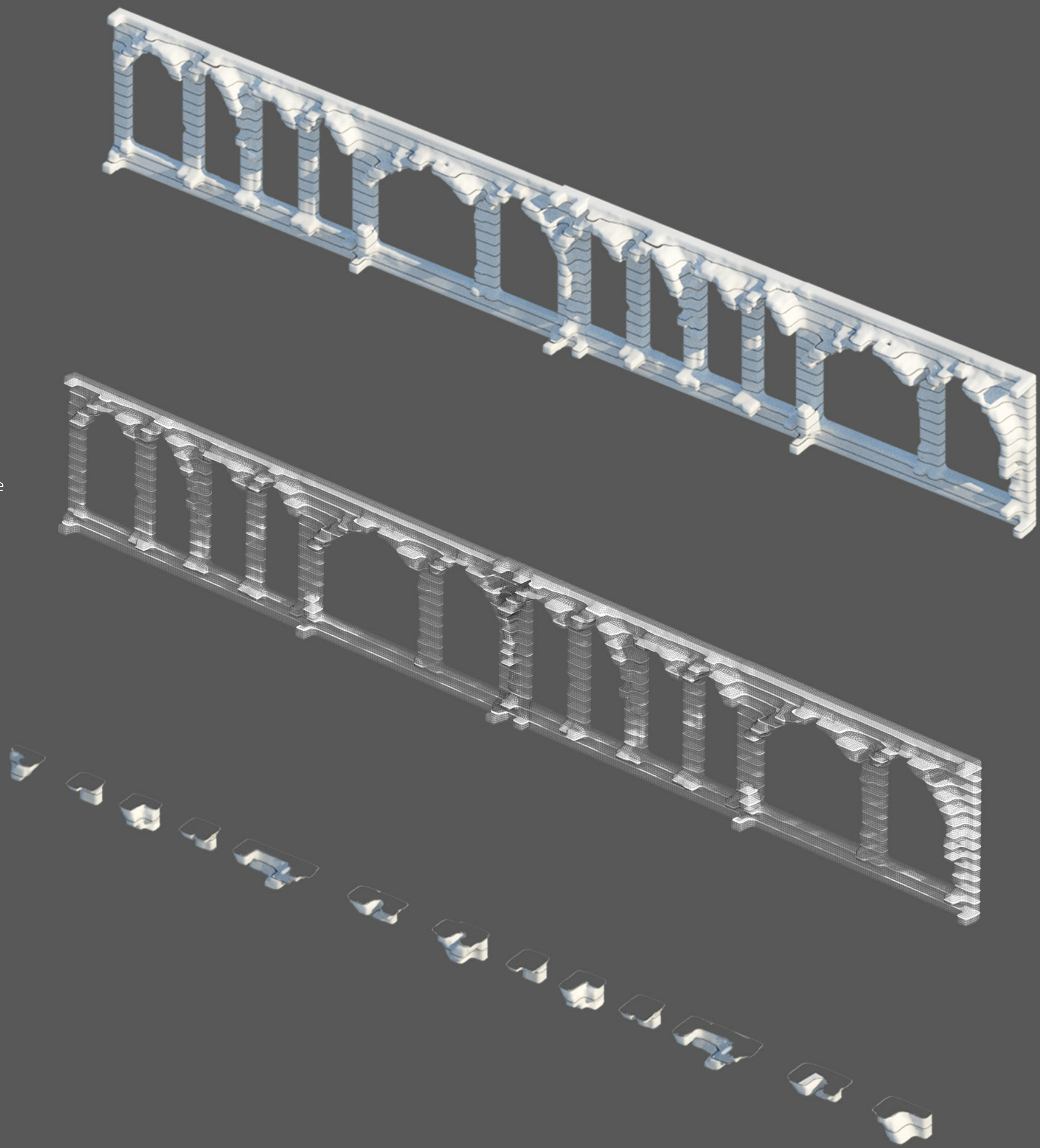


Figure 24: Facade Manufacturing

Assembly

We introduce 3d printing as a manufacturing method for our facade. In our previous spatial experiment courses, we worked a lot with clay 3d printing. From older experiences and digitally examining the facade's shape, we understand that we do not have significant issues like overhangs. That led us to resonate about the possibility of 3d printing the facade and introducing it as a possible manufacturing method. We divided the facade into a brick-based system where we integrated steel rebars and cement filling to stabilize the structure.

We reflect upon the possibility of filling the 3d printed bricks with hempcrete, but the question remains about whether it is heavy enough to stabilize our bricks as cement would do.

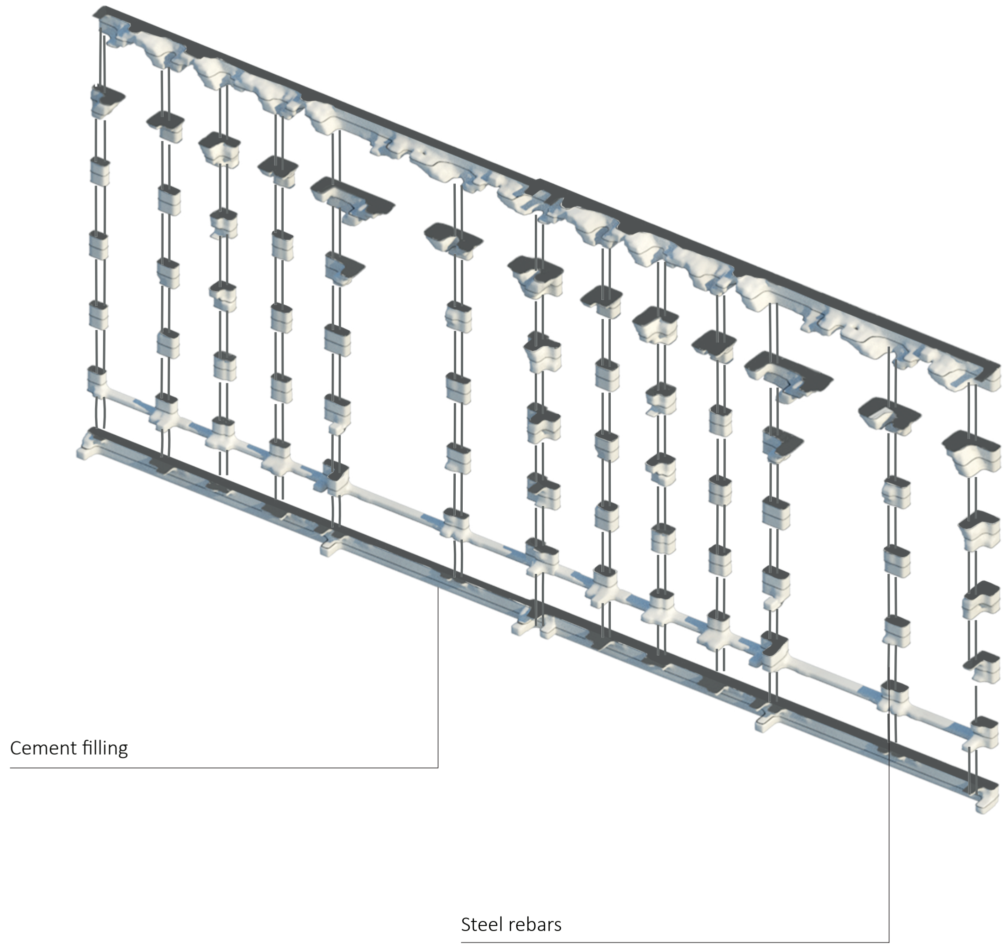


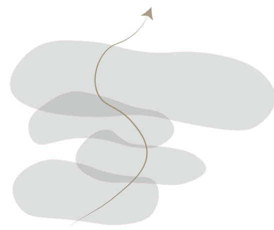
Figure 24: Facade Manufacturing

Design and Concept developement

Our main design parameter was to create a symbiotic relationship between humans and non-humans by creating a structure that brings in nature complexity. At the same time, we made design decisions that were more related to the overall human experience of the building, which helped shape the final results.

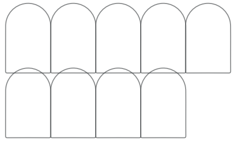
The city of Amman is located on a series of mountains. The movement in the city happens mainly in the z-direction, in other words, vertically rather than horizontally. The transition from one roof to another is widespread in Amman, something we also did a lot during our trip there. This inspired us to make our building have the same concept as the city by making the roofs of the structures act as floor plans. And while generating our structure we made sure to have enough levels to create that feeling in the building.

City expirence through introducing vertical movement that is similar to moving on roofs



Symbiotic Realtionship between humans and nature

Bringing in context through facade design



Main Structure Elements

Stairs

Slabs and some columns

Final hempstructure

Facades

Final Design

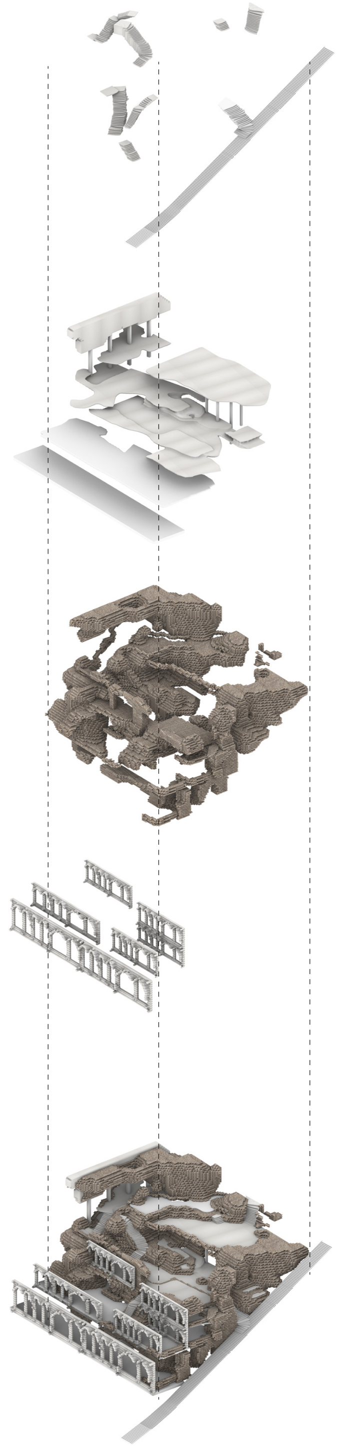
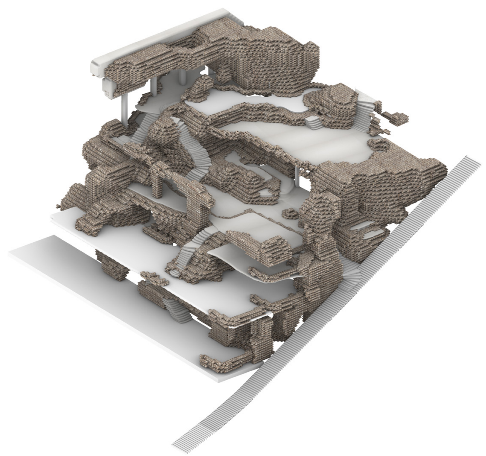
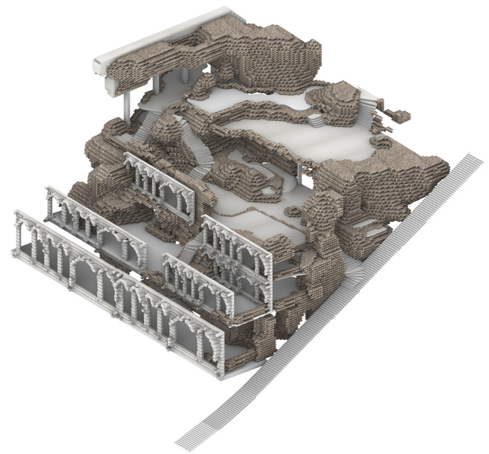


Figure 25: Structure Elements





Hempcrete structure

Hempcrete structure + Stairs

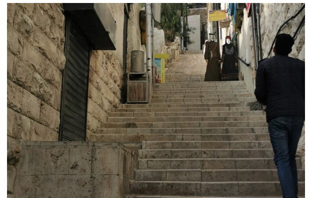
Hempcrete structure + Stairs + Slabs

Hempcrete structure + Stairs + Slabs + Fasads

Amman Site

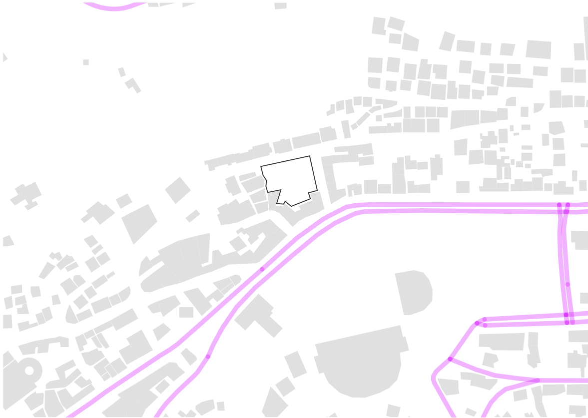

Site view from The Roman Theater


Site

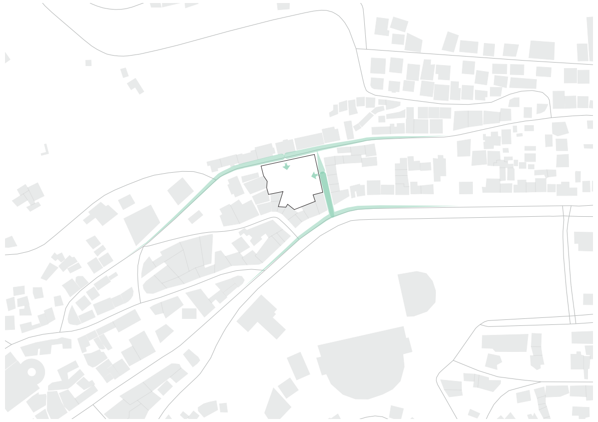

Stairs from the lower street


Roman Theater

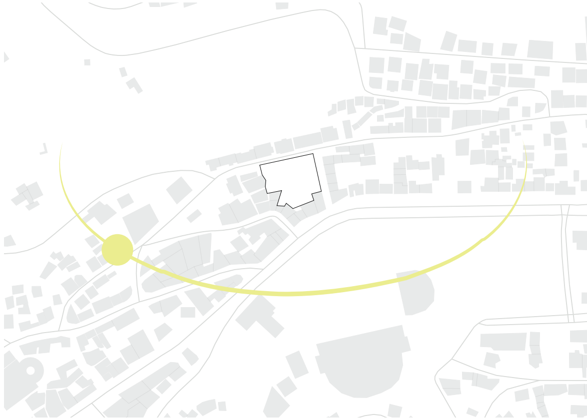
Site Analysis



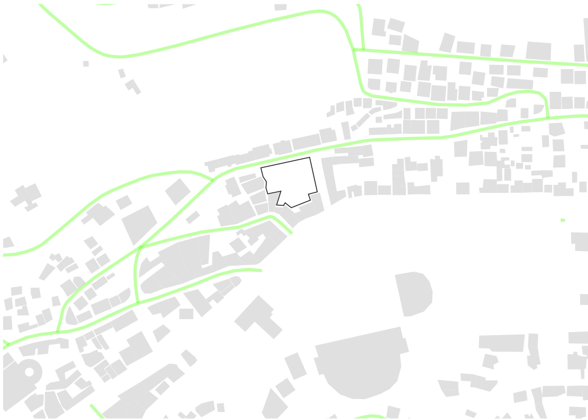
Heavy traffic streets



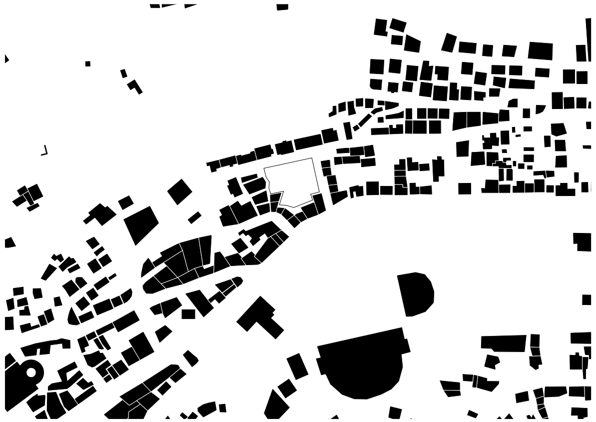
Flows



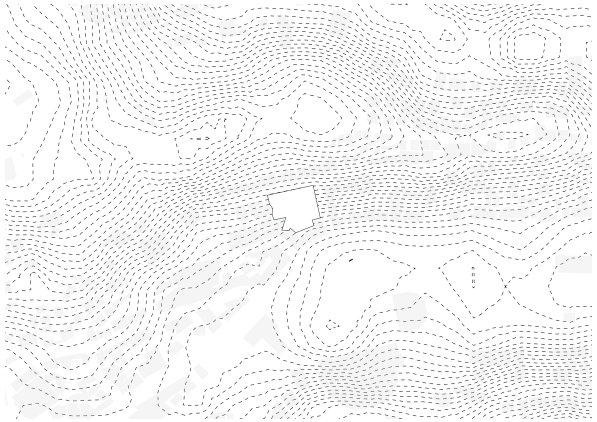
Sun path



Light traffic streets



Context massing

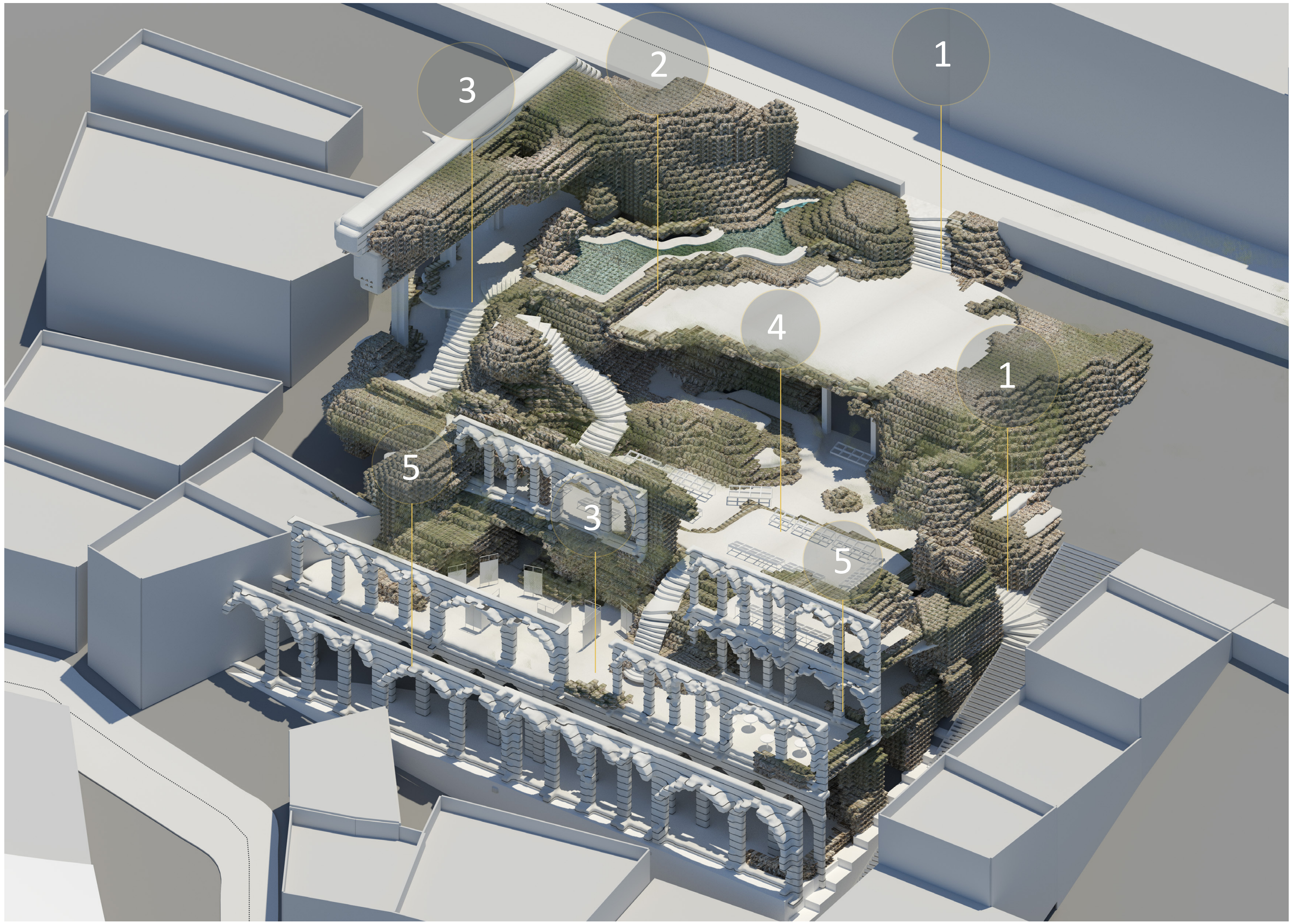


Contours

SitePlan

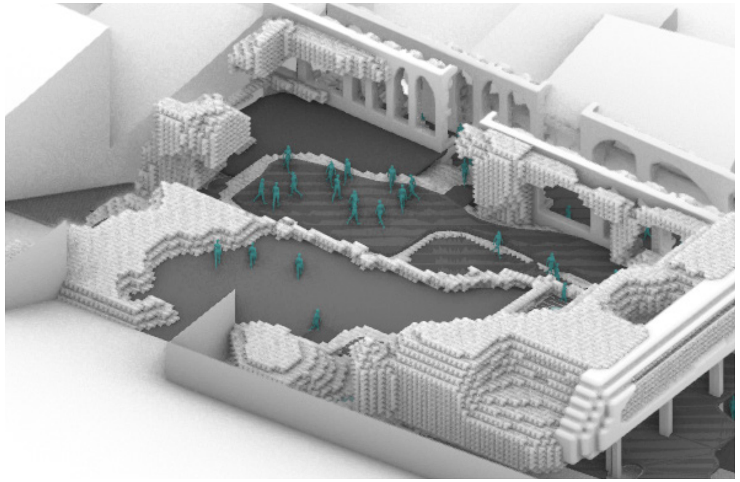
Hotspots

Program and functionality with an overall view. The building is a flexible place that can be used for different purposes. Here we introduce functions like a farmers market and art installations spaces. The building is flexible, and users can redefine spaces, and they get to decide how to use these spaces. The building provides spaces with and without a ceiling.

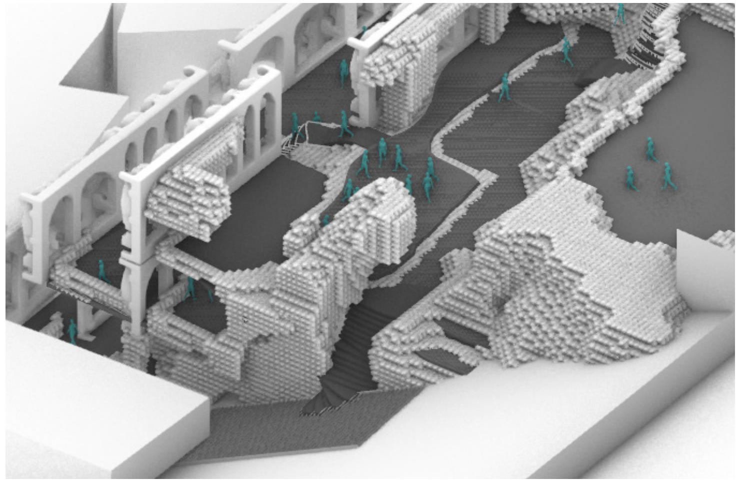


1- Entrances
2- Water Bed
3- Spaces for art installations
4- farmer's Market
5- Seating

Entrances



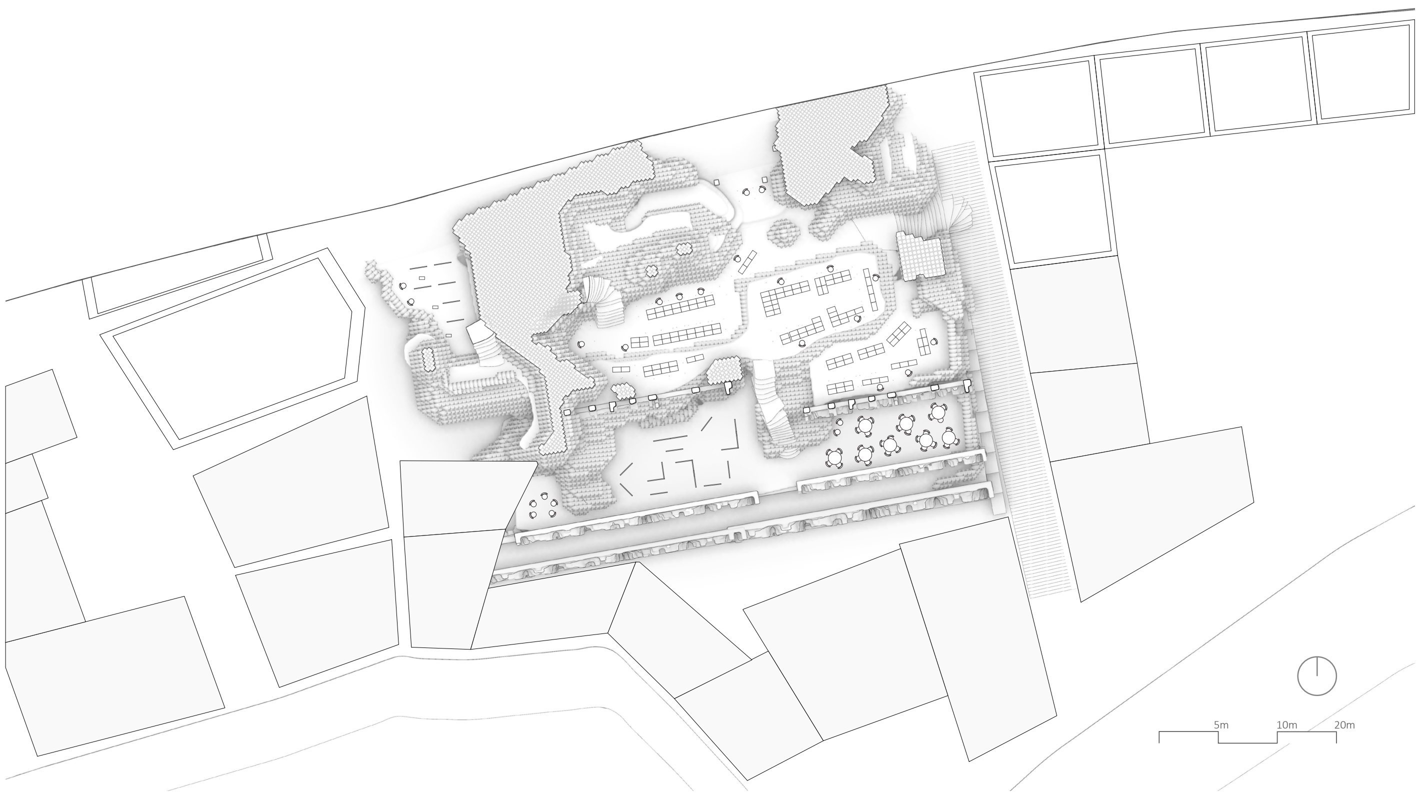
North Entrance



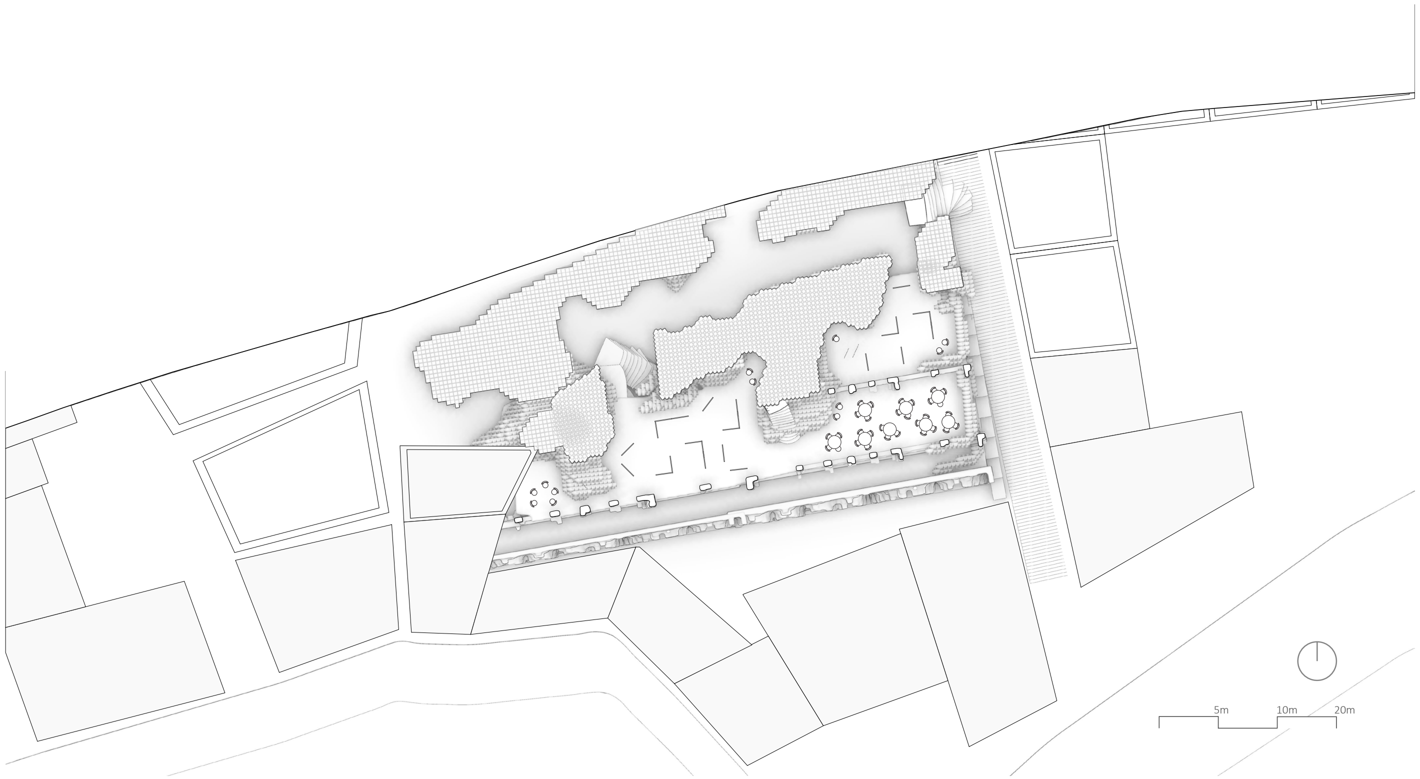
East Entrance

Plan 1

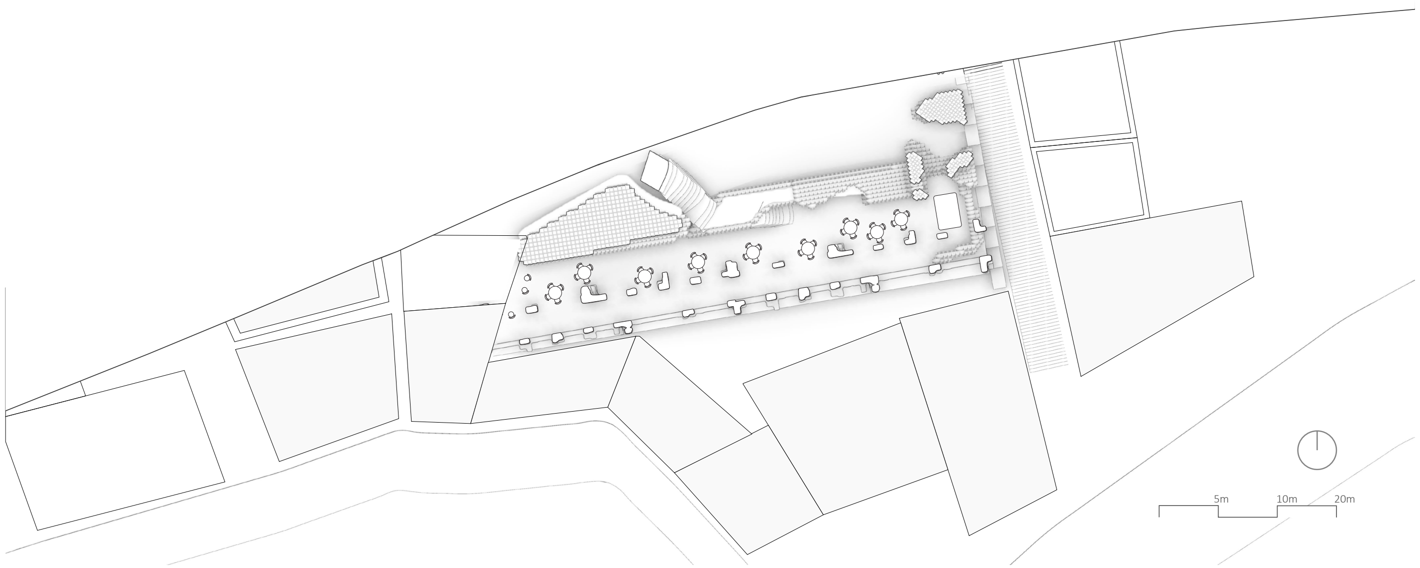
Plan 2



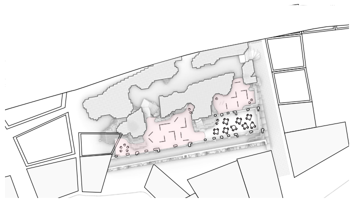
Plan 3



Plan 4

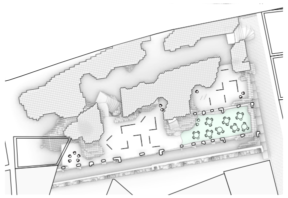


Diagrams

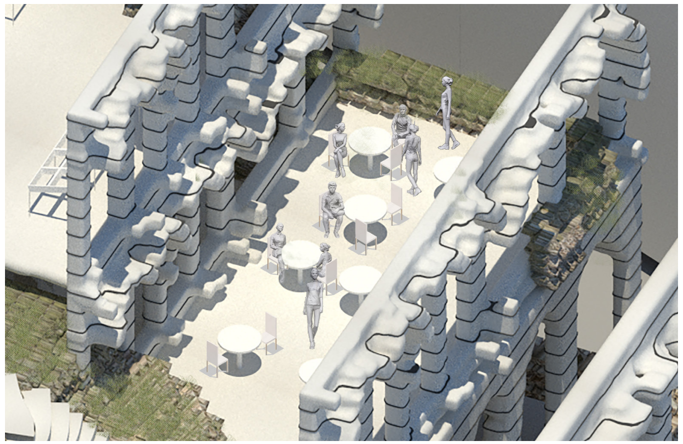


art installation

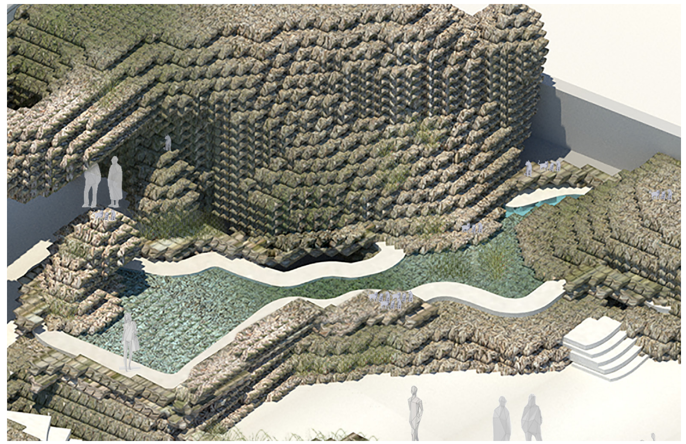
Market



Seating

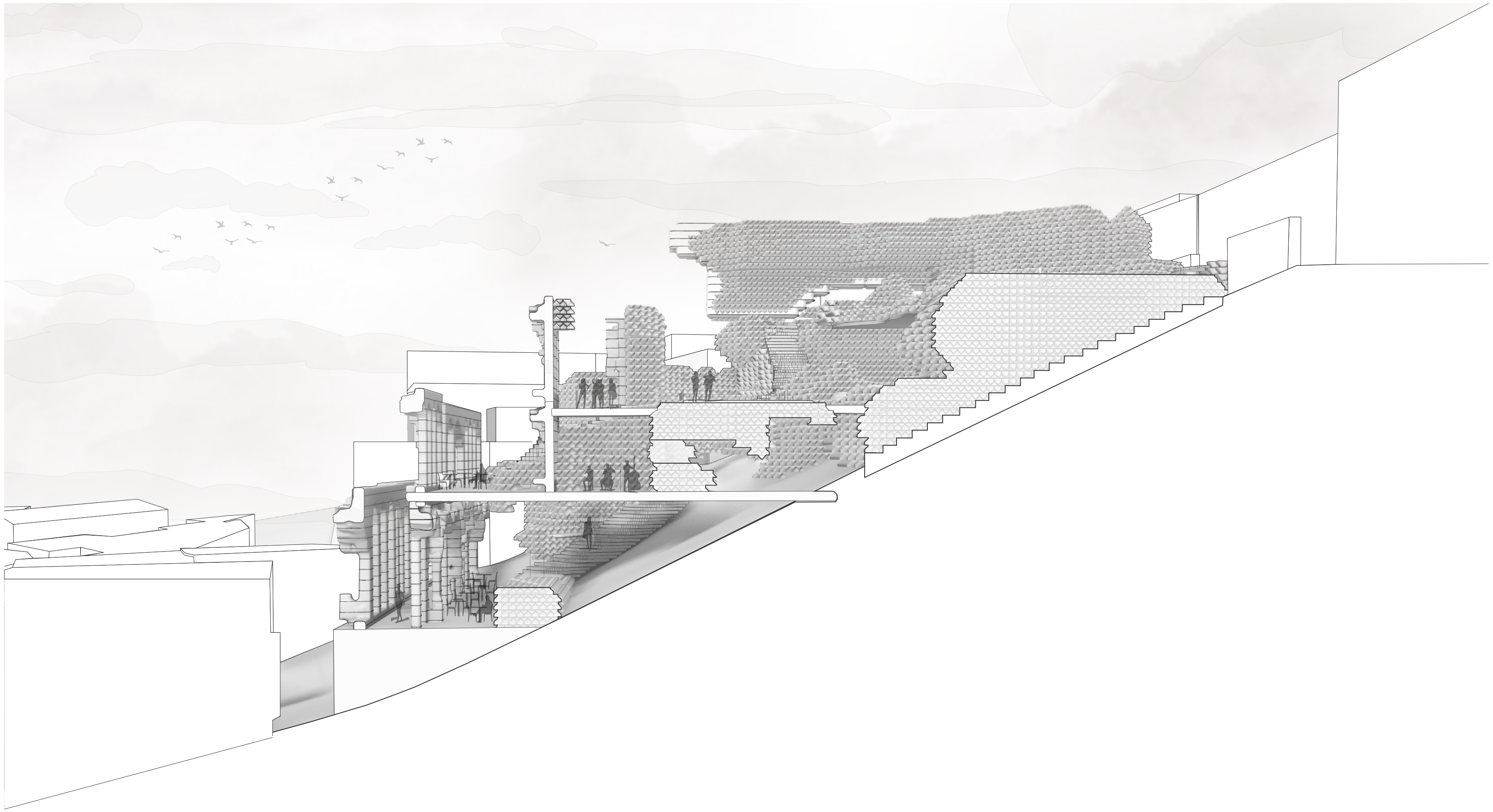


Water space



Elevation

Section



Interior

Interior

Conclusion

We wanted to do Symbiotic Amman because we saw a real problem in the city when we first traveled. We do not necessarily see Amman›s narrow streets and building density negatively. There are issues regarding following a modernist, human-centered approach when designing. From our point of view, the approach should be more environmentally aware and make the city a more desirable place to be in. We need to rethink the built environment, reprioritize, and most importantly, ask ourselves one more time, what is the best for humans? Is it to isolate from the surroundings or find that balance where we could reunite with nature and still have comfort within our cities?

Our main objective was to introduce a novel approach when designing new city elements. We wanted to bring in the indirect complexity of nature and make the humans experience the city in more than streets and cars.

Thinking of today's humans and our needs, we understand that our building is not protecting humans from harsh weather. It is a very complex task to provide a shelter that completely isolates humans but simultaneously provides them with that indirect connection to nature, as we did in our structure. Thinking of the level of comfort humans have today, We believe that it takes time to re-evaluate our need for isolation and the extent to which we should be isolated. We see our building as one of the city elements that provide a space for bio-diversity and human-nature interaction.

The notion of Symbiotic Amman was built on considering the city context, humans, non-humans, and nature all as equals. This was the starting point for the discussion about the importance of bringing some of Amman›s context into our Symbiotic structure. We realized that we were introducing a very unfamiliar notion to the city. Our approach of bringing context through facades helps to communicate the image of Amman to the locals and make it more familiar for them. Machine learning was a convenient tool when we brought the context to our building. It made us reflect more on the potential and possibilities that new technologies could provide for architectural processes. It also made us question the results sometimes and ask ourselves about the actual value of these tools and whether they could do better than us. We eventually understood from the AI/Generative design tools that quantity and variety were the most beneficial aspects. Computers have a better way of storing and displaying information than humans do. Humans, on the other side, are decision-aware and qualitative.

Our project might not give a final solution to the problems we are facing today but what we hope with this project is to change the narrative and the discourse of human centrism in the designs to a more equal and inclusive one.

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