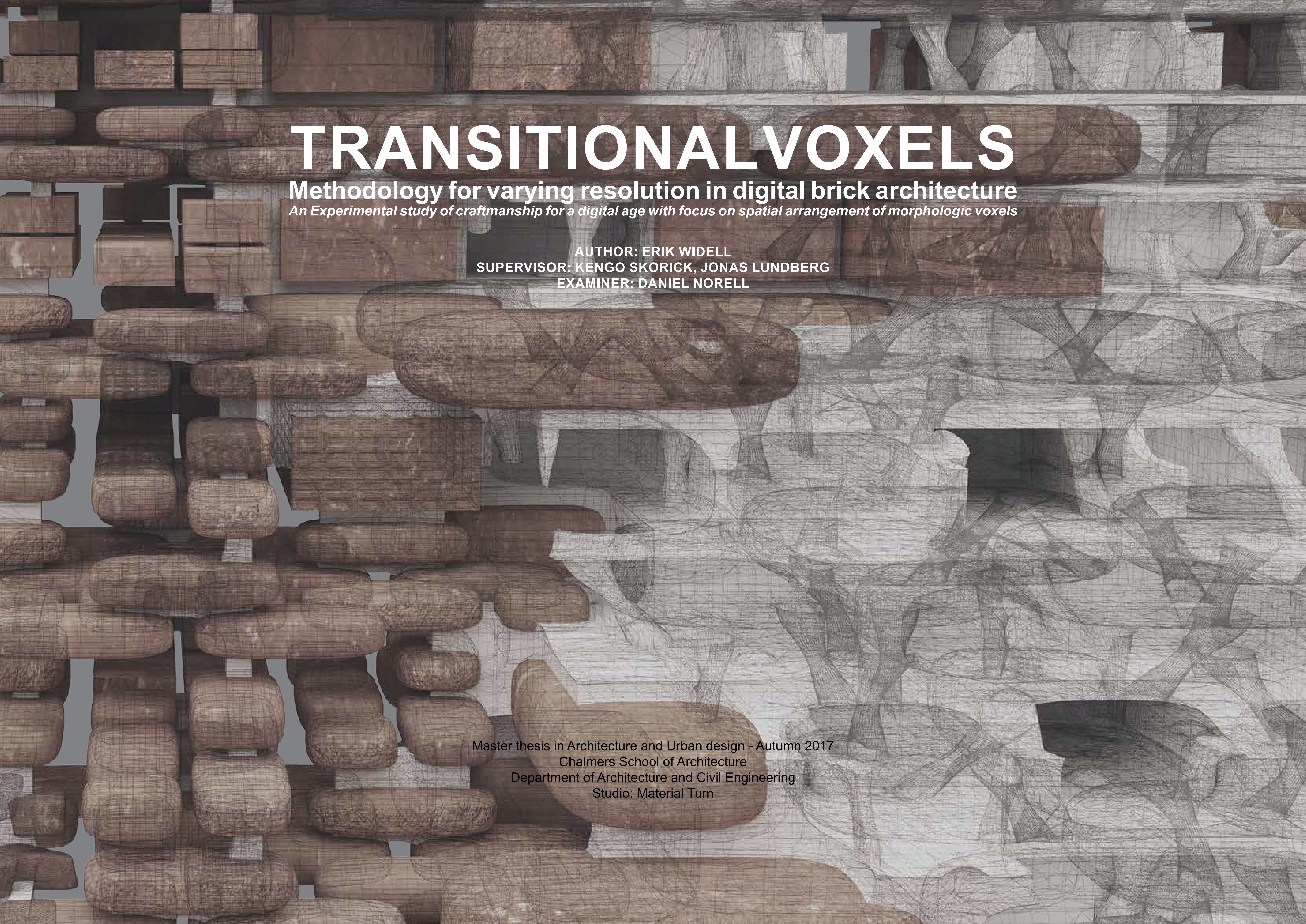

TRANSITIONAL VOXELS

Methodology for varying resolution in digital brick architecture

An Experimental study of craftmanship for a digital age with focus on spatial arrangement of morphologic voxels

AUTHOR: ERIK WIDELL
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EXAMINER: DANIEL NORELL

Master thesis in Architecture and Urban design - Autumn 2017
Chalmers School of Architecture
Department of Architecture and Civil Engineering
Studio: Material Turn

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CHALMERS
UNIVERSITY OF TECHNOLOGY

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Department of Architecture and Civil Engineering
Studio: Material Turn
Author: Erik Widell
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Examiner: Daniel Norell
Examination date: 2018/01/11

ABSTRACT

The purpose of this master thesis is to investigate how craftmanship may be achieved in digital brick architecture with feasible methods. Here, craftmanship is defined as the intersection between quality of the whole, quality of the parts, and quality of the method while feasibility refers to a method that is suitable to achieve a certain quality.

Production- and cost-optimization in the building industry, has during the 20th century led to less craftmanship, and more homogeneity, as an effect of less attention to detailing and materiality. A sober investigation of craftmanship is relevant because of the rise of populistic movements who claims there's a lack of architectural qualities today. Architects in general are the stakeholder since a feasible approach will be useful to reach higher architectural qualities.

The methodology for the study is design by research, meaning that research and design is carried out simultaneously throughout the project. The intention with the approach is to ensure that the proposed design and construction methods are applicable, and that the design proposal is designed and buildable with feasible methods. To manage complexity in data management, low-res voxelization has been used for digital modelling and representation.

The result is a methodology, an iteration of three steps: define, evaluate and evolve. The methodology may be used as presented, or tweaked to suit specific circumstances. The outcome of the methodology is presented as a public bath with flowing spatial sequences and morphologic bricks, represented at varying resolution and detailing. The bath is situated at Valhalla IP in Göteborg, A site that has been proposed for a new central bath in the city.

The conclusion is that craftmanship in digital brick architecture may be achieved through an iterative experimental design process, where the mutual relationship between the parts, the whole, and the methods is considered. Varying voxel resolution may be used as a method for representing various levels of detailing and to maintain the part to whole relationship.

DISCOURSE DIAGRAM

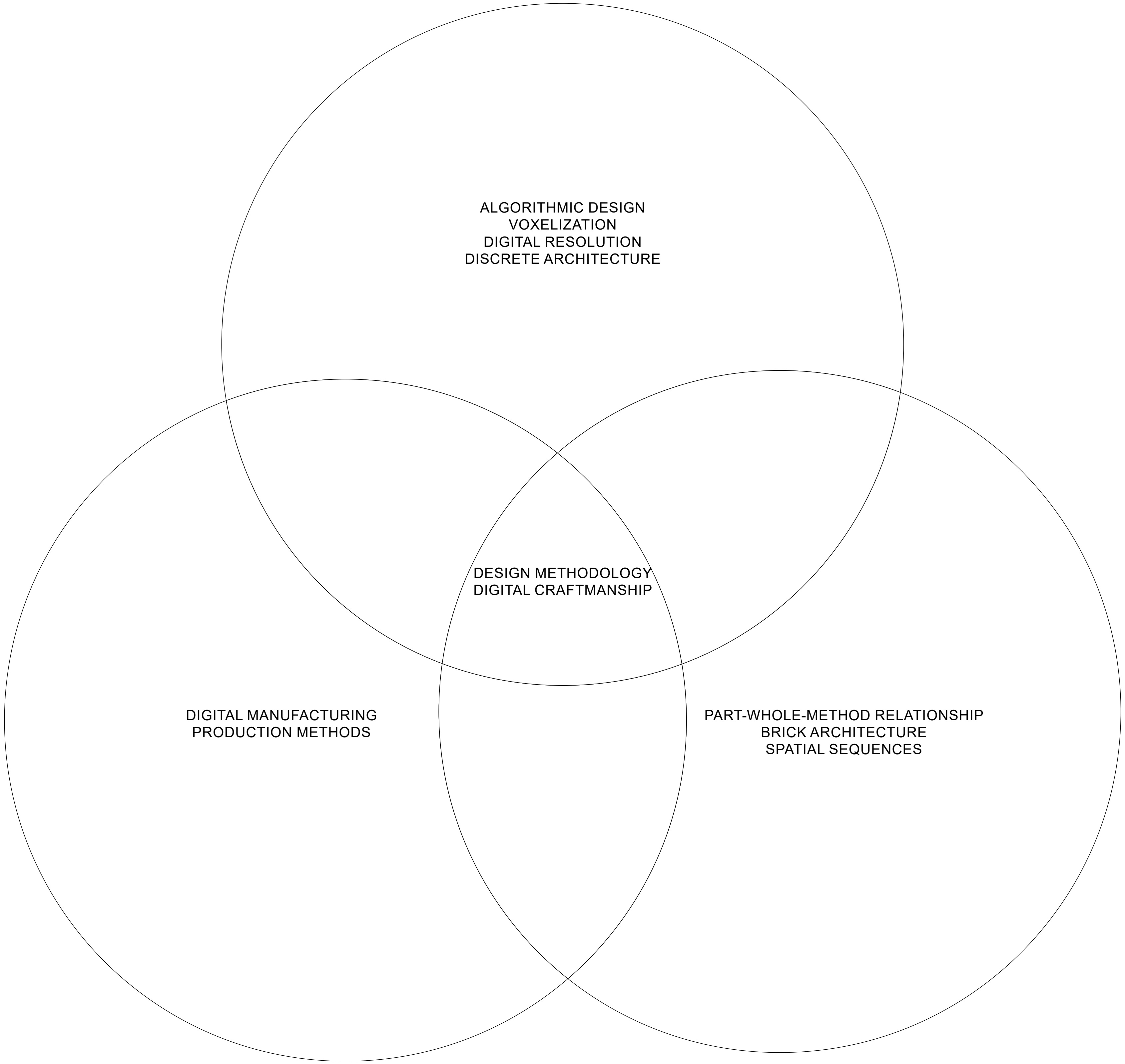
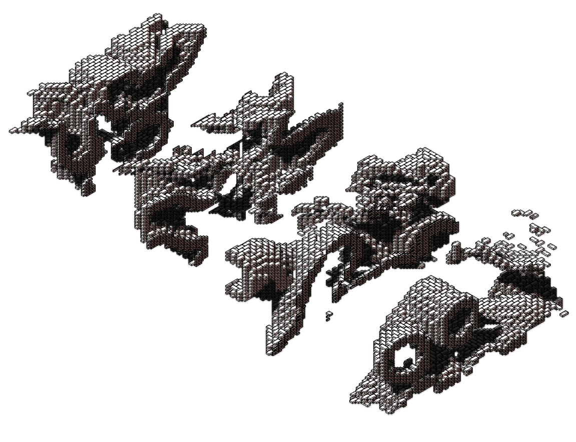


TABLE OF CONTENT

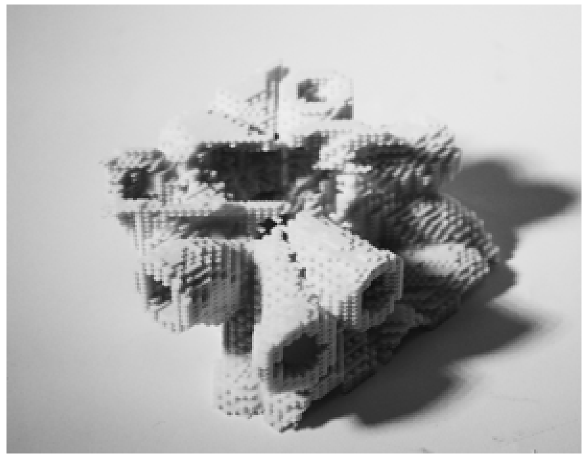
1. INTRODUCTION

1.1 ERIK WIDELL

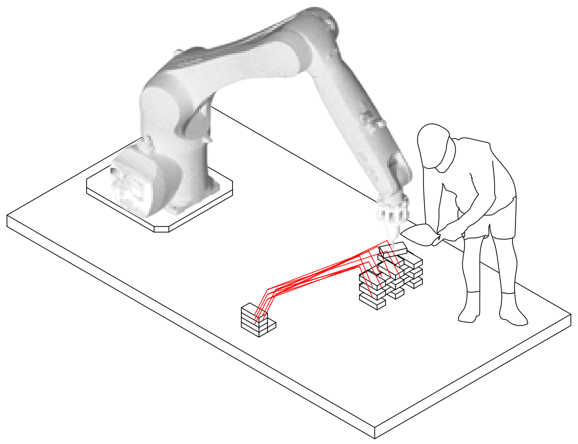
I have a bachelor degree in product design engineering (University of Skövde), and a bachelor in architecture and engineering (University of Chalmers). Apart from this I have studied architecture at EPFL, Lausanne, Switzerland, been employed as a mechanical engineer at Autoliv, and an architectural intern at &Rundquist. I have an interest and knowledge in spatial and material design, structural design, parametric design, design methods and production methods. The master thesis is based on the MSS-prep-project I did at Chalmers during the spring 2017: What do you want brick? To better understand the craftmanship of brick architecture I participated in a one-week practical workshop in Mariestad the summer 2017.



Investigation from prep course

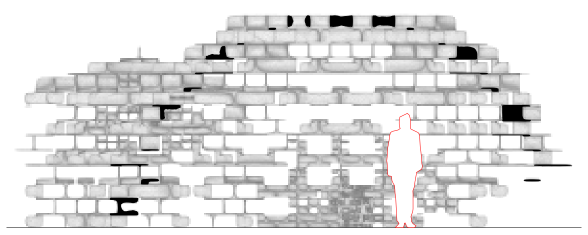


Investigation from prep course



Investigation from prep course

Investigation from prep course



Investigation from prep course

Investigation from masonry workshop

1.2 PURPOSE

The purpose is to investigate how craftmanship may be achieved in digital brick architecture through experimentation and iteration in both digital and physical environments. The purpose is also to challenge the prevailing idea of craftmanship since the traditional view, related to skilled manual labor, might be less useful in a digital context. The focus for the investigation is on spatial sequences and morphologic digital bricks. To be able to make unpredictable findings the approach is to break free from preconceived perceptions of where any independent investigation may lead.

1.3 BACKGROUND

Production- and cost-optimization in the building industry, has during the 20th century led to less craftmanship, and more homogeneity as an effect of less attention to detailing and materiality. This was embraced by the modernistic pioneers. Loos has stated that ornamentation was a crime against economy (Balik & Allmer, 2017). Today however, there is not necessarily a contradiction between ornamentation and economy. As Carpo (2014) claims, it is today potentially possible to manufacture customized objects to no additional cost with the aid of digital technology.

Indeed, the use of computer aided design and manufacturing technology has had a bearing on the reappearance of ornamentation (Balik & Allmer, 2017). But apart from that, craftmanship, that includes but is not limited to ornamentation, is still absent in much of contemporary architecture. Sennett (2009) notes that western civilization has a deep-rooted trouble in recognizing and encouraging craftmanship.

Kaminsky (2017) has written about the issue in a Swedish context. Despite the possibilities today, he sees a rising trend towards less craftmanship. He blames the issue mainly on large building companies and housing shortage, two factors that inevitably leads to less craftmanship in its traditional sense.

A sober investigation of craftmanship is important today as an anti-pole to populistic movements, such as arkitekturupproret.se. The stakeholders for the study is architects in general who wish to remain or improve their positions. Arkitekturupproret have recognized that there’s a lack of architectural qualities, but they have so far been unable to come with a rational solution. Eventhough it is welcoming that there is an awareness of architecture in the public debate, these discussions shall preferably be driven by the group with knowledge in the field: the architects themselves.

In terms of digital modeling Carpo (2014) identifies the use of discrete elements as an alternative to splines to achieve a greater variation in design.

Craftmanship

Sennett (2009) defines craftmanship as follows: "Craftsmanship names an enduring, basic human impulse, the desire to do a job well for its own sake. Craftmanship cuts a far wider swath than skilled manual labor; it serves the computer programmer, the doctor and the artist..." This of course also suggests that not only the bricklayer practice craftmanship, but also the architect who makes the drawings, when using the three basic abilities of craftmanship as stated by Sennett (2009): localize, question and open.

Sennett’s definition is useful in the sense that it expands the traditional view on craft from the execution, finalizing a given proposal, towards a more including definition where everyone can talk about their work in terms of craftmanship. However, in the discourse of architecture a more precise description is required. A suggestion for such a definition is that "craftmanship is found in the intersection between quality of the whole, quality of the parts, and quality of the method". Apart from introducing quality as a part of the definition, it is also suggested that there is an important mutual relationship between the part, the whole and the method.

method

Stein (2011) has proposed that it today is relevant to talk about craftmanship as an open-ended negotiation with material and process, that is, an ongoing experimentation rather than an execution of previously mastered techniques. This also relates to Sennett’s (2009) statement that routines are not static to good craftsmen; they evolve and the craftsmen improve.

Oxman (2007) describes digital craft as a design method which promotes the creation of novel structural systems through processes of digital fabrication and assembly. In relation to this, Sennett (2009) identifies a danger when architects use CAD-programs, since scale, texture and materiality might be less considered. A way to overcome this issue could then be to approach the project by building physical models already at an early stage.

Concerning the execution, in this case the construction work, Sennett (2009) states that "sound judgement about machinery is required in any good craft practice" In the context of his writing, this may be interpreted as: rather than fighting the machines, one shall use the technique that is most suitable to achieve a certain quality.

Parts

Architectural ornamentation today does not have much in common with the prevailing concept before modernism, where sculpture and symbolism played a significant role. Today it is as Picon (2010) notes "conceived as an integral part of a pervasive condition that brings it closer to a pattern than to a sculptural decoration" That is, the parts are important, not only as autonomous elements, but also in conveying an ornamented expression. In this thesis different notions are used for the parts:

voxel = non-material 3-dimensional pixel,
brick = physical building block, primarily made from clay,
discrete element = digital or physical subdivision of the whole,
digital brick = digital representation of brick.

Whole

Retsin (2016b) has aimed for finding a conversation between the parts and the whole. That is, instead of subdividing the whole into parts, the parts form the whole. This creates a strong relationship between the global shape and the discrete elements as well as a potential to form spatial sequences in new innovative ways.

1.5 AIM

The aim is to make a design proposal that manifests theory of craftmanship in digital brick architecture. This means letting craftmanship pervade everything from design process to design proposal to ideas about feasible design and production methods. The focus is on spatial arrangement of morphologic digital bricks. The project will be presented through diagrams, drawings and models. Apart from this, the objective is also to provide an integrated design process that deals with craftmanship on all scales and to bring up issues within the discourse for discussion. Through the design process and the design proposal the goal is also to answer the thesis question: how may craftmanship be achieved in digital brick architecture?

1.6 DELIMITATIONS

The focus of the thesis is not on structural behavior. Neither is the focus on creating a functional plan, creating a vibrant social life, nor adapting a new building in an already built environment. The focus is digital craftmanship, spatial configurations, design methods and to some extent alternative production methods.

A brief proposal of the entire production chain is presented, and different production methods for each step is considered. However, some steps and methods are treated just as proposals, and not further investigated. The steps and methods that are considered more thoroughly are those that are considered as most important for the chosen design proposal. It may be that some proposed methods appear as visionary or even unrealistic today. In that case it is considered as a possibility to replace one method with another without affecting the overall design. The intention with this approach is to push the limits and to be able to extract, if not all, at least some realistic ideas that could be implemented already today, and some that may be used in the future.

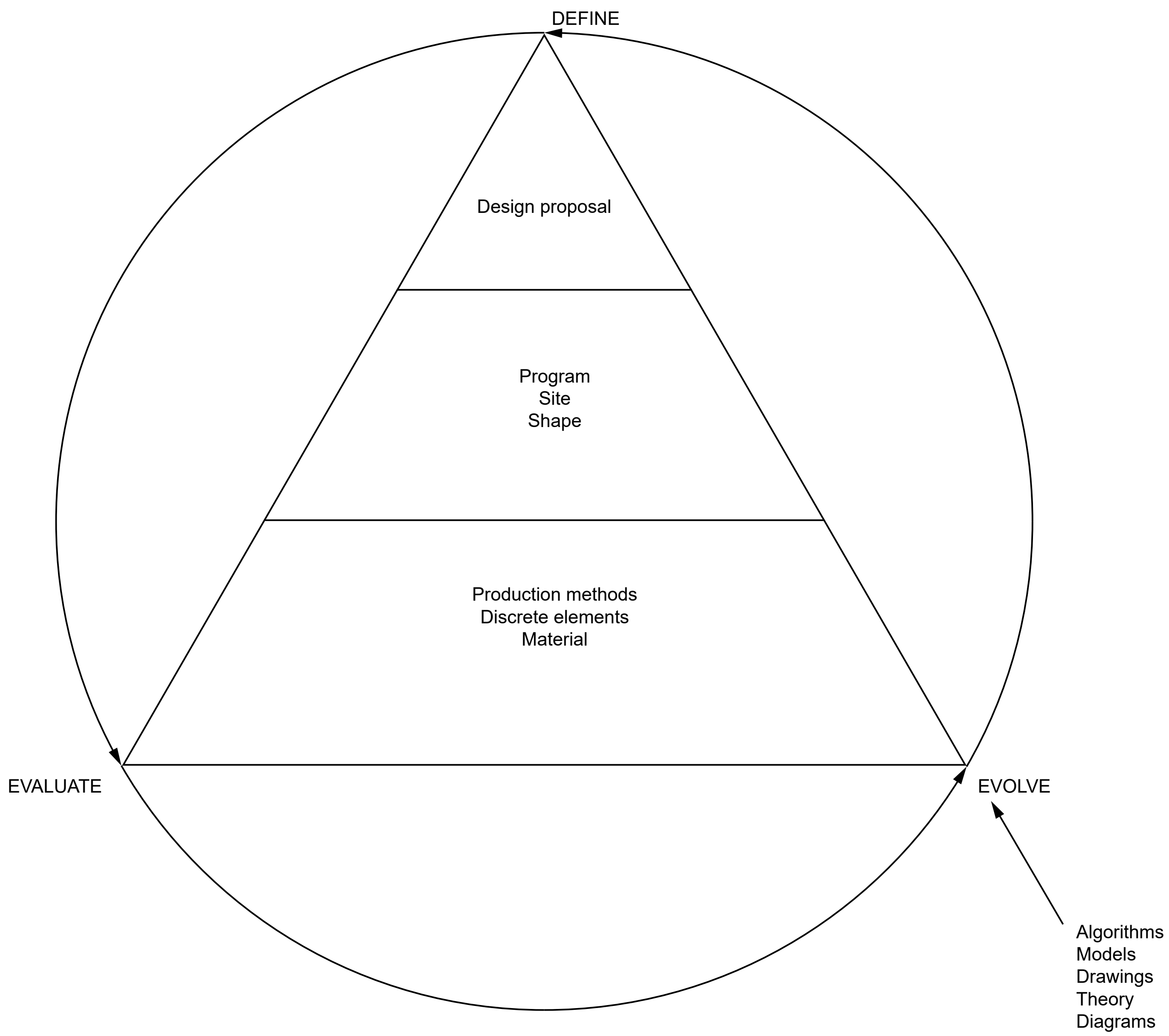
1.7 METHOD

The project may be categorized as research by design, which means that research and design is carried out simultaneously. Literature studies and design experiments are constantly feeding the process.

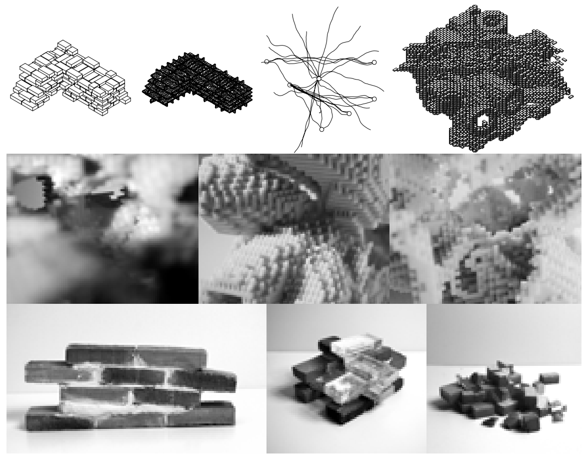
The methodology includes three fundamental steps: define, evaluate and evolve. Sennett (2009) has labeled these steps as localize, question and open, and argues that these three basic abilities are the foundation of craftmanship. By iterating the steps, the project is gradually developed from independent investigations of production methods, discrete elements and materials towards more contextualized investigations that includes site, program and global shape. The final design proposal summarizes the previous investigations.

A fundamental part of the project is the development of an algorithm that is used to generate multiple alternatives. The algorithm is scripted with grasshopper and c#. To manage complexity and data quantity, various voxel resolution is used for various levels of detailing.

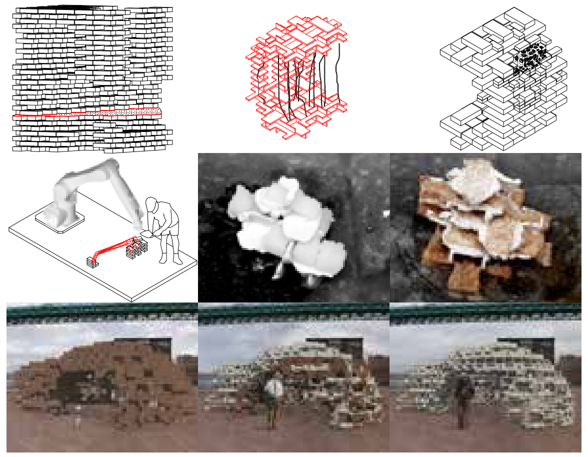
Other digital tools that are used is Rhino, Qgis, Autocad, Vray, Photoshop, Illustrator and Indesign. Apart from this, traditional techniques such as hand sketching, hand models, drawings and diagrams are used to feed the process and to visualize ideas.



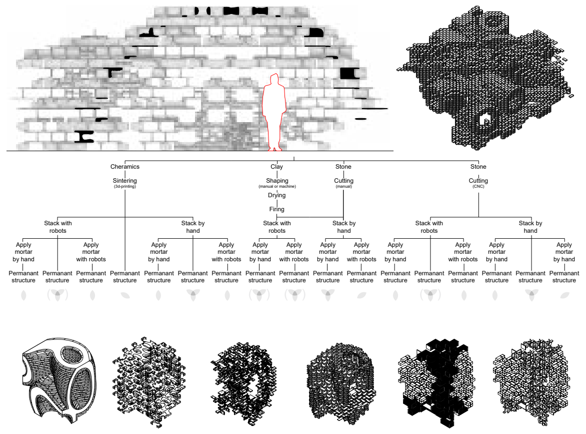
1.8 PROCESS



Deconstruct / Reconstruct*
1. Define. Deconstruct bricks and mortar and define an algorithm for reconstruction.
2. Evaluate. Analyze structure and spatial qualities.
3. Evolve. Build models based on evaluation.

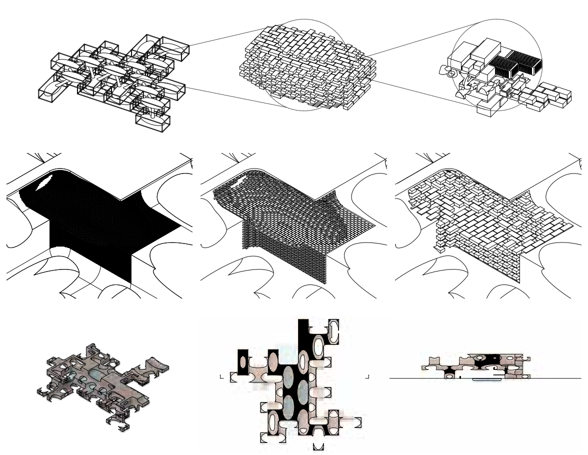


Construction / Erosion*
1. Define. Define new algorithm based on models.
2. Evaluate. Investigate production methods that may relate to algorithm.
3. Evolve. Redesign structure with aid of new knowledge and updated algorithm.



Grammar
1. Define. Define two structure experiments from previous process.
2. Evaluate. Investigate multiple production methods that may result in the structures.
3. Evolve. Redesign the structures with different characteristics depending on the production method.

Construction experiment
1. Define. Define two of the new structures, one that appears most rational to build, and one that appears to be the most artisanal.
2. Evaluate. Rethink the thought out production step.
3. Evolve. Execute the steps to build the structures.



Scale and resolution
1. Define. Define scales for various resolution and detailing.
2. Evaluate. Evaluate the appropriate resolution and detailing for different scales.
3. Evolve. Propose a building design.

Siteless Design
1. Define. Define a program that suits the develop typology: Bath-house. Flowing water matches the flowing spatial sequences.
2. Evaluate. Suggest an appropriate scale for the building by investigating precedents.
3. Evolve. Re-propose a building design.

Grafting on site
1. Define. Define a site that needs / lacks the program and the spatial qualities.
2. Evaluate. Evaluate how the design proposal suits the site.
3. Evolve. Evolve the design until it is adapted to the site and the program. Loop step 2 and 3 until satisfaction.

Design proposal
Make drawings that summarizes the project and reconsider production methods.

*) Described more thoroughlya in "What do you want brick" - Widell (2017)

1.9 PRECEDENTS - CRAFTMANSHIP AND SPACE

La Miniatura - Frank Lloyd Wright (wikiarquitectura, 2017)

In the 1920s, Frank Lloyd Wright built a series of so called textile-block-houses, which were made of patterned concrete blocks (Moffet. et. al, 2008). The block system was intended to be fast and cheap to build and to not require skilled labor. La Miniatura House for Alice Millard in Pasadena was the first textile block-house, built in 1923.

Baker house - Alvar Aalto (Archdaily, 2010)

The Baker house was designed by Alvar Aalto as a student residence. It was constructed between 1946 and 1949. Blackened and twisted bricks that normally would be ejected were used in each course. As Sennett (2009) notes, these bricks contrast to the regular fresh bricks and brings forward the character of booth.

Winery Gantenbein - Gramazio & Kohler and Bearth & Deplazes Architekten (Gramazio & Kohler, 2012)

A wine producer hired Gramazio & Kohler and Bearth & Deplazes Architekten 2006 to design a new service building. The building consists of a simple concrete skeleton with bricks filling the frames. 72 facade elements were constructed at the robotic research facilities at ETH, transported to the site by lorry and installed on construction site using a crane. (Archdaily, 2012).

Ningbo Museum - Wang Shu (cfileonline, 2017)

The Ningbo museum was designed by Wang Shu in 2008. For the facades he used recycled material from demolished buildings in the region. Some of the bricks date back over a thousand years. The traditional technique wa pan was used, where found material fragments of different sizes are used. Wang Shu has said that only the craftsmen in the region know the techniques, and that he believes that it will be forgotten if it's not used in modern architecture (Clark, 2017).

Bartlet RC4 - ongoing research - Gilles Retsin (2017)

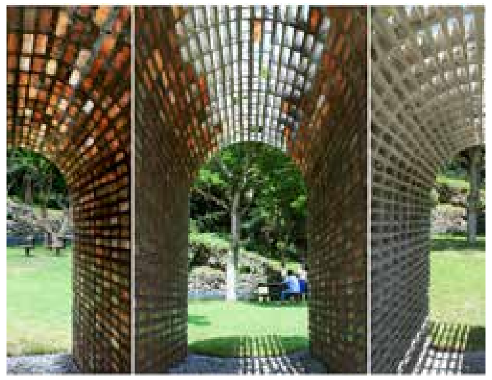
Is this still masonry? This work questions what kind of elements can be used in contemporary masonry. More important however, what Retsin is actually trying to do, is to bridge the gap between discrete digital modeling and analogue robotic modeling. According to Retsin (2016b) Gramzio and Kohler's wall is not truly discrete, since each brick has endless of connection possibilities. Retsin (2016a) states that discrete fabrication has the same type of advantages in terms of problem-solving as discrete computation: problems are serialised and solutions therefore become repeatable and cheap.

Klippan - Sigurd Lewerentz (Sankt Petri Kyrka, 2015)

Equal weight to, and the relation between, discrete elements, continuous mass and absent material reveals structural logic in this chapel in Klippan by Sigurd Lewerentz 1962-1966. In Respect of the bricks, Lewerentz decided that no bricks should be cut. Instead mortar was used to compensate when necessary.

Brickless brickwall (Archdaily, 2016)

A group of South American architects, Benítez, Benítez, Cabral, Rovea and Sargiotti, designed a brickless brick wall in 2014. Unfired bricks were used. Four days after construction, the bricks were pushed out with the aid of pressure washers and any other tools that could break through the bricks (Franco, 2016).



Temporary installation - spmj (Archdaily, 2017)

The structure, in its initial state consists of salt-bricks and mortar. The semi-transparent bricks allow light to penetrate the structure. Rain and humidity slowly dissolved the salt-bricks and at the end of the 3-month exhibition only a mortar skeleton remained. The location for the project was in Korea, and it was designed by spmj Abourezk (2017).

The Souk Mirage - Sou Fujimoto (Archdaily, 2013)

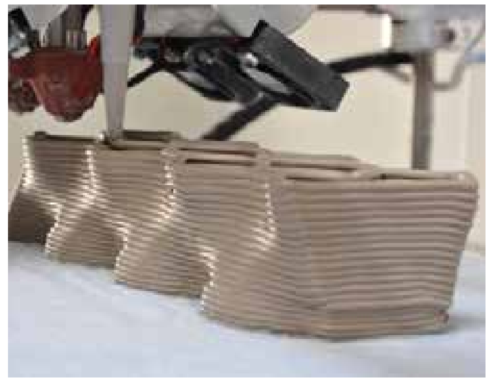
Sou Fujimoto proposed this masterplan 2013 for a commercial complex in the Middle East. He has described the concept as: “By combining the transparency of the arches with the stepping waterfalls, a dynamic play with light and shadow is created, while appearing mirage-like” (Rosenfield, 2013).

Oblique circulation 3 - Benjamin Dillenburger (A as architecture, 2014)

Intricate and systematically arranged flowing spatial sequences, creates a contrast to articulated and jagged discrete elements in this design: Oblique circulation 3 by Benjamin Dillenburger.

Droneport Prototype - Venice Bienale 2016 - Philippe Block (Designboom, 2016)

Block research group is led by Prof. Dr. Philippe Block and Dr. Tom Van Mele at ETH. They focus on analysis and form finding of masonry structures using graphic methods. The goal is to understand complex structural systems and to develop algorithms for structural efficient designs (Block, 2017).



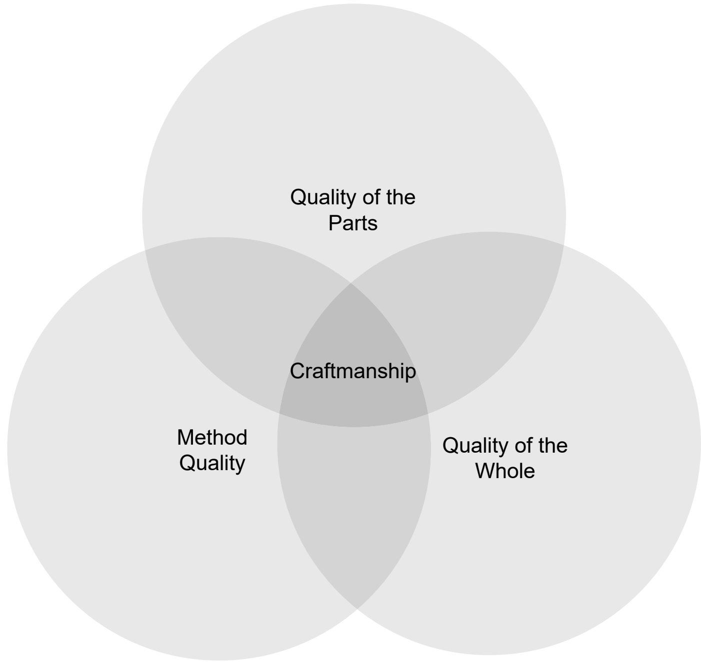
3d-printed brick - Brian Peters (Dezeen, 2012)

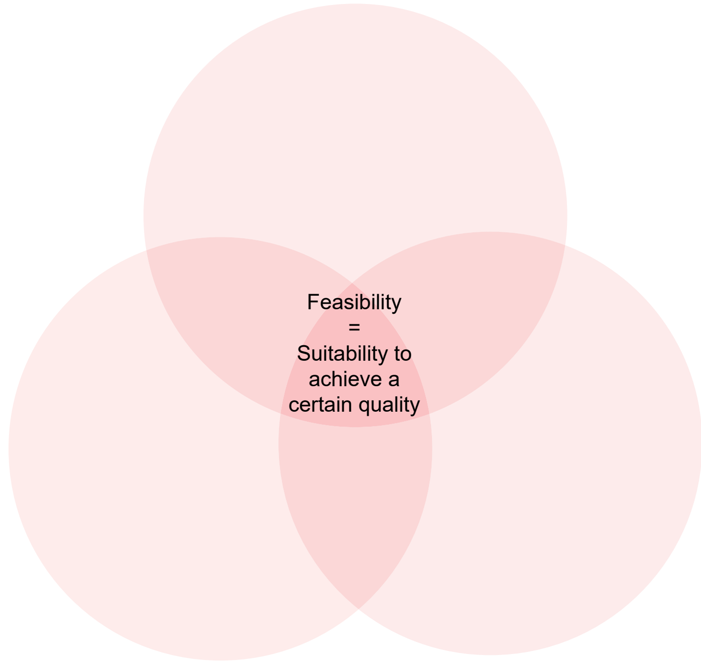
Architect Brian Peters has developed a 3d-printer that produce ceramic bricks. It has the capacity to print clay, concrete or any mixture of building material. He suggests that several machines shall be used on the building site. (Etherington, 2012).

2 GRAMMAR

2 GRAMMAR

Just like classic architecture has its grammar in form of the classical order, and traditional masonry has its grammar in form of different bound systems, a set of grammar was developed within the bounds of this project. The intention is to provide the architect with a wide range of design opportunities that reflects any chosen production method.



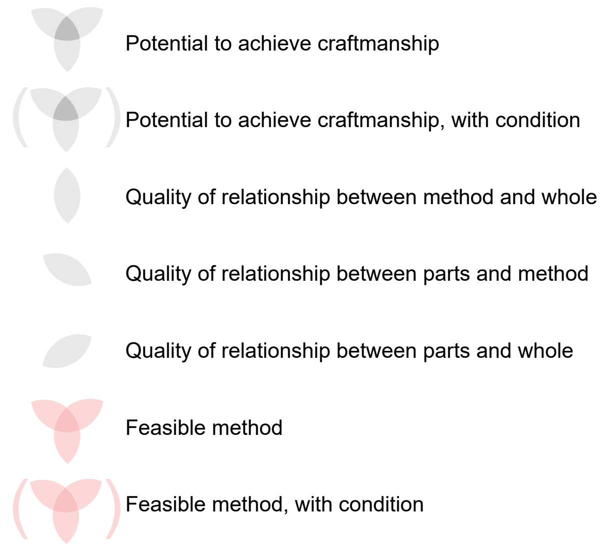


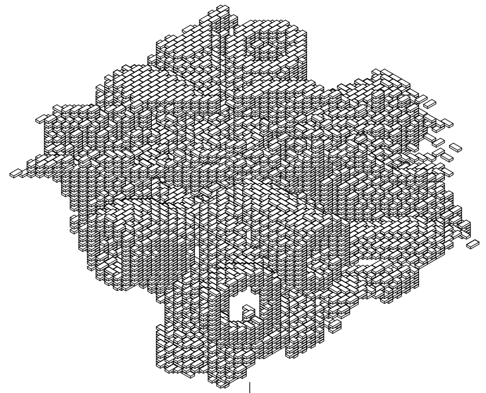
These notions of craftmanship and feasibility has been used to rank production methods in the following diagrams with the underlying purpose to bring forward a set of grammar.

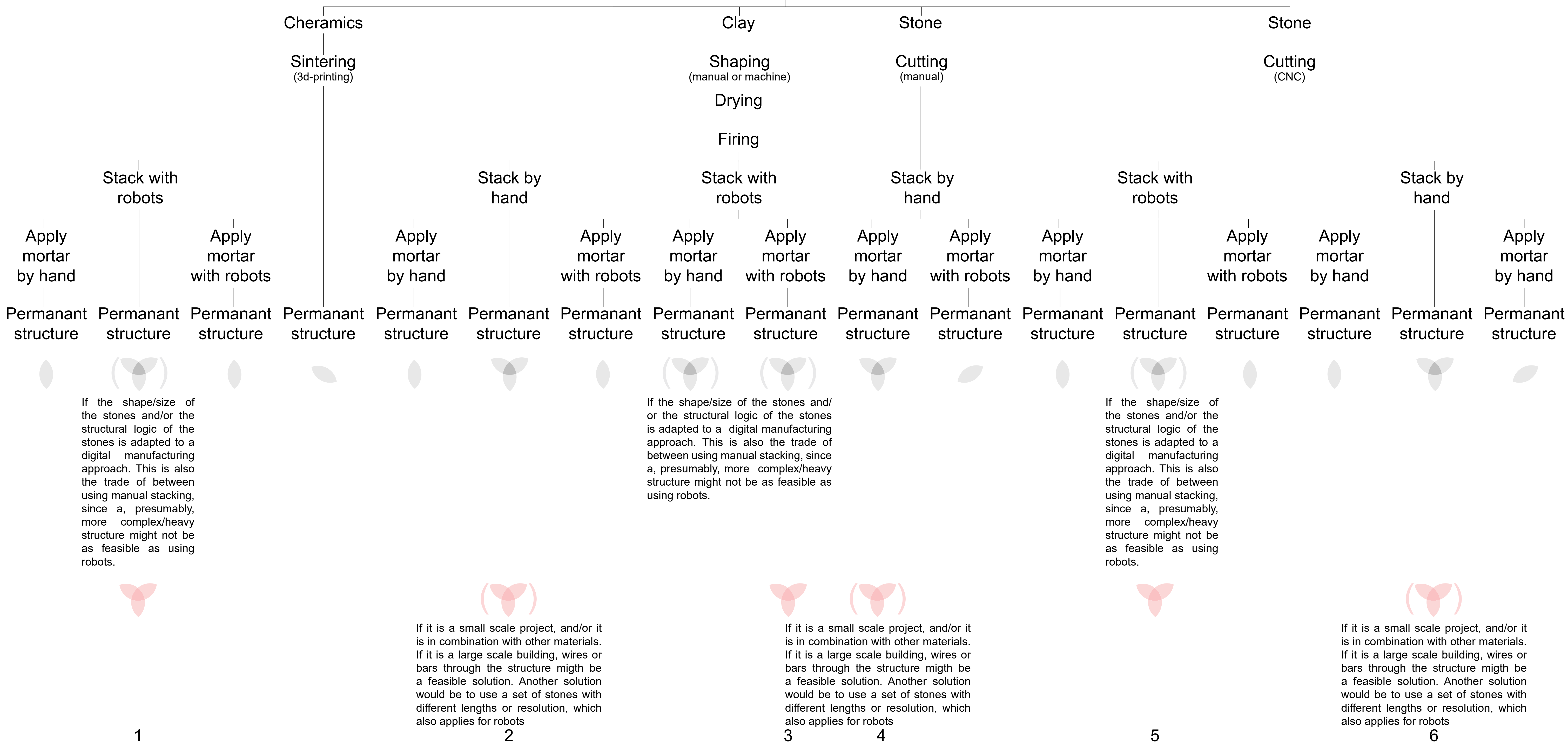
2.1 MEANS TO ACHIEVE CRAFT QUALITIES

- BASIC STRUCTURE

This diagram defines different process cycles, and predicts the potential of craftmanship for each and every process, and if the proposed methods are feasible. The diagram is partly speculative, partly based on experiments, and partly based on research. The purpose is to generate a catalogue of design modifications to a brick structure related to a specific series of production methods. The investigation departures in a shape that was generated with the aid of agents, scripted in grasshopper and quelea.



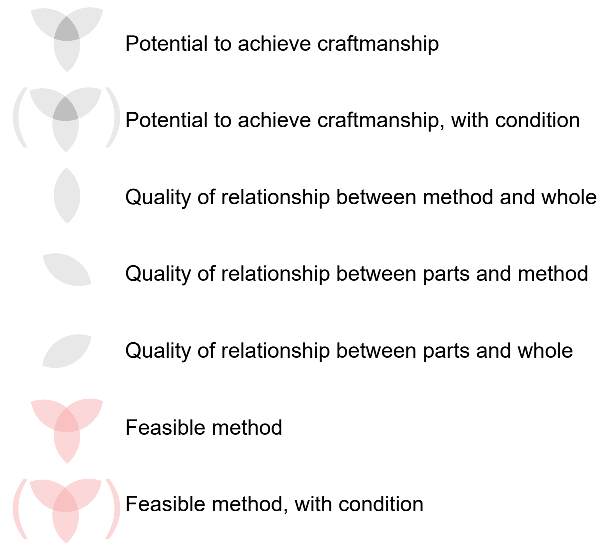


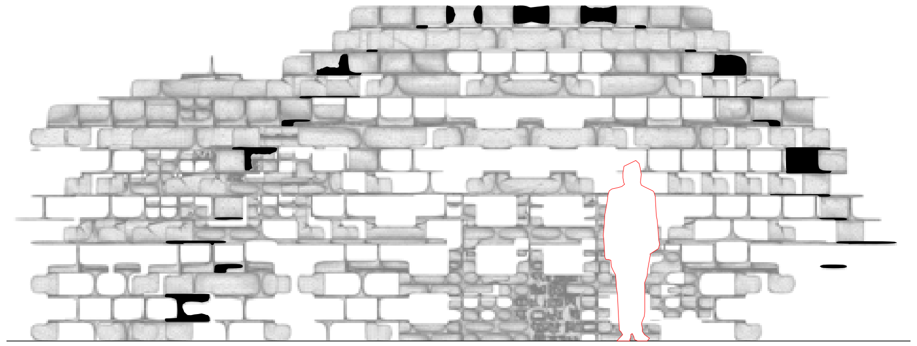


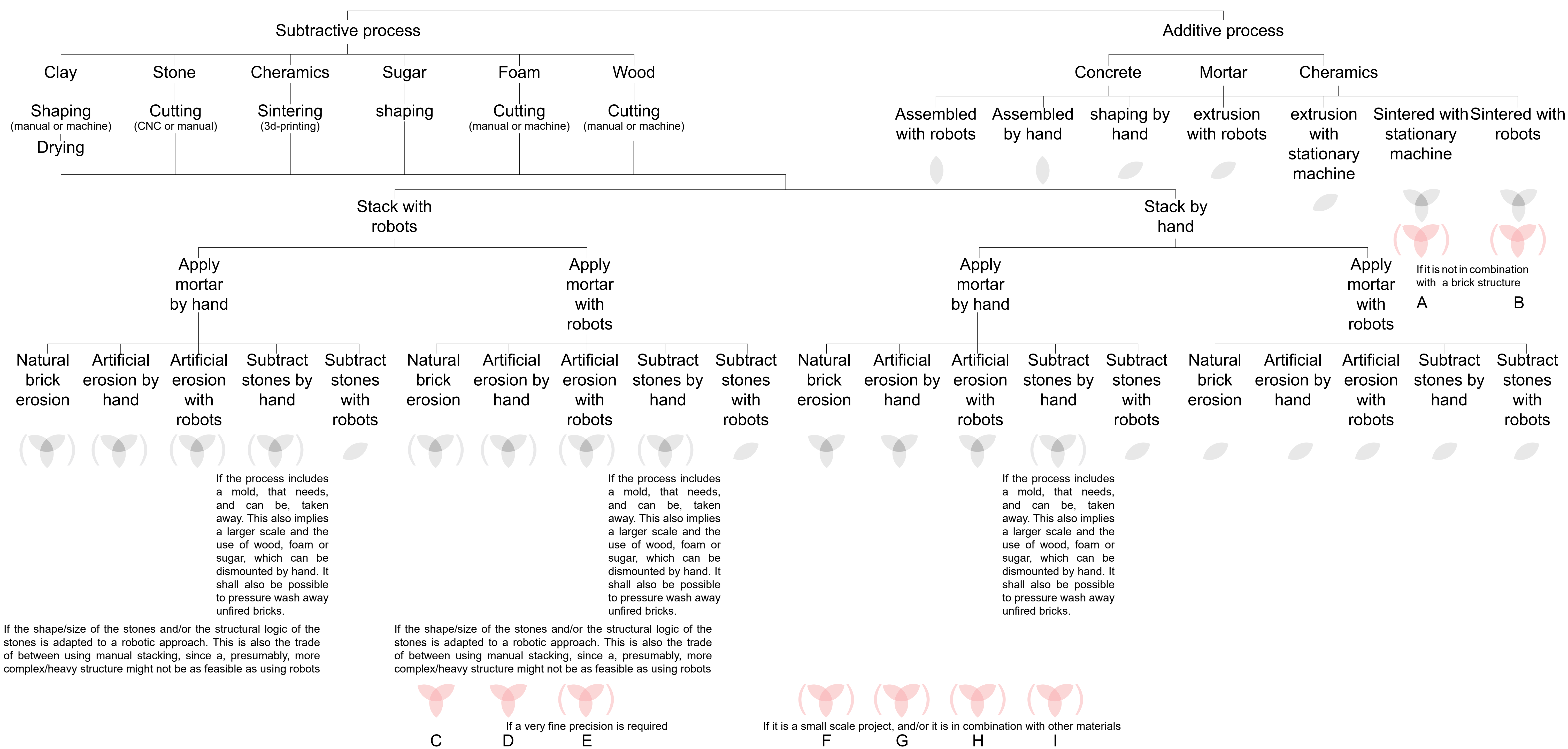
2.1 MEANS TO ACHIEVE CRAFT QUALITIES

- ELABORATED STRUCTURE

This diagram defines different process cycles, and predicts the potential of craftmanship for each and every process, and if the proposed methods are feasible. The diagram is partly speculative, partly based on experiments, and partly based on research. The purpose is to generate a catalogue of design modifications to a mortar structure related to a specific series of production methods. The investigation departures in a shape that was generated with the aid of boolean operations in rhino and scripting in grasshopper.



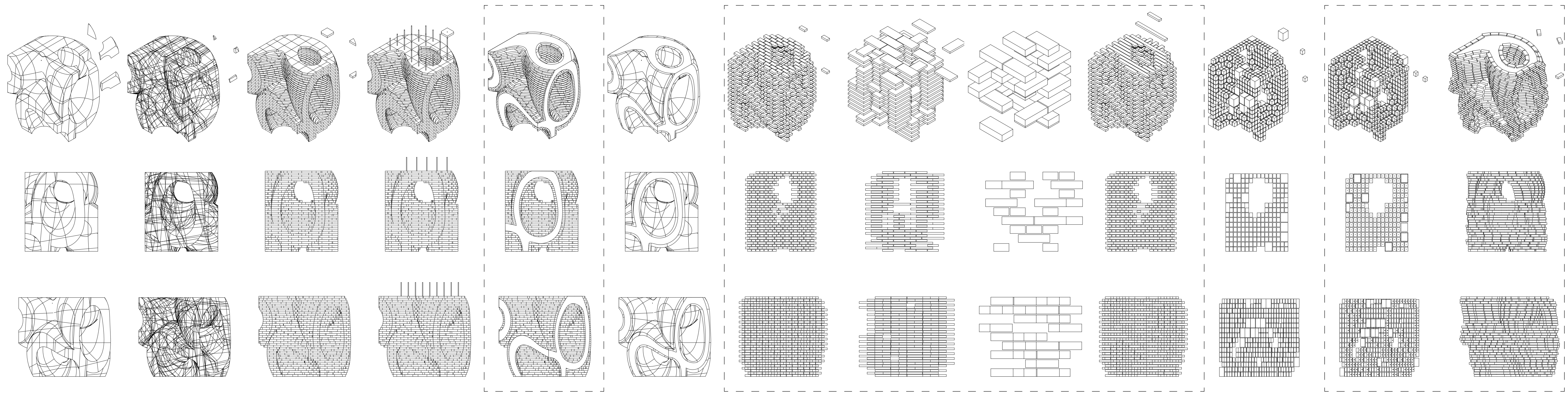




2.2 CRAFT QUALITIES ACHIEVED BY DIFFERENT MEANS

- BASIC STRUCTURE

These diagrams show the potential outcome from different production methods. The numbers indicate the corresponding production cycle as indicated in previous diagrams in chapter 2.1.

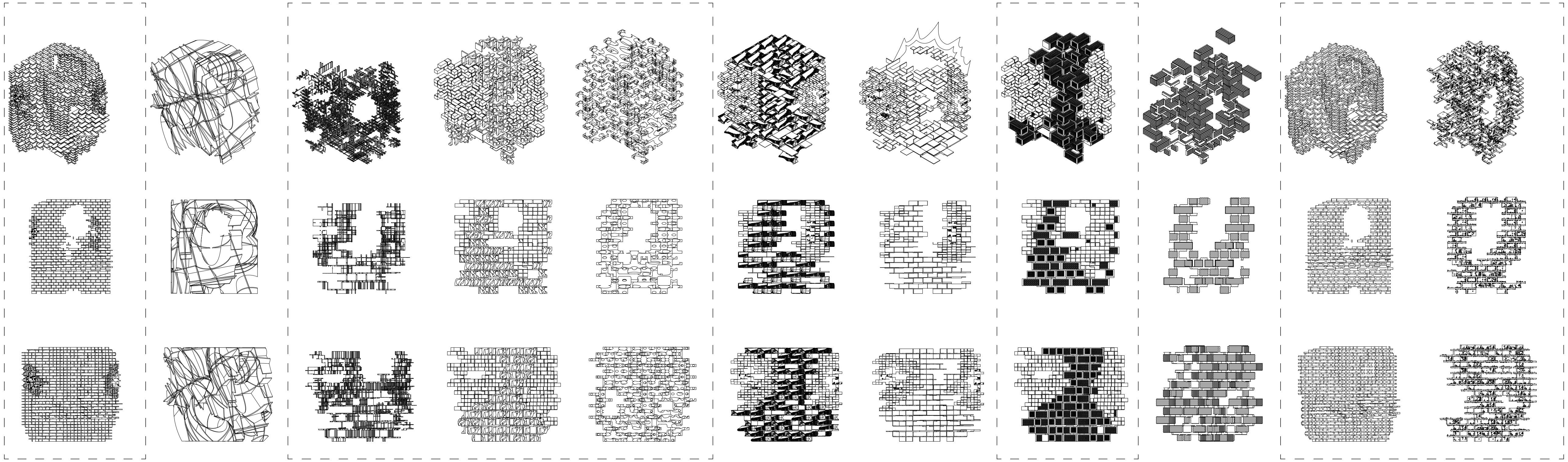


1/5	1/5	1/2/5/6	2/6	2/6	2/6	3	3/4	3	3/4	3/4	4	4
MATERIAL cheramics, (stone)	MATERIAL cheramics, (stone)	MATERIAL cheramics, (stone)	MATERIAL cheramics, (stone)	MATERIAL cheramics, (stone), + concrete structure	MATERIAL cheramics, (stone), + concrete structure	MATERIAL clay	MATERIAL clay	MATERIAL clay	MATERIAL clay, (wood)	MATERIAL clay	MATERIAL clay	MATERIAL clay + concrete structure
PREPARATION sintering, (cnc-cutting)	PREPARATION sintering, (cnc-cutting)	PREPARATION sintering, (cnc-cutting)	PREPARATION sintering, (cnc-cutting)	PREPARATION sintering	PREPARATION sintering	PREPARATION shaping + drying + firing	PREPARATION shaping + drying + firing	PREPARATION shaping + drying + firing	PREPARATION shaping + drying + firing (cutting)	PREPARATION shaping + drying + firing	PREPARATION shaping + drying + firing	PREPARATION shaping + drying + firing
CONSTRUCTION stack with robots	CONSTRUCTION stack with robots	CONSTRUCTION stack with robots or hand	CONSTRUCTION stack by hand	CONSTRUCTION stack by hand	CONSTRUCTION stack by hand	CONSTRUCTION stack with robots + apply mortar with robots	CONSTRUCTION stack with robots (by hand) + apply mortar with robots (by hand)	CONSTRUCTION stack with robots + apply mortar with robots	CONSTRUCTION stack with robots (by hand) + apply mortar with robots (by hand)	CONSTRUCTION stack with robots (by hand) + apply mortar with robots (by hand)	CONSTRUCTION stack by hand + apply mortar by hand + using bars and/or wires	CONSTRUCTION stack by hand + apply mortar by hand
DISMISSED: no mortar	DISMISSED: no mortar	DISMISSED: no mortar	DISMISSED: no mortar	ALTERNATIVE shape clay bricks into curved stones	DISMISSED: no mortar					DISMISSED: not rational: big stones lead to many small stones		

2.2 CRAFT QUALITIES ACHIEVED BY DIFFERENT MEANS

- ELABORATED STRUCTURE

These diagrams show the potential outcome from different production methods. The letters indicate the corresponding production cycle as indicated in previous diagrams in chapter 2.1.



A/B

MATERIAL
cheramics

PREPARATION
-

CONSTRUCTION
sintered with stationary machine or robot

A/B

MATERIAL
cheramics

PREPARATION
-

CONSTRUCTION
sintered with stationary machine or robot

DISMISSED:
unrelated to brick / mortar logic

A/B

MATERIAL
cheramics

PREPARATION
-

CONSTRUCTION
sintered with stationary machine or robot

A/B/D/E/G/H

MATERIAL
cheramics, (foam), ((clay)), (((clay)))

PREPARATION
-, (cutting), ((partly fired, partly unfired bricks)), (((unfired bricks with voids)))

CONSTRUCTION
sintered with stationary machine or robot, (stack and apply mortar with robots + artificial erosion with corrosive solution), ((unfired brick parts washed away)), (((wash away unfired bricks)))

A/B/D/E/G/H

MATERIAL
cheramics, (clay or sugar)

PREPARATION
-, (shaping, drying)
CONSTRUCTION
sintered with stationary machine or robot, (bricks washed away))

C/F

MATERIAL
clay

PREPARATION
shaping, drying
CONSTRUCTION
stack and apply mortar with robots or by hand + natural erosion

DISMISSED:
requires strong mortar and weak stones: not an ideal structure

D/G

MATERIAL
wood

PREPARATION
cutting

CONSTRUCTION
stack and apply with robots or by hand + burn wood

DISMISSED:
too much material waste

D/E/G/H

MATERIAL
clay

PREPARATION
shaping, drying

CONSTRUCTION
stack and apply mortar with robots or by hand + artificial erosion

ALTERNATIVE
let brick erode before construction, or shape bricks with a relief pattern

I

MATERIAL
wood boxes

PREPARATION
-

CONSTRUCTION
stack and apply mortar by hand + subtract wood by hand

DISMISSED:
appears unnecessarily complicated

I

MATERIAL
clay

PREPARATION
shape + dry

CONSTRUCTION
stack and apply mortar with robots or by hand + wash away bricks

I

MATERIAL
Foam

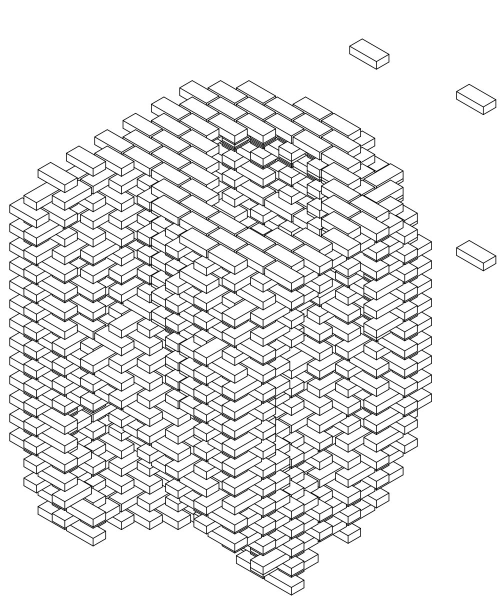
PREPARATION
cut

CONSTRUCTION
stack and apply mortar with robots or by hand + rip away bricks

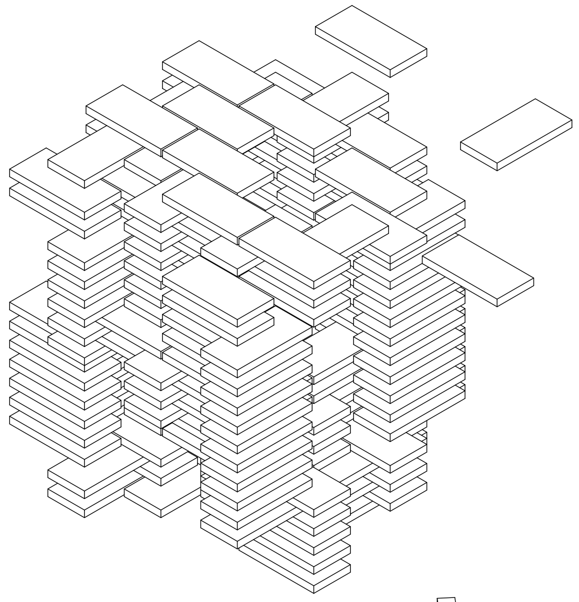
2.3 HIGHLIGHTED QUALITIES - BASIC STRUCTURE

These diagrams highlight a selection of qualities from previous diagrams (chapter 2.2). They are grouped depending on similarity and reflected upon as a guide for design application.

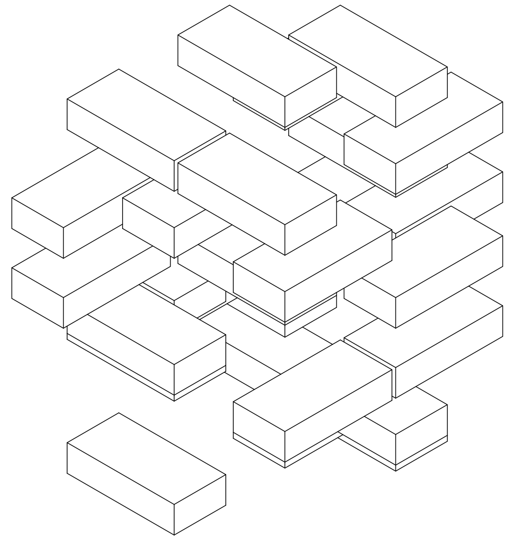
DIFFERENT RESOLUTION



small

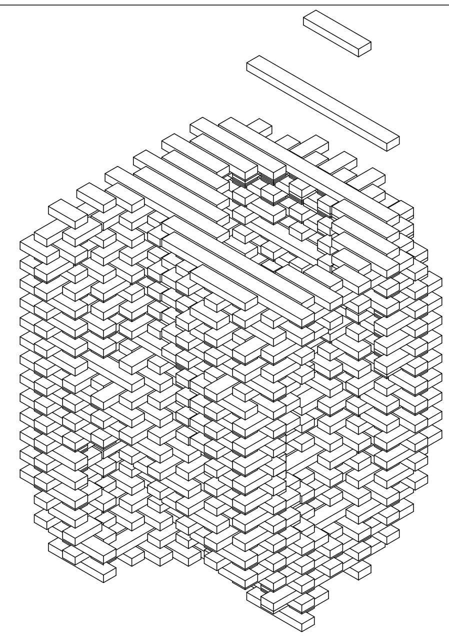


flat

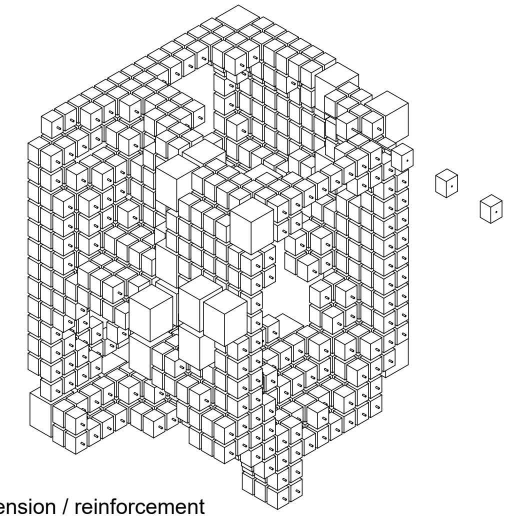


big

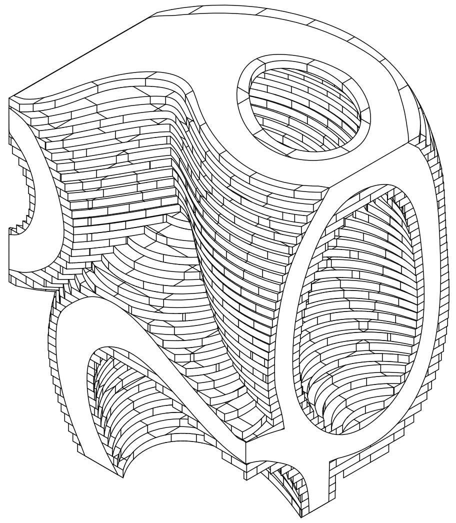
RATIONAL AND STRUCTURAL SOLUTIONS



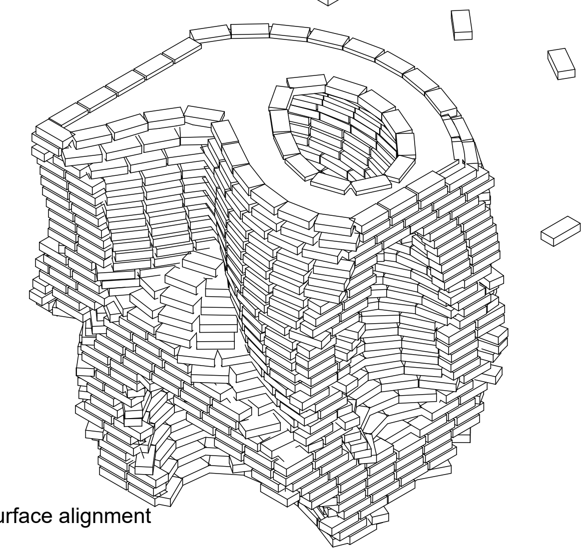
long



pre-tension / reinforcement



Curved



surface alignment

SMOOTH STRUCTURE

RESOLUTION

Artisanal qualities
The artisanal qualities depend on the execution.

Feasible aspects
There's a tradeoff between using many small light weight elements in a complex array and using few big heavy elements in a not so complex array.

Spatial features
At a certain resolution the shape and space disappears. The balance between the elements and the whole is important.

Combinations
A combination of different resolutions may be used to achieve a certain expression or to emphasize certain things.

RATIONAL AND STRUCTURAL

Artisanal qualities
Artisanal qualities may be achieved through honest exposure of feasible and structural features.

Feasible aspects
long bricks, up to a certain length, may facilitate the building process and make up functional lintels.

Spatial features
It's a fair judgement that feasible and structural efficient solutions won't affect the space in a negative way.

Combinations
Feasible brick shapes and pre-tensioned / reinforced is applicable on any design.

SMOOTH VS. JAGGED

Artisanal qualities
The artisanal qualities depend on the execution.

Feasible aspects
A variety of curved stones may be difficult to produce and stack using traditional methods. However, booth the surface aligned and curved bricks are presumably easier to combine with other materials in e.g. a wall, compared to a pixelated structure.

Spatial features
Smooth surfaces may be more functional in some cases; where people move, sit, play etc.

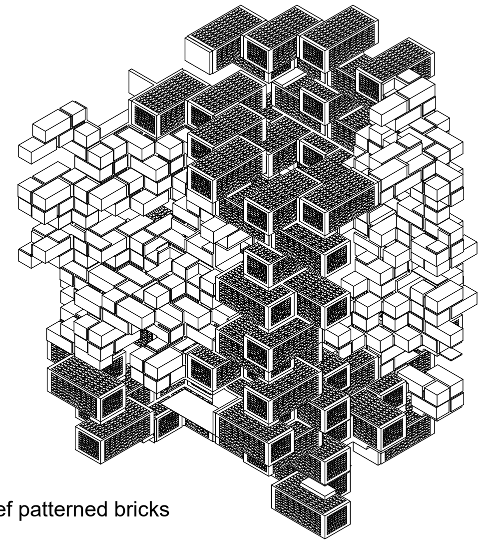
Combinations
functional spaces such as walking paths may be emphasized by using smooth surfaces.

2.3 HIGHLIGHTED QUALITIES - ELABORATED STRUCTURE

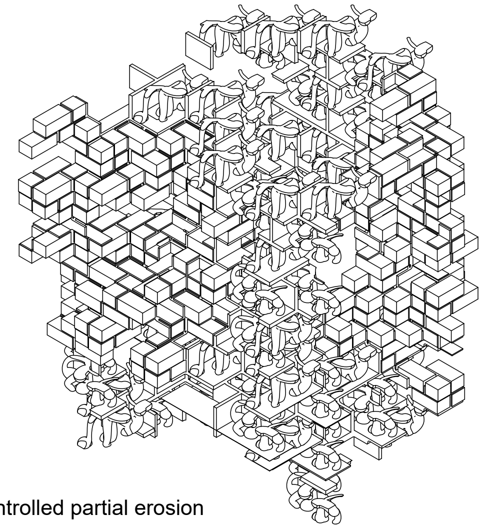
These diagrams highlight a selection of qualities from previous diagrams (chapter 2.2). They are grouped depending on similarity and reflected upon as a guide for design application.

CRAFTED BRICKS

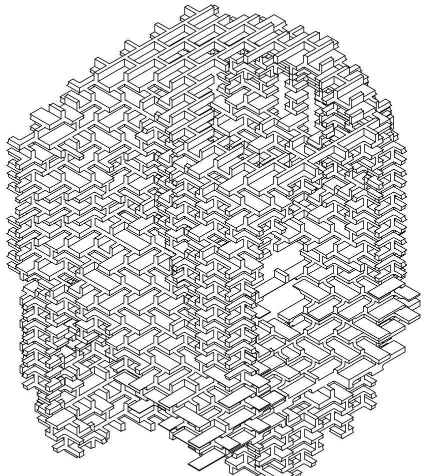
ARTICULATED MORTAR



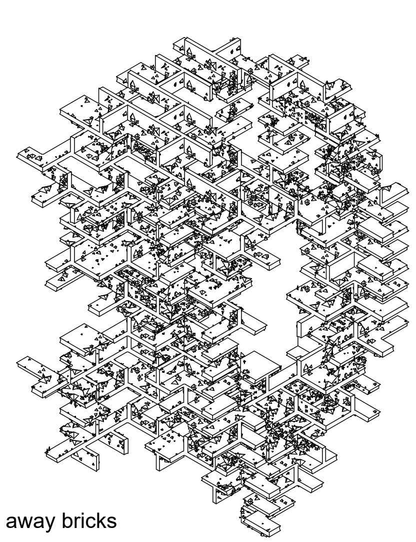
relief patterned bricks



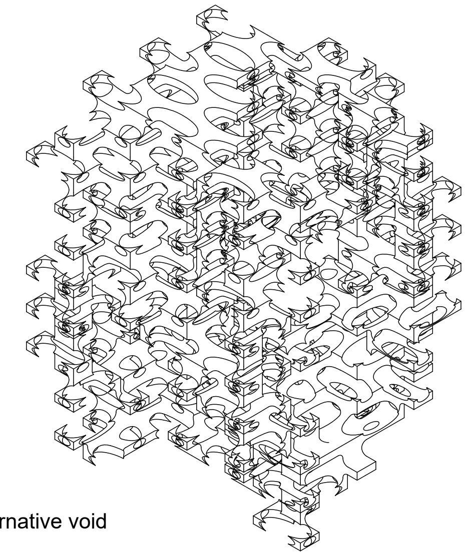
controlled partial erosion



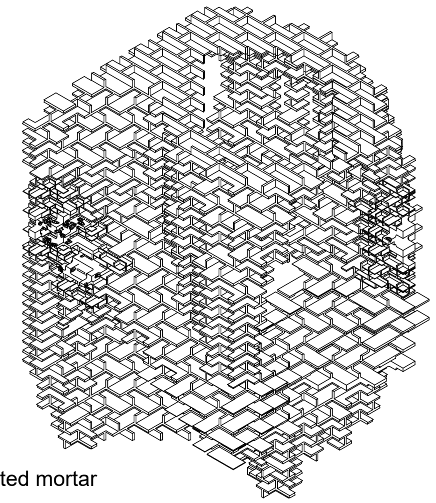
washed away bricks



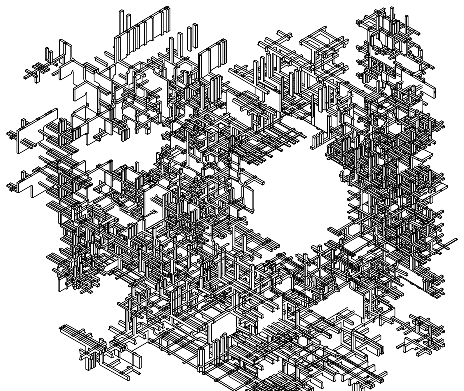
ripped away bricks



alternative void



3d-printed mortar



3d-printed disolved mortar

HIGH LEVEL OF DETAILING

CRAFTED BRICKS

Artisanal qualities
The use of custom made bricks is per definition artisanal.

Feasible aspects
A fair judgement is that it is less feasible to produce crafted bricks using traditional methods.

Spatial features
In an already complex space it may be too messy.

Combinations
Patterned bricks may be used all through the structure or in combination with other bricks.

ARTICULATED MORTAR

Artisanal qualities
The artisanal qualities depend on the execution.

Feasible aspects
Another moment is added to the production chain, which can be considered as less feasible. This is however compensated by also reducing one moment: the brick firing.

Spatial features
This method gives a light expression to the structure that will inherit complex sequences of cavity spaces

Combinations
bricks to be eliminated may be used all through the structure or in combination with other bricks.

HIGH LEVEL OF DETAILING

Artisanal qualities
If the structure is specifically adapted to a 3d-printing approach, it may be considered as artisanal.

Feasible aspects
The method require space on the building site for a large scale 3d-printer or a robot.

Spatial features
This method gives a light expression to the structure that will inherit complex sequences of cavity spaces

Combinations
It might be difficult to combine with other methods if a smooth transition is desired between parts produced with different means.

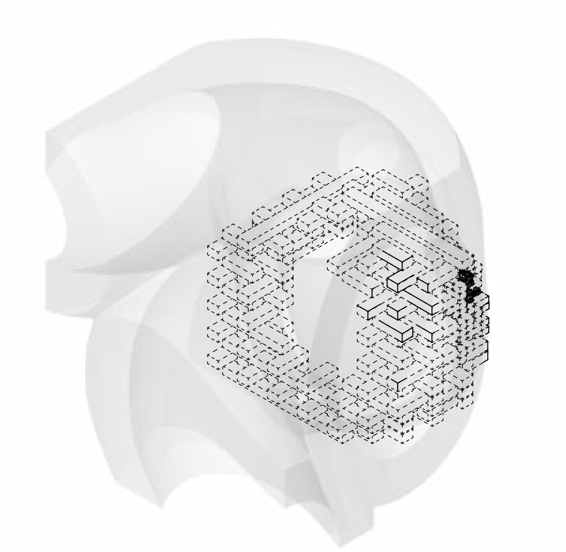
3 CONSTRUCTION EXPERIMENTS

3 CONSTRUCTION EXPERIMENTS

In a digital design context, it is as Sennett (2009) has noted a danger that the sense of materiality, scale, texture etc. might get lost. These experiments were carried out to stay in touch with the material world, to test the suggested production methods for two chosen models and to be able to evaluate the process with the aid of physical models.

3.1 ASSEMBLY

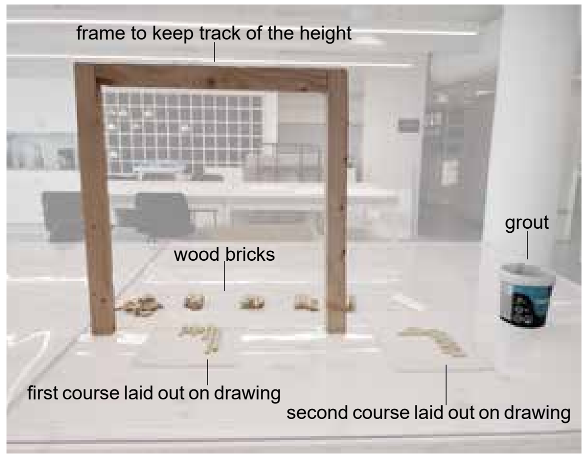
These images show the steps for building the model with long bricks (chapter 2.3)



scale 1:10
dimensions ~ 100*180*165mm
cross section main brick: 7*10mm
- length 140mm: 2 pcs
- length 112mm: 8 pcs
- length 84 mm: 11 pcs
- length 56 mm: 33 pcs
- length 28 mm: 75 pcs

cross section subdivided bricks: 5* 6.3mm
- length: 12.6mm: 101 pcs
- length: 6.3mm: 60 pcs
- small fragments: 32 pcs

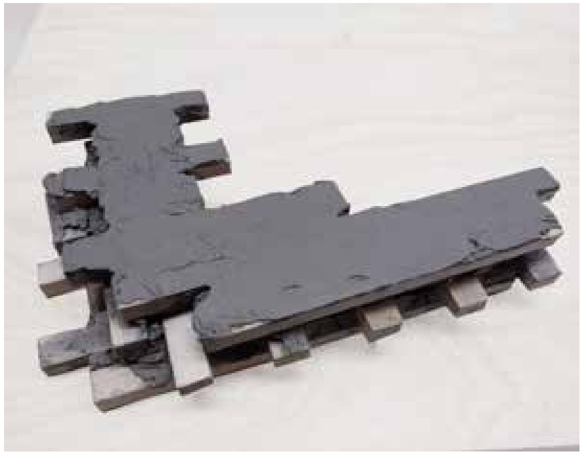
perpend: 4mm
bed joint: 4mm
time cutting wood pieces and building frame ~ 4 hrs
time building structure ~ 20 hrs
cost wood ~ 22 SEK
cost mortar (grout ~2.5kg incl. waste) ~ 78 SEK



1. Construction setup

2. Depending on the situation, mortar was applied either on the brick or on the course below.

3. Cracks appeared after drying



4. Cracks were filled, and a layer of mortar was applied on top of each course for better cohesion

5. When structure started to cantilever it could no longer withstand the tension

5. Critical areas were reinforced with glue.

5. A support was placed below cantilevered parts to resist tension during construction

6. The height of the covering mortar layer was constantly measured to ensure the geometry.

3.1 ASSEMBLY

construction experiment

construction experiment

Artisanal qualities
areas of smaller bricks create smooth fields that contrasts to the pixelated overall structure.

As an effect of the mortar being squeezed out between the bricks, unexpected shapes appear in the ceiling of the structure, where the mortar is difficult to scratch away.

Feasible aspects
The number of subdivided bricks must be reduced in this scale, because of construction difficulties. This is considered fine from an aesthetic point of view, since even a reduced number of subdivided bricks serves the purpose of making a certain area smoother.

it's difficult to judge whether long bricks make the construction process more efficient.

Long bricks make functional lintels that blends in to the structure if long bricks are used in other positions as well. It's difficult to imagine another solution for the structural logic except for perhaps corbel vaults.

If wanted, it shall be relatively easy to achieve inclined courses with the aid of a frame and a rope. Using traditional methods, it would however be difficult to achieve a course that forms a double curved surface.

Spatial features
flowing space

Cracks
Cracks appear when wood bricks are being used.

It gets messy when trying to repair cracks afterwards.

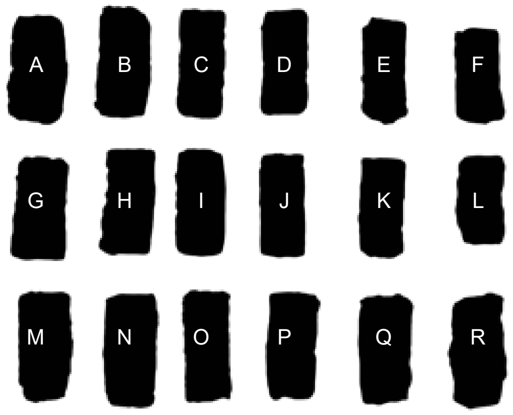
Reinforcement
Reinforcement is necessary for cantilevered and other critical parts.

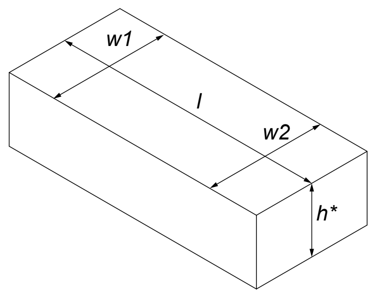
3.2 BRICK MANUFACTURING

Types of bricks

3.2 BRICK MANUFACTURING

The matrix shows an analysis of bricks produced in slightly different ways. The purpose was to find feasible production methods for permanent bricks as well as eroding bricks. Two bricks are marked with "Brick to erode" and "permanent brick" for following experiments. As will be shown, it turned out the brick marked with "permanent brick" appeared to be suitable as a brick to erode, while it is probably necessary to fire the brick with conventional methods to achieve real permanent bricks.





*) unprecise measurement

A
Soil 45%, Sand 45%, Blue clay 10%
Dried: 105° 4 hrs, 300° 1 h

	before drying [mm]	after drying [mm]
l	*47*	*47*
w1	*20*	*20*
w2	*20*	*20.5*
h	*15*	*13.5*

easy to get out of mold
very fragile

B
Sand 90%, Blue clay 10%
Dried: 105° 4 hrs, 300° 1 h

	before drying [mm]	after drying [mm]
l	*47*	*47*
w1	*20*	*20*
w2	*20.5*	*20*
h	*13*	*12*

very easy to get out of mold
fragile, easy to shape

C
Sand 75%, Blue clay 25%
Dried: 105° 4 hrs, 300° 1 h

	before drying [mm]	after drying [mm]
l	*48*	*46*
w1	*21*	*21*
w2	*21*	*20.5*
h	*12.5*	*13*

easy to get out of mold
quite fragile, easy to shape

D
Sand 50%, Blue clay 50%
Dried: 105° 4 hrs, 300° 1 h

	before drying [mm]	after drying [mm]
l	*48.5*	*45*
w1	*21*	*19*
w2	*21*	*20*
h	*12*	*12*

difficult to get out of mold
quite durable

E
Sand 25%, Blue clay 75%
Dried: 105° 4 hrs, 300° 1 h

	before drying [mm]	after drying [mm]
l	*48.5*	*43.5*
w1	*19*	*17*
w2	*19*	*17.5*
h	*11.5*	*9.5*

very difficult to get out of mold
durable

F
Blue clay 100%
Dried: 105° 4 hrs, 300° 1 h

	before drying [mm]	after drying [mm]
l	*47*	*41*
w1	*20.5*	*16.5*
w2	*20*	*17*
h	*11*	*10*

very difficult to get out of mold
very durable

G
Soil 45%, Sand 45%, Blue clay 10%
Dried: 105° 4 hrs

	before drying [mm]	after drying [mm]
l	*47*	*46*
w1	*19*	*19*
w2	*19.5*	*19*
h	*14*	*13*

easy to get out of mold
fragile

H
Sand 90%, Blue clay 10%
Dried: 105° 4 hrs

BRICK TO ERODE

	before drying [mm]	after drying [mm]
l	*47*	*47*
w1	*20.5*	*21*
w2	*21*	*20.5*
h	*12.5*	*14*

very easy to get out of mold
very fragile, easy to shape

I
Sand 75%, Blue clay 25%
Dried: 105° 4 hrs

PERMANENT BRICK

	before drying [mm]	after drying [mm]
l	*48*	*47*
w1	*21*	*20.5*
w2	*21*	*20.5*
h	*12*	*12*

easy to get out of mold
quite fragile, easy to shape

J
Sand 50%, Blue clay 50%
Dried: 105° 4 hrs

	before drying [mm]	after drying [mm]
l	*49*	*47*
w1	*20.5*	*19.5*
w2	*20*	*19*
h	*12*	*11.5*

difficult to get out of mold
quite durable

K
Sand 25%, Blue clay 75%
Dried: 105° 4 hrs

	before drying [mm]	after drying [mm]
l	*48*	*43*
w1	*19.5*	*18*
w2	*19*	*18*
h	*11.5*	*11*

very difficult to get out of mold
durable

L
Blue clay 100%
Dried: 105° 4 hrs

	before drying [mm]	after drying [mm]
l	*47*	*40*
w1	*19*	*17*
w2	*19.5*	*16.5*
h	*13*	*11*

very difficult to get out of mold
very durable

M
Soil 45%, Sand 45%, Blue clay 10%
Dried: 20° 20 hrs

	before drying [mm]	after drying [mm]
l	*47*	*46*
w1	*19.5*	*19*
w2	*19*	*19*
h	*13.5*	*12.5*

easy to get out of mold
wet and fragile

N
Sand 90%, Blue clay 10%
Dried: 20° 20 hrs

	before drying [mm]	after drying [mm]
l	*47*	*47*
w1	*20*	*20*
w2	*20.5*	*20*
h	*13.5*	*12*

very easy to get out of mold
very fragile, easy to shape

O
Sand 75%, Blue clay 25%
Dried: 20° 20 hrs

	before drying [mm]	after drying [mm]
l	*46*	*45.5*
w1	*19.5*	*19*
w2	*20*	*19.5*
h	*13.5*	*13*

easy to get out of mold
quite fragile, easy to shape

P
Sand 50%, Blue clay 50%
Dried: 20° 20 hrs

	before drying [mm]	after drying [mm]
l	*45.5*	*44*
w1	*19.5*	*19*
w2	*19.5*	*19*
h	*13*	*12.5*

difficult to get out of mold
wet but quite durable

Q
Sand 25%, Blue clay 75%
Dried: 20° 20 hrs

	before drying [mm]	after drying [mm]
l	*48*	*44.5*
w1	*20*	*19*
w2	*21*	*19*
h	*13.5*	*13*

very difficult to get out of mold
wet but durable

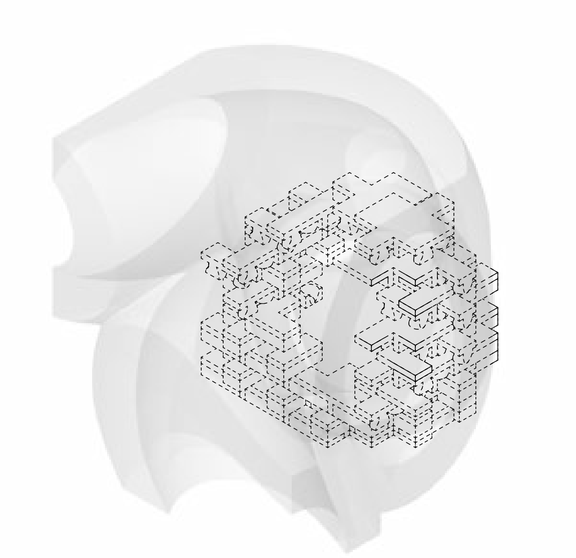
R
Blue clay 100%
Dried: 20° 20 hrs

	before drying [mm]	after drying [mm]
l	*48*	*46.5*
w1	*19.5*	*18*
w2	*19.5*	*18*
h	*14*	*12.5*

very difficult to get out of mold
wet but durable

3.3 CONSTRUCTION AND EROSION

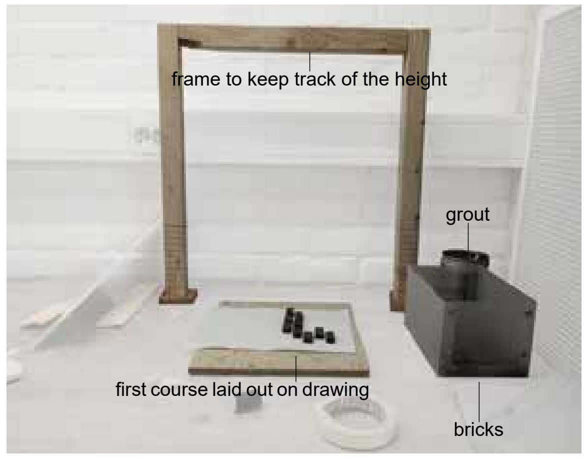
These images show the steps for a failed attempt to build the model with controlled partial erosion (chapter 2.3). The gained knowledge however, is that sundried bricks that consists of 75 % sand and 25 % clay might be used as building elements that can be washed away to build a pure mortar structure.



scale 1:10
dimensions ~ 100*180*165mm
brick dimension: 9*15*36mm
permanent brick: 67 pcs
bricks with voids to eliminate: 21 pcs
normal bricks to eliminate: 8 pcs

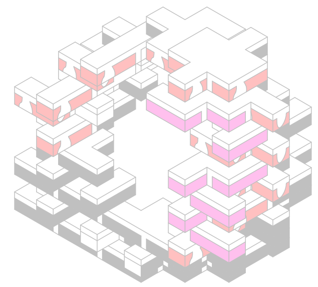
perpend: 5mm
bed joint: 5mm
time to mold 75 bricks to keep ~ 6 hrs
time building structure ~ 2 hrs
cost bricks: free (blue clay and sand)

1. Molding Bricks, 75% sand, 25 % blue clay.



3. Construction setup.

1. first course. Bricks gets soaked and soft.

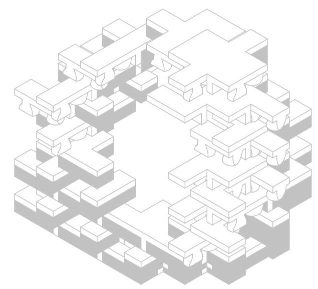


5. Imagined step. Finnish structure. Black bricks will be kept. Magenta (normal) and red (voids) bricks will be eliminated.

2. Baking bricks in oven, 105° 1 hr. (to simulate sun drying)

4. Depending on the situation, mortar was applied either on the brick or on the course below.

2. Soaked bricks appeared to be very fragile and ruptures emerged in the structure, when moving it before drying.



6. Imagined step: eliminate chosen bricks.

3.3 CONSTRUCTION AND EROSION

bricks and mortar

Mortar after bricks being washed away

Artisinal qualities
This experiment aimed for a combination of *controlled partial erosion* and *washed away bricks*, as described in the chapter *2.4*. However, by eliminating the intended permanent bricks, the qualities that emerged resembles more of *ripped away bricks*, described in the same chapter.

Feasible aspects

The bricks that where meant to be permanent appeared to fall apart as an effect of of getting soaked by the applied mortar. The failure was probably also caused by the model gently being moved during construction.

Bricks of higher qualities shall be used as permanent bricks.

The bricks that were intended to be permanent may probably be used as bricks to be eliminated, if higher causion is paid to the construction work.

Molding bricks one by one is very time consuming

Cracks

No visible cracks appeared

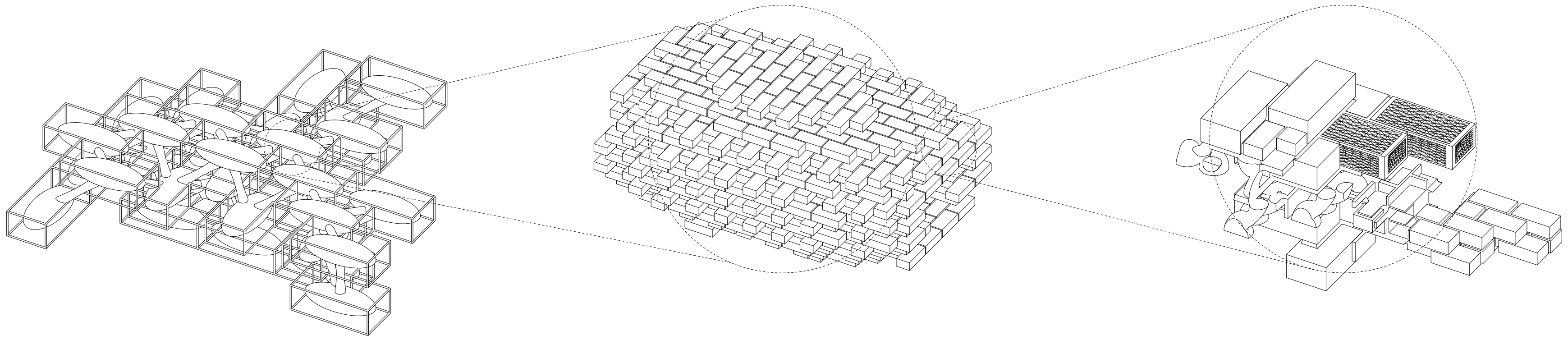
4 SCALE AND RESOLUTION

4 SCALE AND RESOLUTION

This chapter aims to investigate the effect of different scales, resolution and detailing. three different scales are explored: global scale, mid-scale and small scale. In the global scale the aggregation of spaces and the overall geometry of a building is defined. In the mid-scale, the shapes of the spaces are defined. In the small scale individual elements are treated. Gilles Retsin (2016b) argues that lowering the resolution may result in more efficiency and feasibility, and pose the question: "How far can we drive the resolution before the object becomes something truly different?" The benefits of lowering the resolution in a digital context is that it makes the data more manageable and drastically lowers the computational time. Too high resolution literally means that any computer will crash. Hence the proposed method is to use a relatively low resolution for representations of global geometries, while a higher resolution may be used for details.

A question that may be raised is of course why not simply model the geometries with NURB surfaces with a brick texture or brick hatch. There are two answers to that question. The first is to maintain the part-whole relationship, and the second is that it appeared that NURBS are much more sensitive for complex geometries than voxels. Many failed attempts have been carried out to reconstruct complex shapes with NURBS, which manifests that the relationship between the method, the parts and the whole, must not be underestimated in digital craft.

It shall be noted that there is on purpose no clear distinction between voxels and building elements in this chapter, to open for multiple interpretations.



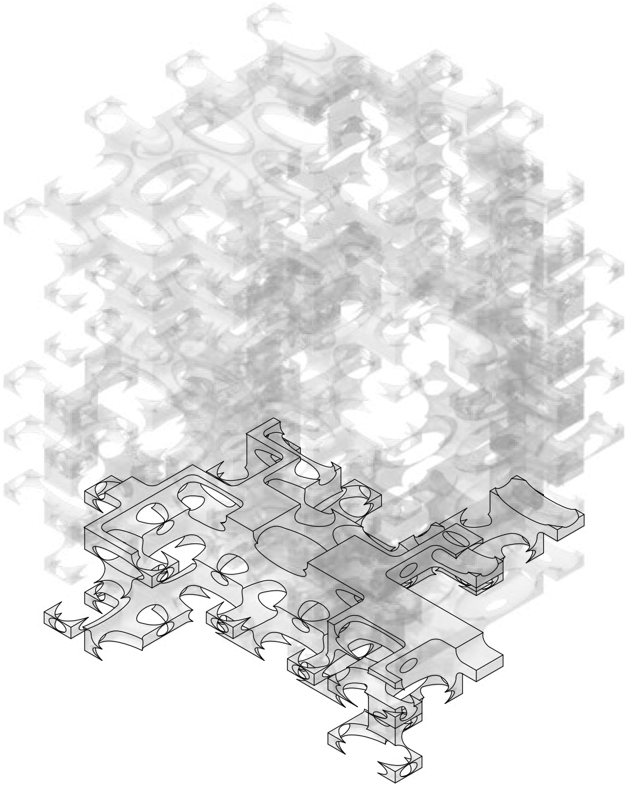
1. Global scale
aggregation of spaces
global geometry

2. Mid scale
shape of spaces in relation to resolution

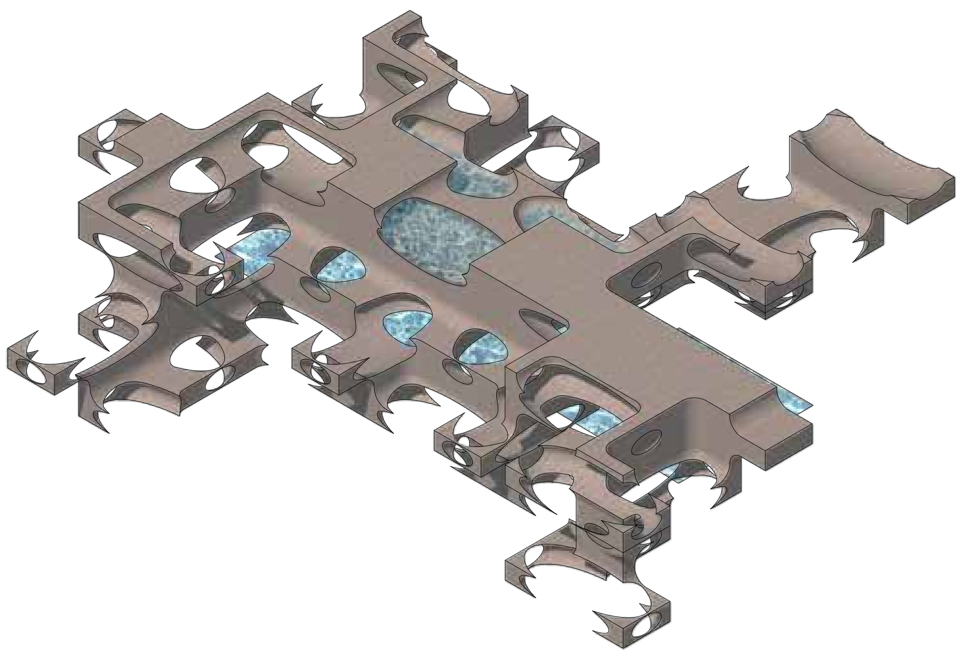
3. Small scale
brick - shape and material
mortar - shape and material
structural system

4.1 GLOBAL SCALE

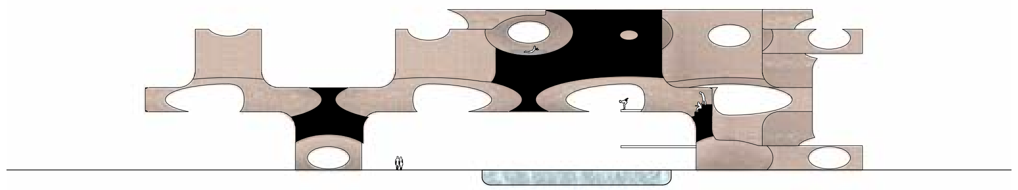
At this page the resolution is so low, that, each voxel, with a size that is equivalent to a Swedish standard brick scaled up 100 times, becomes a space itself. A big disadvantage of using such a low resolution is that it drastically limits fine tuning of spatial configurations.



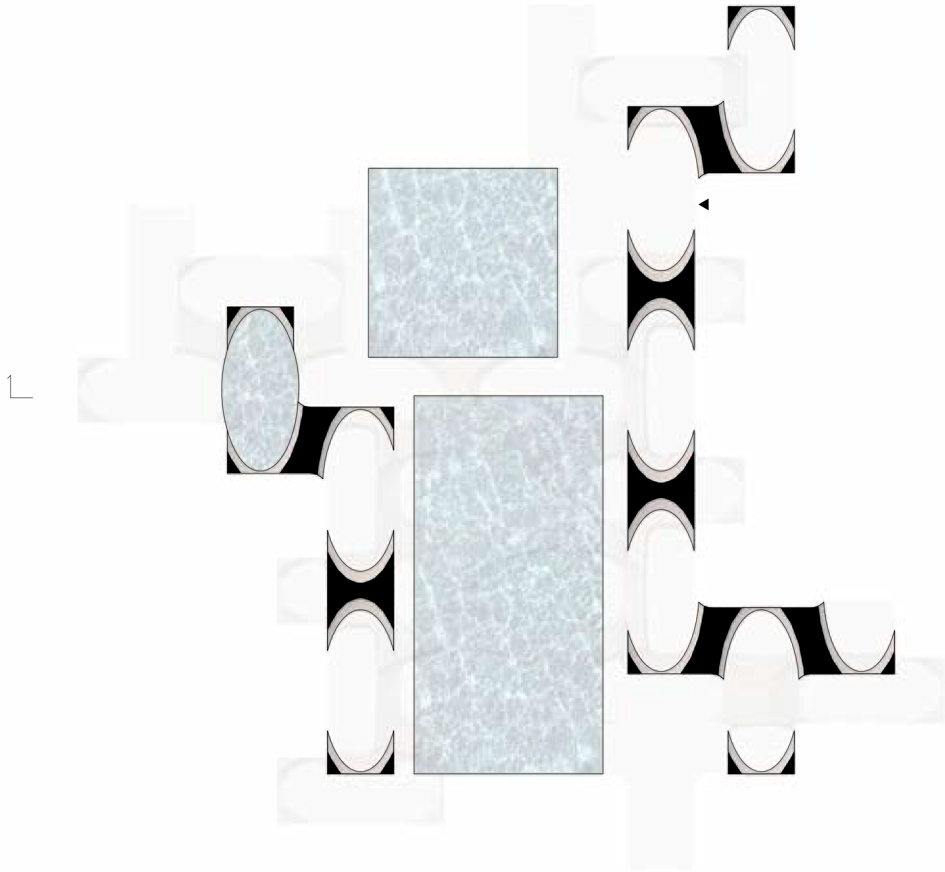
Shape derived from diagram: alternative void in chapter 2.4



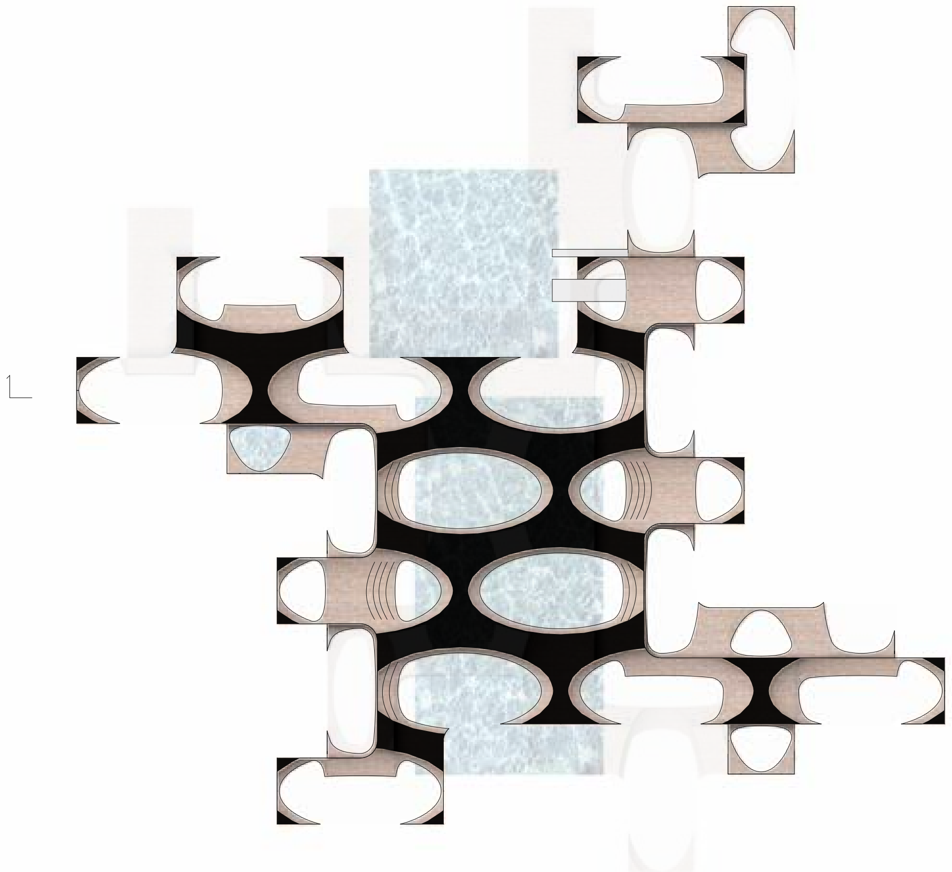
Isometric view of global shape



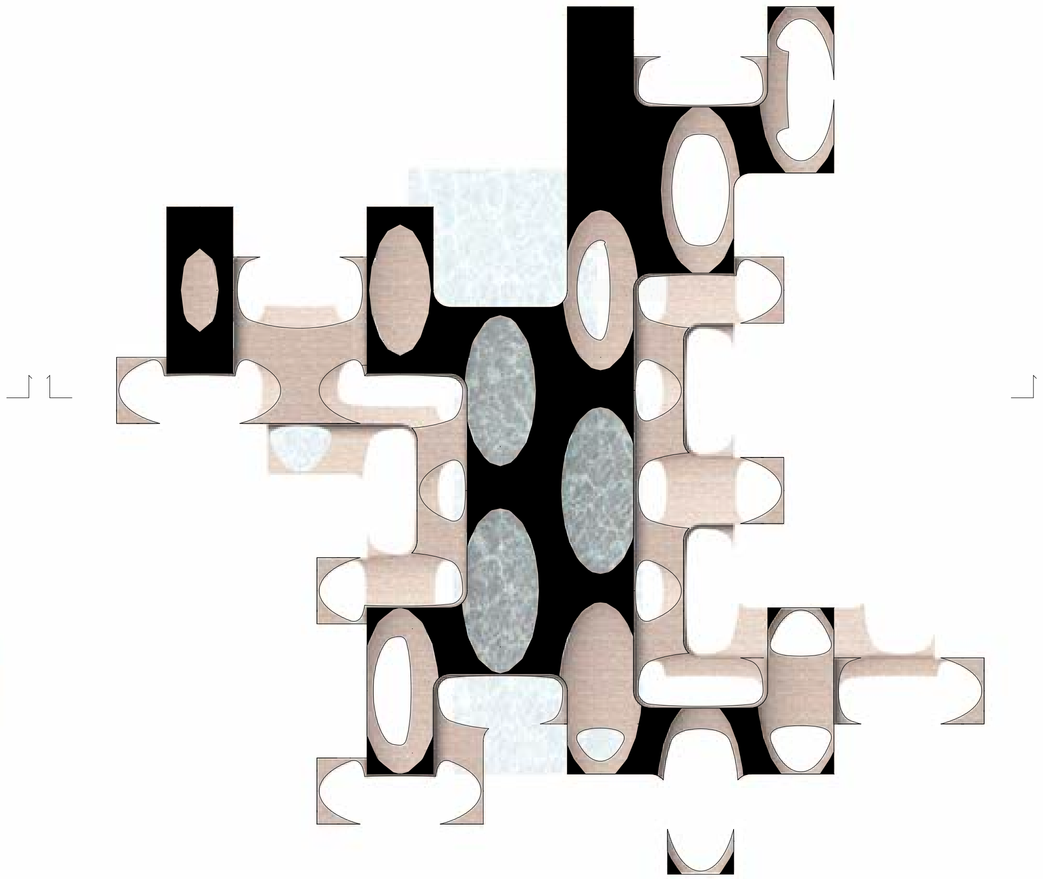
Section 1:1000



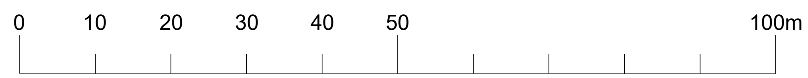
Entrance floor 1:1000



First floor 1:1000

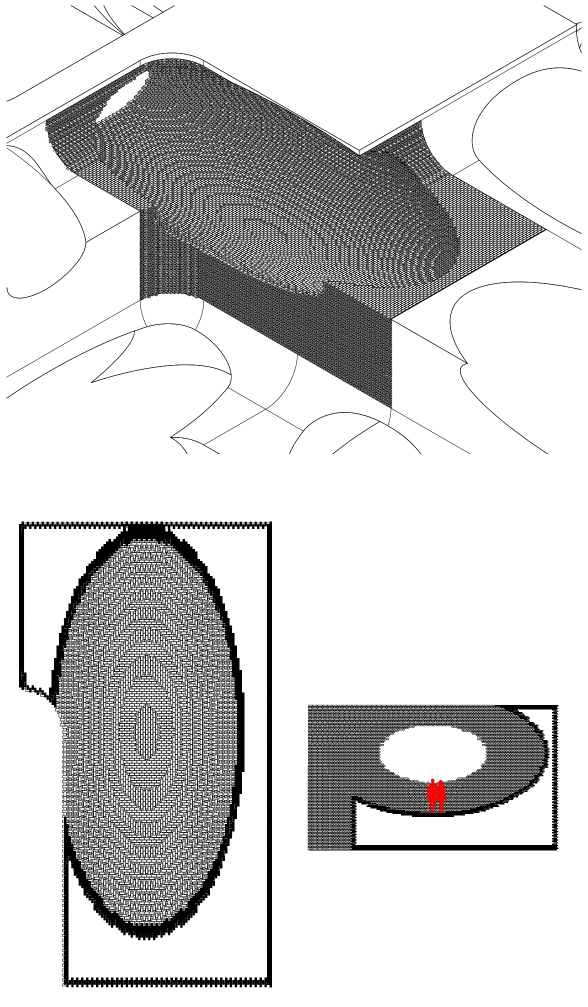


Second floor 1:1000



4.2 MID SCALE

There are pros and cons for different resolution as a mean to represent a geometry. A high resolution means higher accuracy for depicting the space but difficulty in data management, while a low resolution entails a bad depiction of the space but a manageable amount of data. A feasible method is to go for a medium high resolution that gives a somewhat realistic idea of the space.



Swedish standard brick size

Scale 1:400

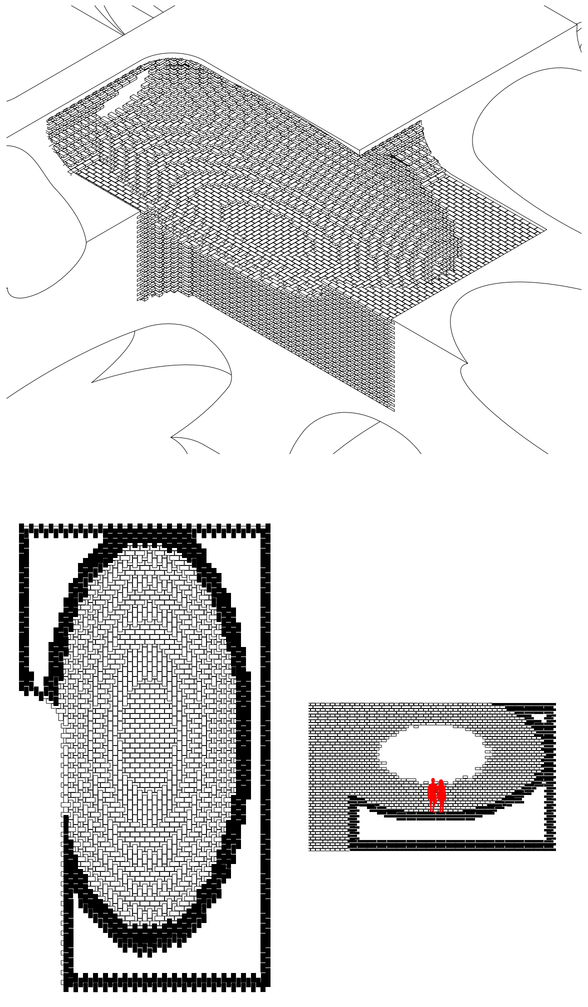
Voxel proportion in relation to void: ~ 1%

Voxel quantity: 113501 pcs

Resolution effect: The Voxels depicts real bricks. The space appears as smooth, but pixelated. The downside is that this resolution requires tremendous computational force.

Voxel relation to human scale: The scale of each individual brick is on an intimate level.

Space relation to human scale: The size of the space is comparable to an average school gym, in other words, it's a big space.



Double Swedish standard brick size

Scale 1:400

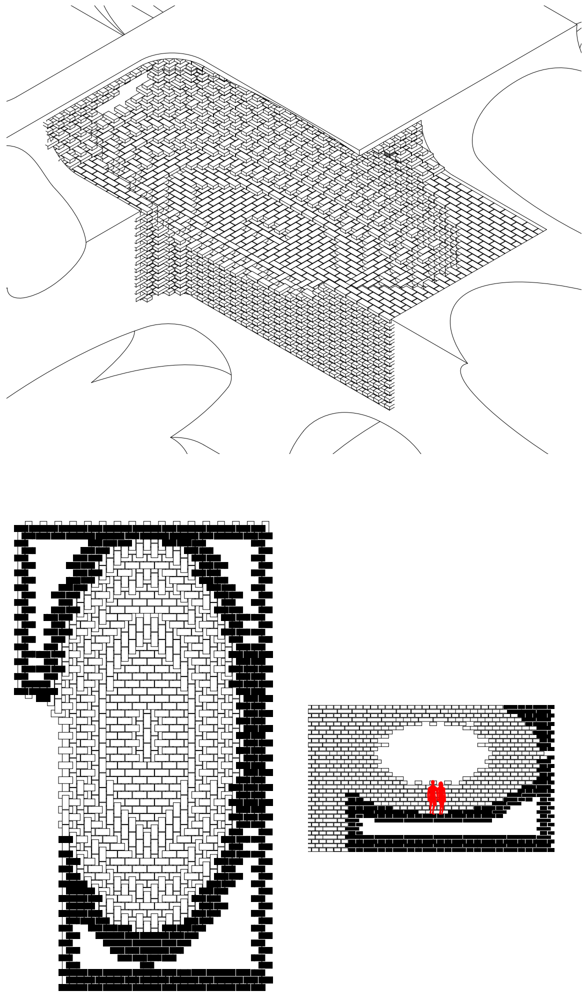
Voxel proportion in relation to void: ~ 2%

Voxel quantity: 26752 pcs

Resolution effect: The voxels are still subordinated to the shape of the space. The space is easy to read, but individual elements are more prominent. The sense of smoothness is gone.

Voxel relation to human scale: The intimacy is still there, but perhaps not so striking.

Space relation to human scale: The size of the space is comparable to an average school gym, in other words, it's a big space.



Triple Swedish standard brick size

Scale 1:400

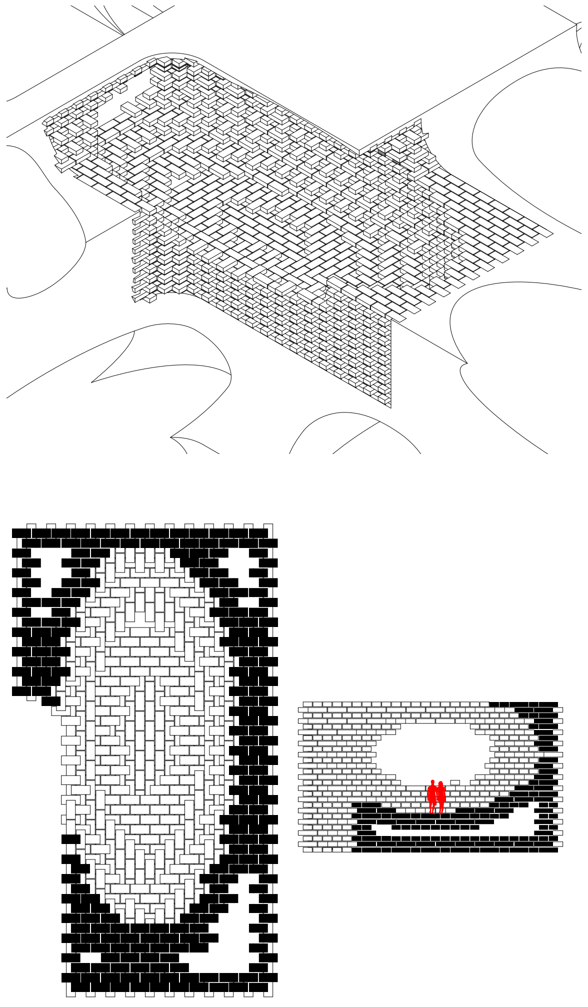
Voxel proportion in relation to void: ~ 3%

Voxel quantity: 10640 pcs

Resolution effect: A balance between the parts and the whole is achieved, and there's a conversation between the parts and the whole. The space is still easy to read even though it starts to get blurred.

Voxel relation to human scale: It's on the verge between being intimate and monolithic.

Space relation to human scale: The size of the space is comparable to an average school gym, in other words, it's a big space.



Quadruple Swedish standard brick size

Scale 1:400

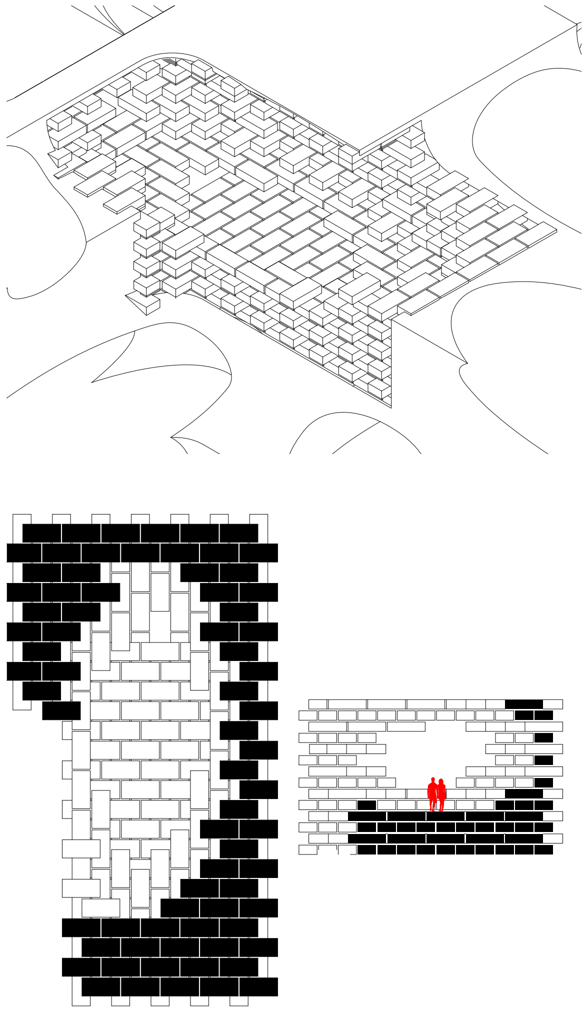
Voxel proportion in relation to void: ~ 4%

Voxel quantity: 5249 pcs

resolution effect: The voxels starts to dominate the space. The space is readable but blurred.

Voxel relation to human scale: The voxels are big. They are now monolithic elements that forms the space.

Space relation to human scale: The size of the space is comparable to an average school gym, in other words, it's a big space.



Eightfold Swedish standard brick size

Scale 1:400

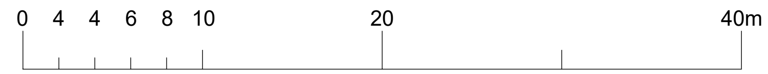
Voxel proportion in relation to void: ~ 8%

Voxel quantity: 831 pcs

Resolution effect: The space is now on the verge to become something else. The space is subordinated to the bricks.

Voxel relation to human scale: The stretcher dimension of the brick is now longer than the average human, which would make anyone feel small in comparison

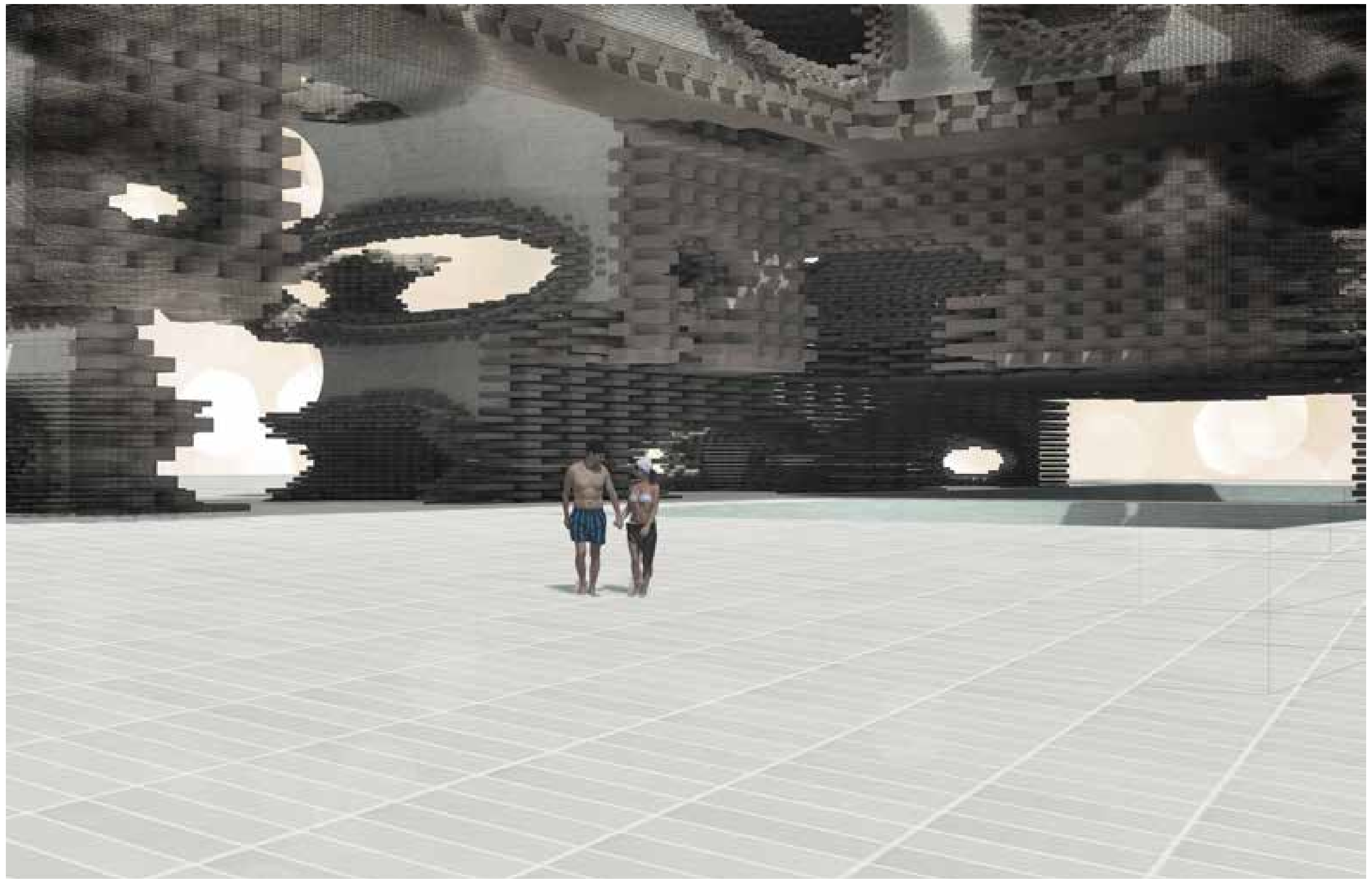
Space relation to human scale: The size of the space is comparable to an average school gym, in other words, it's a big space.



4.3 MID SCALE - RESOLUTION EVALUATION

In the images below, various voxel resolutions have been used depending on the size of the space they defined. Here the voxel size approximately corresponds to 3% of the size of the spaces. The images leave a messy impression. If the voxels would represent actual building elements it is also likely that the spatial experience is not only linked to the interplay between the size of the space and the building elements, but also to the curvature of the geometry. Hence, as a ground rule, the conclusion is that the same compromised voxel size shall be used all through the building for representations, and that the spatial experience might be tweaked by adjusting the size of each building element in relation to the curvature global geometry.

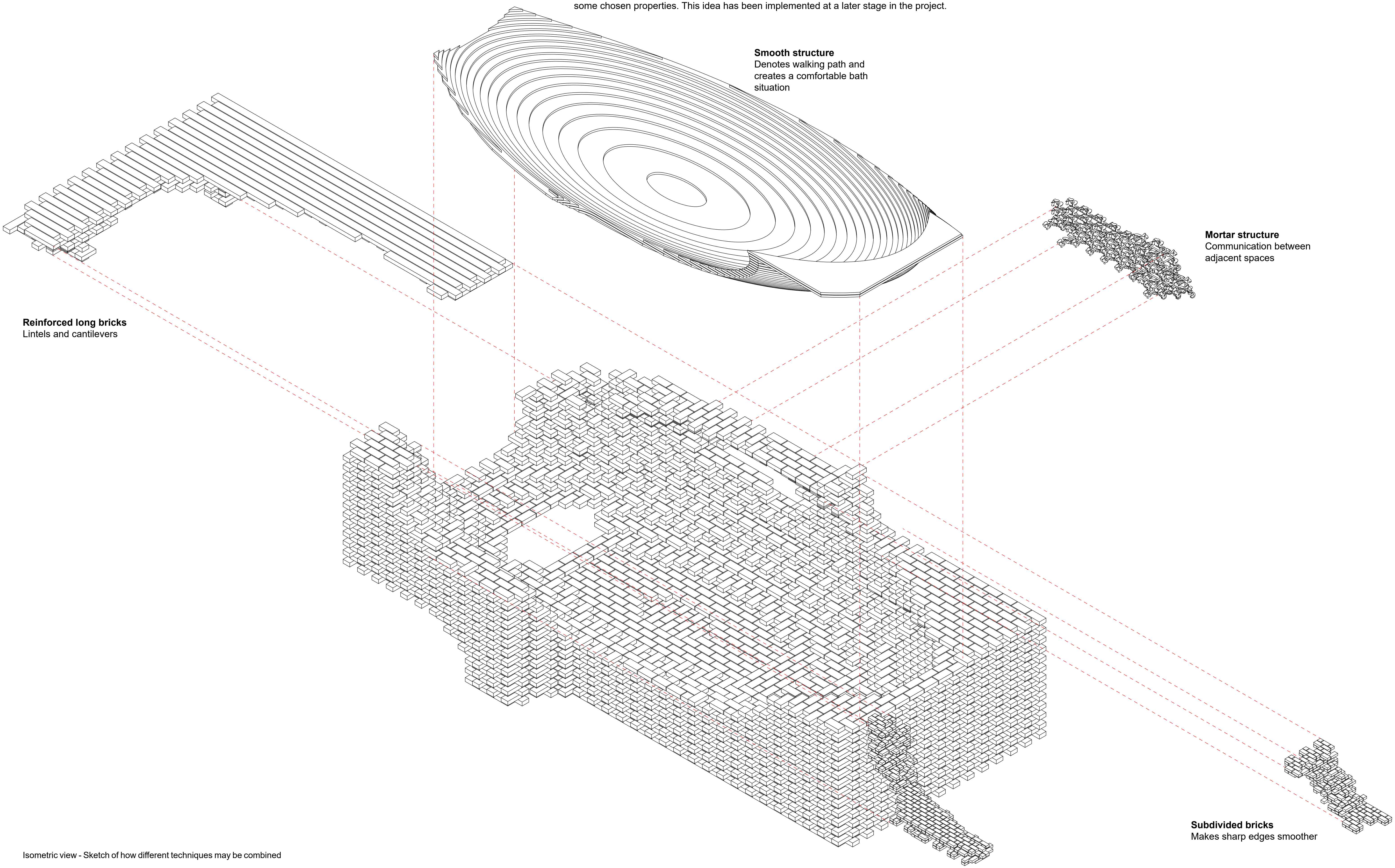
Isometric line drawing of global shape, where the voxel size approximately corresponds to 3% of the space they define.



Interior perspective. The voxel size approximately corresponds to 3% of the space they define.

4.4 SMALL SCALE - COMBINATIONS

This investigation was carried out to see how different techniques may be combined. The conclusion is, neglecting the success of the chosen combination, that the outcome leaves a static impression. There's a great potential in the developed algorithmic 3d-modeling technique to create an effect of gradual shifts of properties, where each voxel has layers with different levels of some chosen properties. This idea has been implemented at a later stage in the project.



Isometric view - Sketch of how different techniques may be combined

5. SITELESS DESIGN

5 SITELESS DESIGN

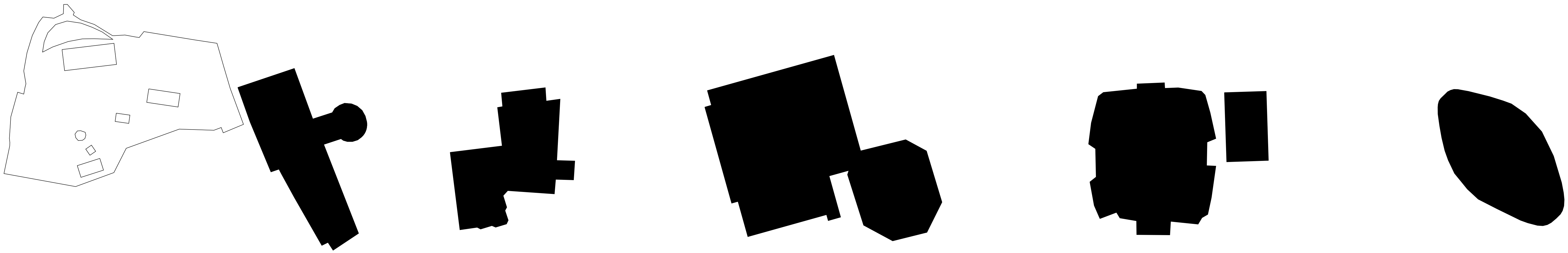
While previous chapters have treated independent experiments. This and the following chapters deals with the development of an actual design proposal, a central bath house in Göteborg as a future replacement for Valhallabadet.

As a starting point for the design, one geometric shape from previous investigations (the initial brick construction that was used in the diagram for the basic structure in chapter 2.1) is used to define the global geometry of the building. The approach takes inspiration from Blanciak (2008) who explores a wide variety of shapes and then seemingly arbitrarily pick one of them to inhabit in a certain context. In this, he is implicitly using the three basic abilities of craftmanship, as stated by Sennett (2009): localize, question and open. That is: localizing a shape, question what it can be used for, and then open for the possibility to define it as a building at a certain location.

The benefits of taking a detour in the design process and then return to an early sketch is that it provides the project with new layers of knowledge and information.

5.1 PRECEDENTS

As a starting point for the design development, the scale of central baths and aquatic centers were investigated.



Valhallabadet Göteborg

footprint: ~ 9000 m^2

audience capacity: n/a

Olympic aquatic centre Athen

footprint: ~ 24000 m^2

audience capacity: ~ 23000 (total of three pools)

Olympic aquatics stadium Rio de Janeiro

footprint: ~ 17000 m^2

audience capacity: ~ 18000

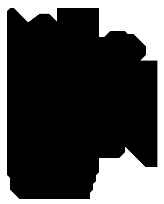
London Aquatics centre

footprint: ~ 10500 m^2

audience capacity: ~17500

5.2 DESIGN EVOLUTION

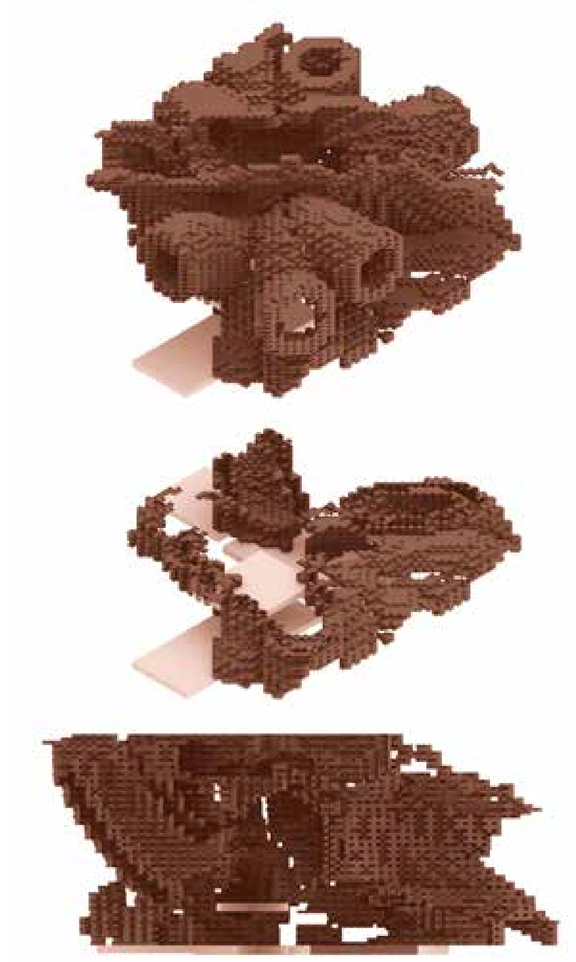
The basic structure in chapter 2.1 has been scaled up 10 times to achieve a size that approximately corresponds to the size of the bath houses presented under chapter 5.1. A simple layout of pools has also been included to test the potential. The diagrams explain a few initial modifications of the shape to make it more eligible as a building. At this scale, the representation of the building shall be seen as a voxelization of the space, rather than a material representation that consists of bricks.



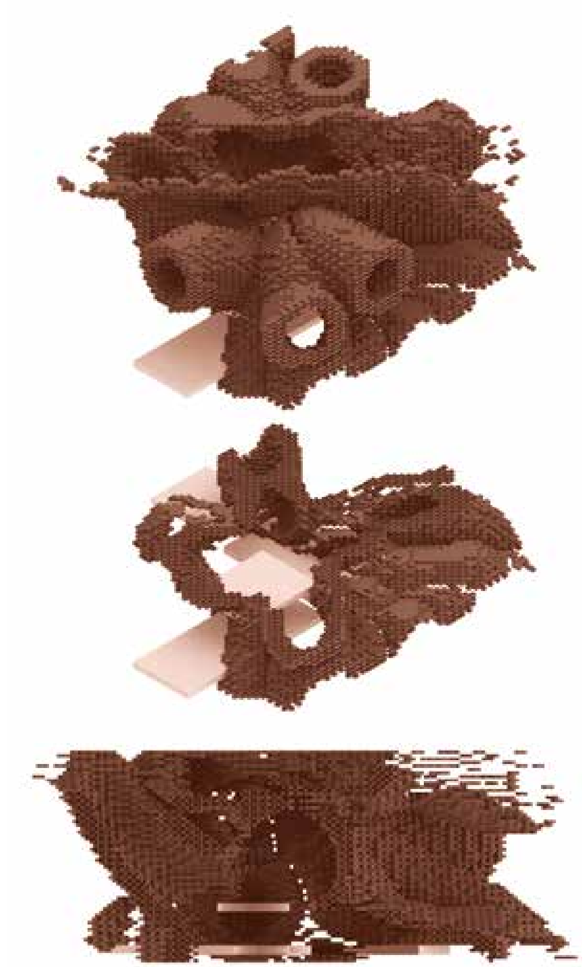
Bath house proposal

footprint: ~ 6500 m^2

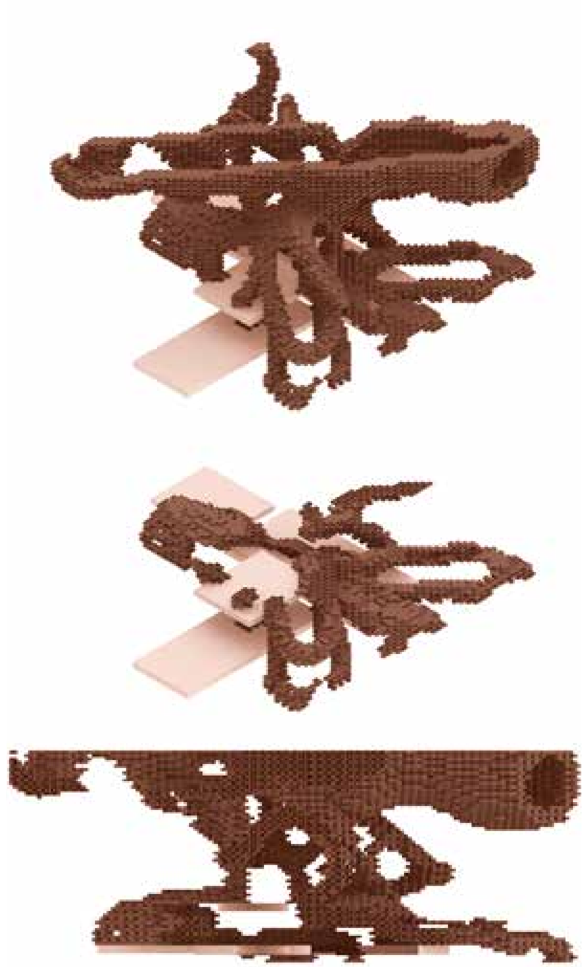
audience capacity: n/a



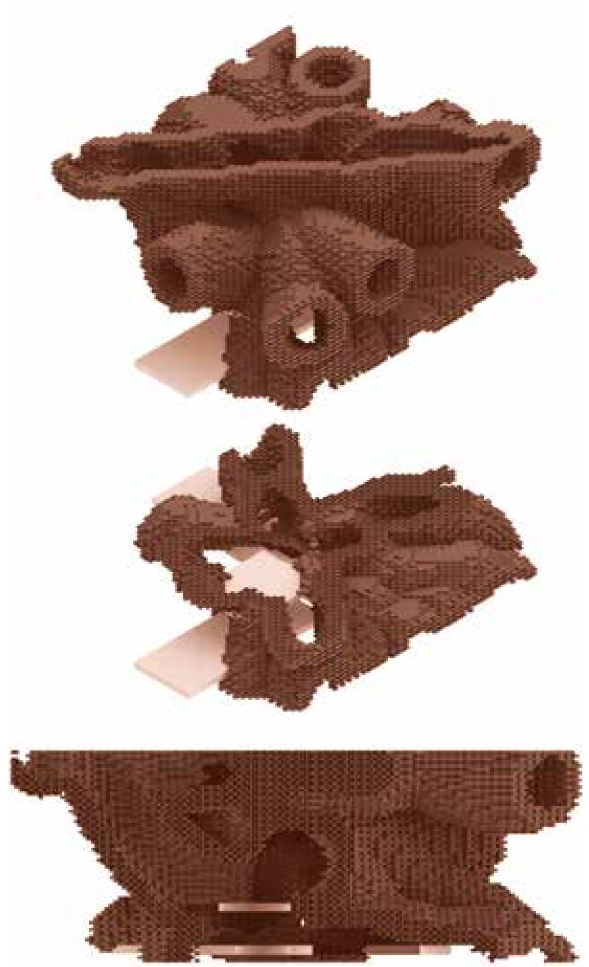
Scaled up structure that accommodates two 25m pools and two 50m pools.



Changed bonding pattern with overlapping bricks, to avoid perpends that runs through the structure.



Due to an error in the algorithm, bricks in intersections of the geometry, as shown above, has not previously been represented. This error gave the structure a fragmented appearance. It may appear as a quality, but for an actual building design, a more solid structure is preferable.



These diagrams show a solid structure where all the bricks in the intersections of the geometry is included as well. This shape is the foundation for the following development

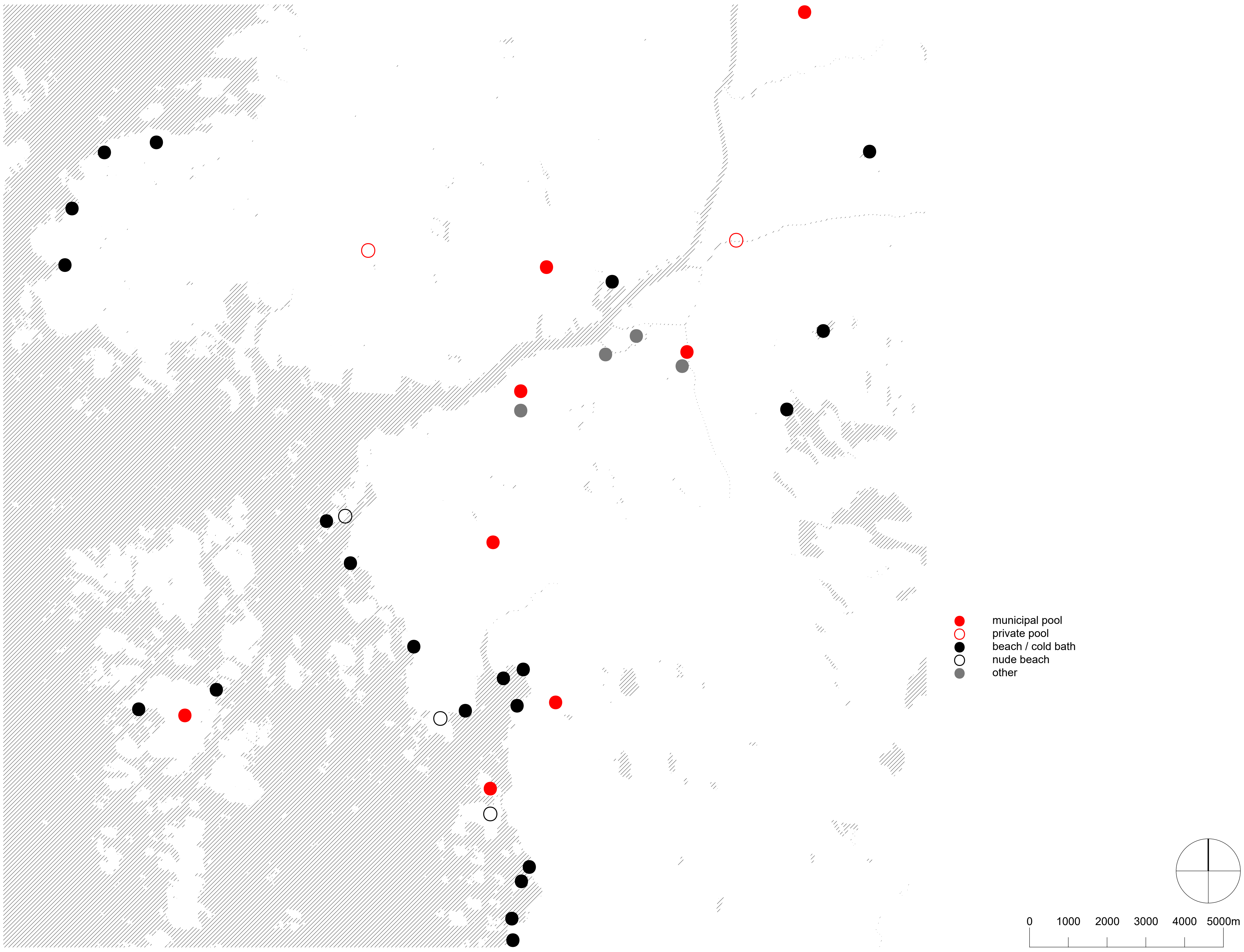
6. GRAFTING ON SITE

6 GRAFTING ON SITE

In this chapter, a site analysis is presented as well as the adaption of the building to the site and the program. This adaption is performed in small steps. The benefits with this approach is that qualities in the conceptual sketch potentially is preserved, and that site, program, and design is adapted to each other at the same time as it ends up in an architectural expression that is booth unique and site specific. The qualities that are desirable to preserve is the dynamic shape, the intricate flowing spatial sequences and the contrast to the jagged discrete elements. Bringing these qualities to the site may bring vibrancy and compensate for a lack of natural flow. The idea of using water as an element is, apart from being a media where people can swim, to emphasize the flowing spaces.

6.1 SITE CONTEXT - POOLS AND BEACHES

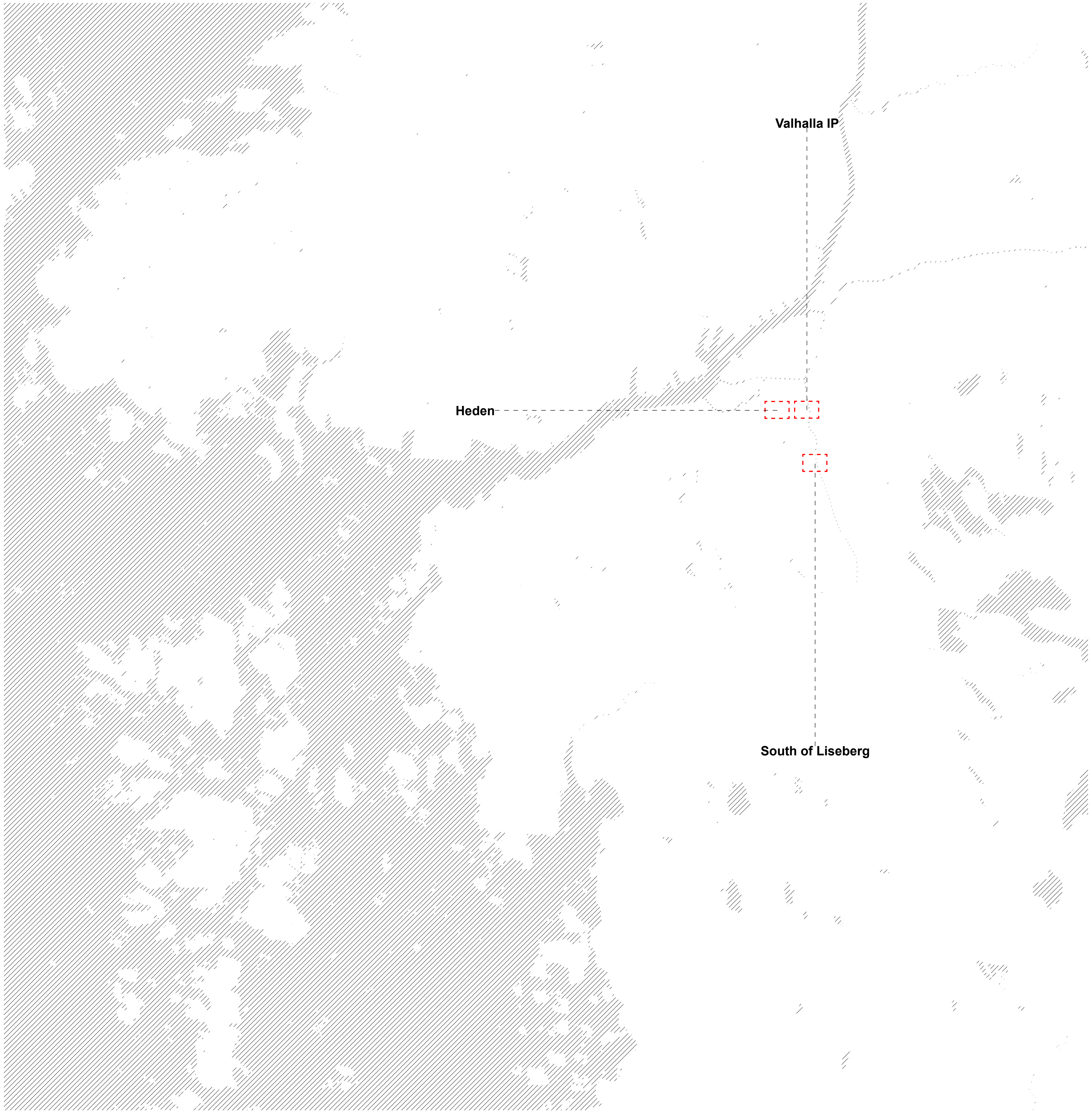
Map shows bath opportunities in Göteborg today. A new central bath may be considered as a node.



Site 1:100000. Map from Sveriges lantbruksuniversitet (2017).

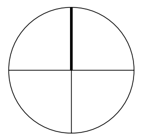
6.2 SITE CONTEXT - LOCALISATION

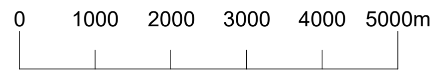
Three sites have been considered by the sports administration in Göteborg for a new central bath, Valhalla IP, Heden and south of Liseberg (Malmryd, 2016). This project investigates the opportunities at Valhalla IP.



"Förvaltningen anser att Valhallabadet inte uppfyller kriterierna för ett centralbad och föreslår därför att anläggningen ersätts. Dagens anläggning är i dåligt skick och kan inte längre fylla den funktion som den en gång byggdes för. En lokalisering på befintlig tomt skulle innebära att det inte finns någon anläggning i området på minst två år. På grund av de skador detta medför för föreningslivet ser vi detta alternativ som uteslutet. Vi har istället undersökt tre alternativa lokaliseringar: Heden, söder om Liseberg samt Valhalla IP"

(Malmryd, 2016)

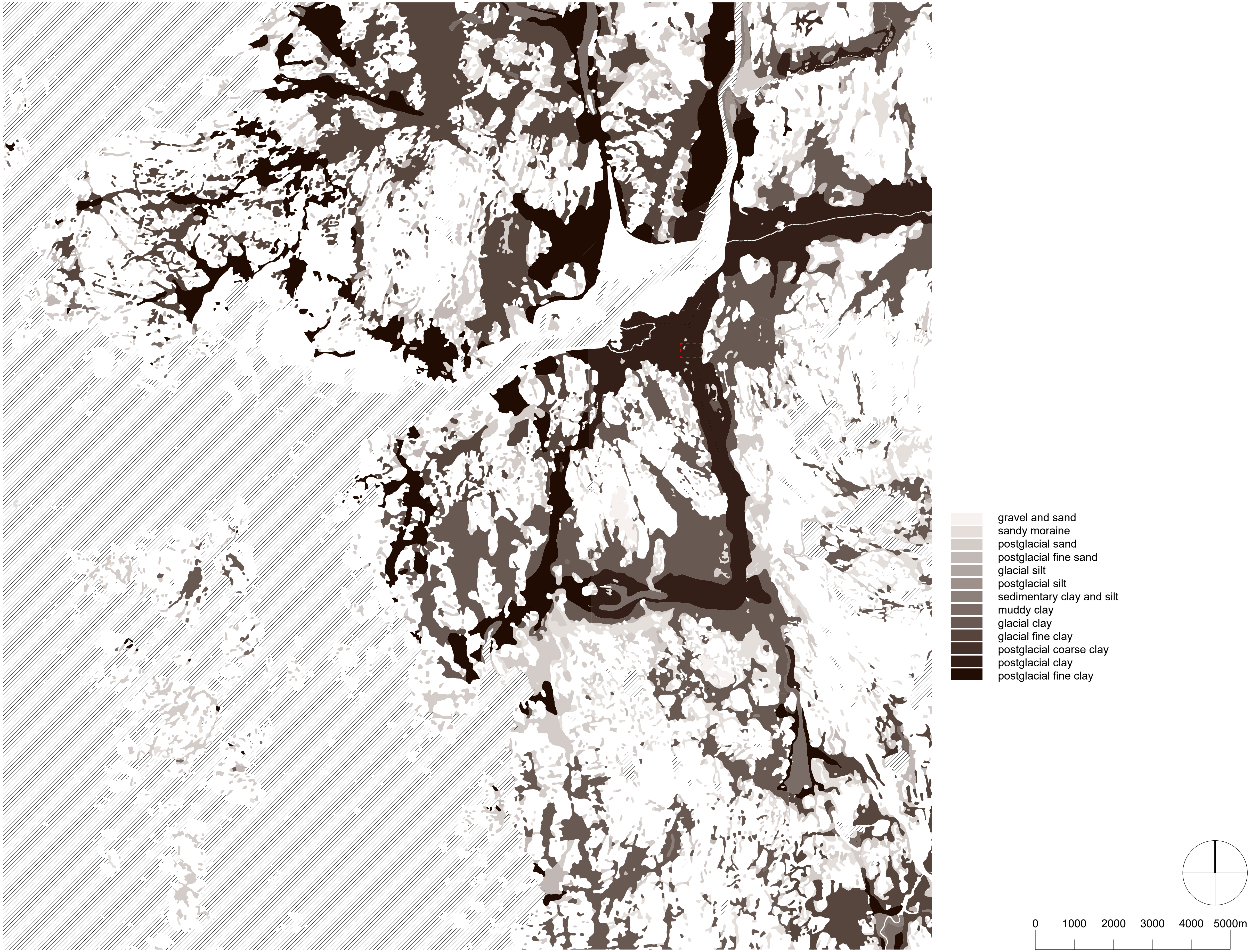




Site 1:100000. Map from Sveriges lantbruksuniversitet (2017).

6.3 SITE CONTEXT - NATURAL RESOURCES

Natural resources for brick making, clay and sand, is found all over Göteborg. The map shows the main components in the geological ground layer. At the specific site for the proposed bath house, the ground layer consists of post glacial clay, and the surroundings consists of glacial clay which is excellent for brick making (Bergström, 1936).



Site 1:100000. Map and data from Sveriges lantbruksuniversitet (2017).

6.4 SITE WALK

Collecting impressions from the site increases the ability to be site specific. Below are some collected impressions.

Most surrounding buildings are made of bricks.

The current central bath is also made of bricks.

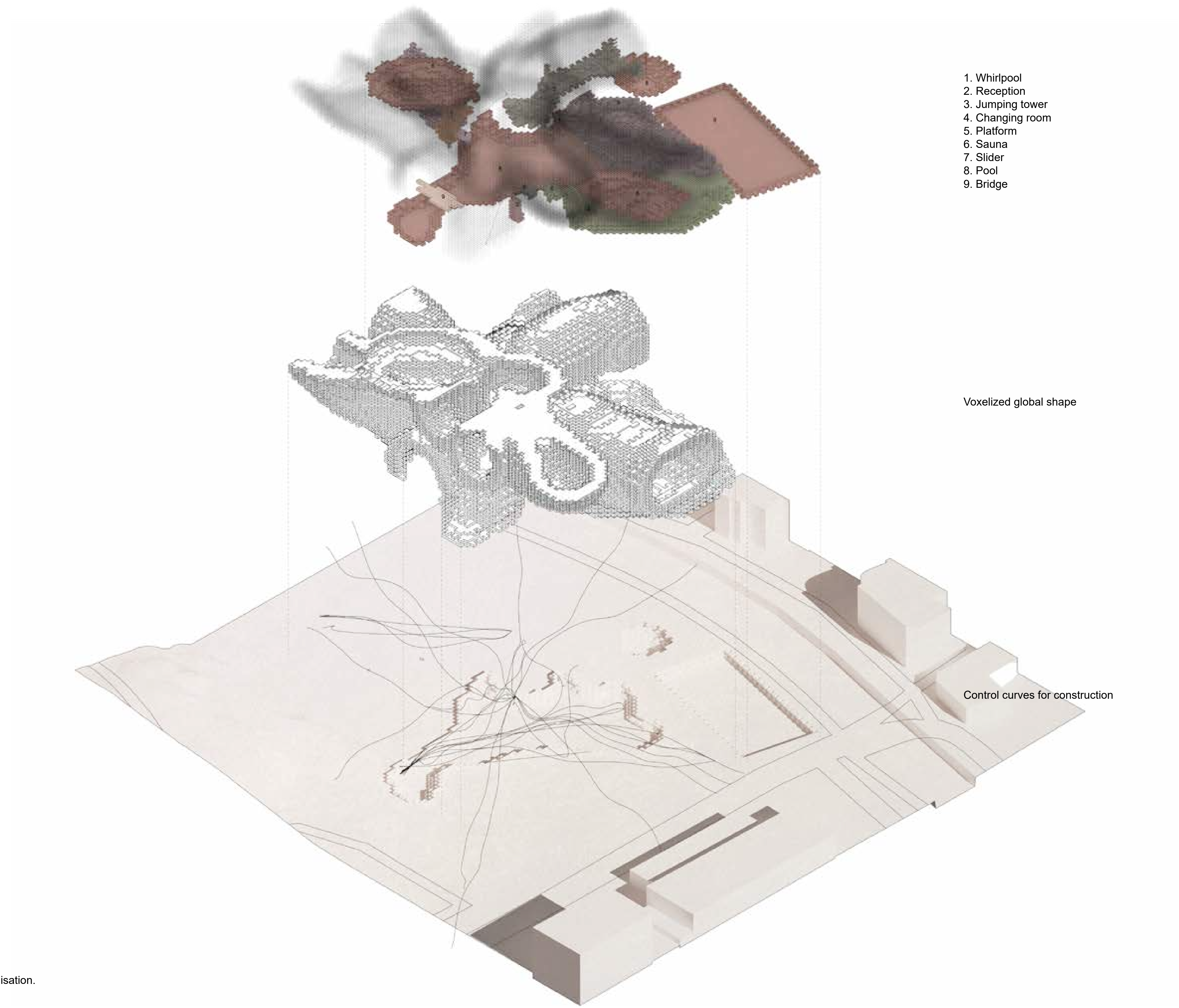
Empty site adjacent to proposed building site, which can be used to dig up clay.

Current landmarks in the surroundings are the Gothia towers and the ice hockey arena Scandinavium. These landmarks are merely scenery. A new architectural landmark may add vibrancy to the site.

An important feature is the stream Mölndalsån, that runs to the east of the site. Another important feature is the hill to the west.

6.5 SPATIAL ORGANISATION

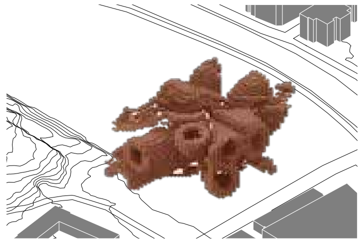
The exploded isometric view describes, not only the spatial organisation of main functions within the building, but also an iterative loop to generate the final form. Control curves are used to generate a voxelated global shape, wherein functions are fitted. These functions are then used in the next iteration to affect the shape as well as the constantly updated control curves.

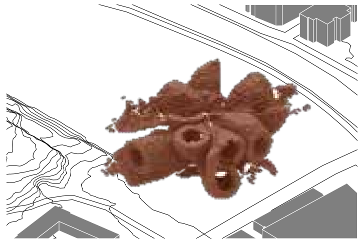


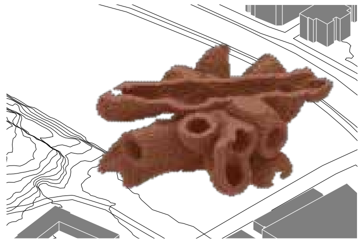
Exploded isometric view of spatial organisation.

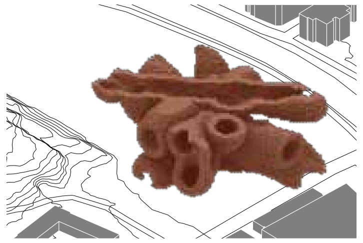
6.6 SITE AND PROGRAM ADAPTION

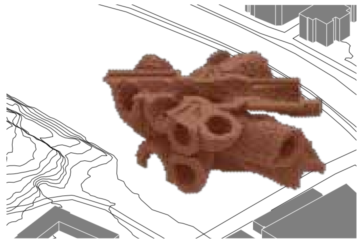
The shape of the building is derived from a sculptural model from an early design experiment (chapter 5.2), where agent paths, scripted with grasshopper and quelea is used to define a semi-controlled global shape. The shape is then gradually transformed and adapted to the site and a program, which is visualized in the diagram series below. This is done by fine tuning the algorithm and the conditions that generates the shape, adjusting the agent curves, and using the program itself, including, pools, changing-room etc. as agents to affect the shape.

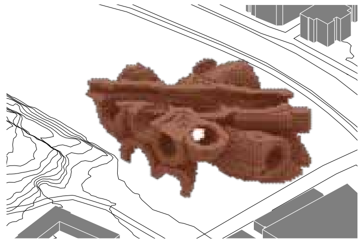

0. Original. Derived from agent paths.

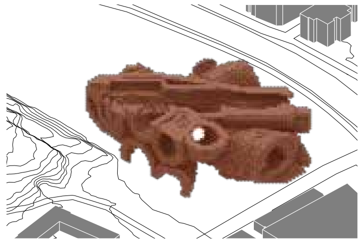

1. Bond system changed to avoid continuous perpends.

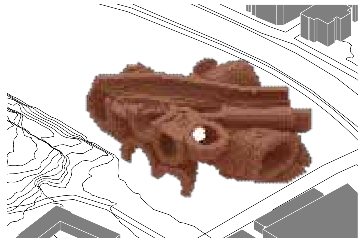

2. Intersections repaired to avoid floating bricks.

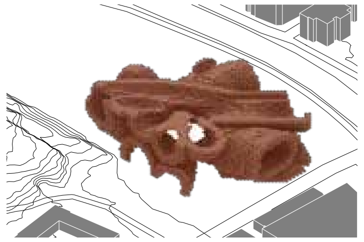

3. Rotated and mirrored to achieve a slope towards the water. Shape adjusted to accommodate the pools.

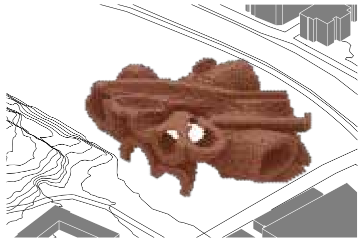

4. Shape adapted to surrounding buildings.

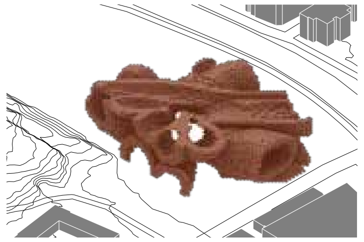

5. Building height adapted to surrounding buildings. Entrance adjusted.

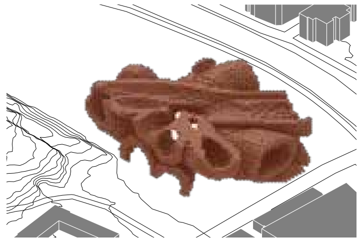

6. Adjustment of geometry to better fit the pools within.

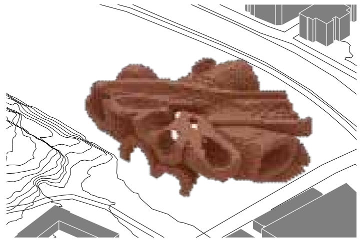

7. Smoothened geometry around the pools.

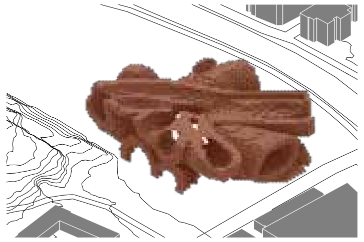

8. Building height lowered again for context adaption.

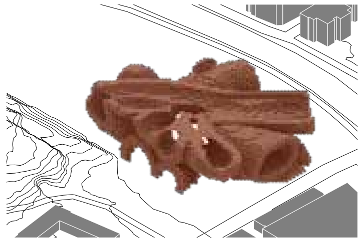

9. Finetuning of south cantilever for better functionality.

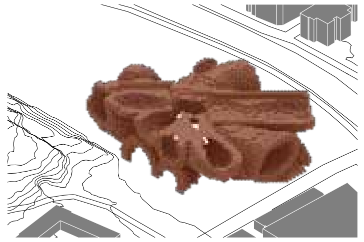

10. Small adjustments to make shape smoother.

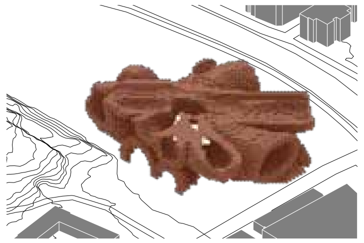

11. Entrance emphasized.

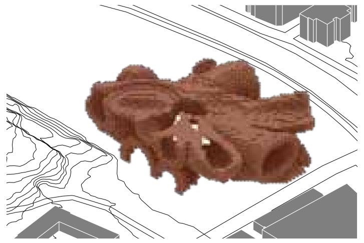

12. Entrance further emphasized.

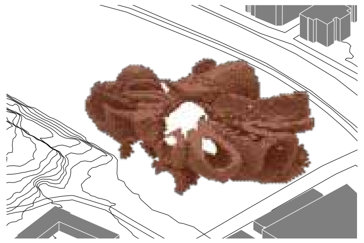

13. Entrance framed by adjusting direction of adjacent cylinders. Southeast top cantilever extended to connect it to the water.

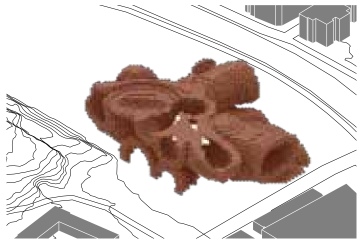

14. Southeast top cantilever opened towards water.

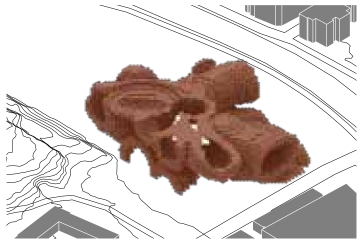

15. Edges at top cylinder adjusted to improve water capacity.

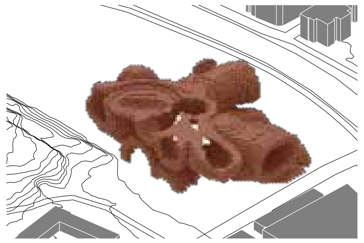

16. Second floor adjusted to improve water capacity. Top floor made les stiff.

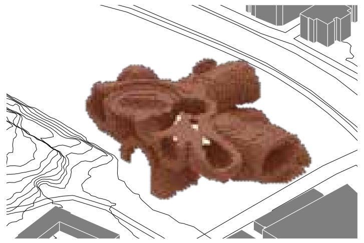

17. More dynamic shape.

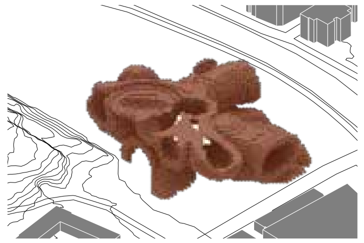

18. Fragmented expression recre-ated.

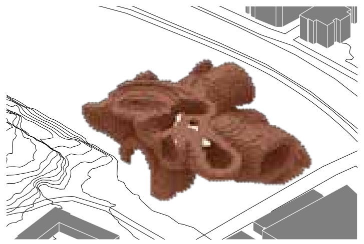

19. Fragmentation tuned down. Southeast cantilever removed for structural reasons and to bring sun-light to outdoor platform.

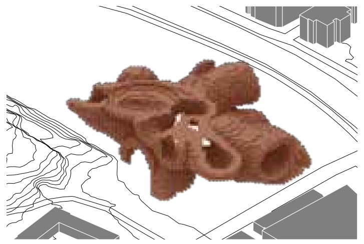

20. More dynamic entrance by adjusting adjacent cylinder.

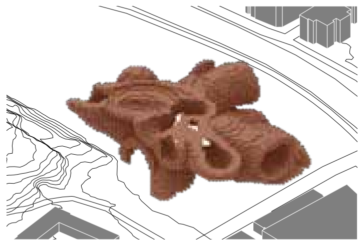

21. Further adjustment of entrance.

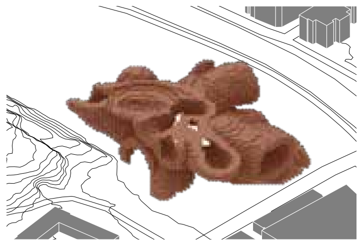

22. Private zoon created adjacent to entrance, towards the hill.

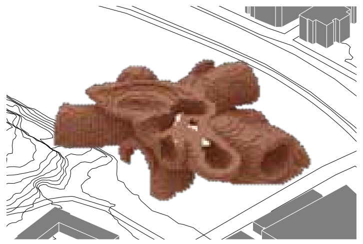

23. Portico around entrance re-moved.

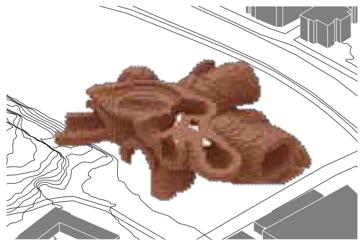

24. More dynamic shape.

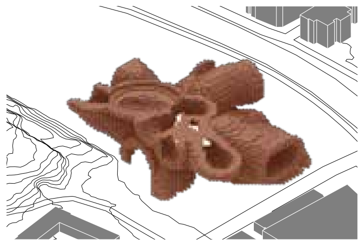

25. Northwest top cantilever extend-ed, and shape adjusted to match the shape of the hill.

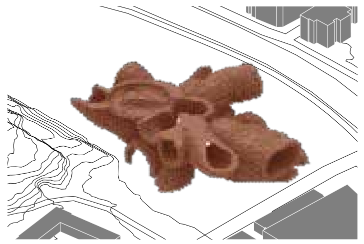

26. Lockers room defined next to entrance.


27. Interior flow adjusted.


28. Shape reaching for the hill.


29. Shape opened towards the hill


30. Outstretch towards hill tuned down. Connection to water empha-sized by extending cantilever to east.


31. walls made thinner.

6.7 MODEL EVOLUTION

Scripted digital models are useful, since it is relatively easy and time saving to generate a large quantity. However, to really get an idea of the geometry, spatial qualities, light conditions, relation to site etc. physical models are better for careful investigation and evaluation. Some of the computer-generated model diagrams in previous chapter were 3d-printed and evaluated in relation to the site model.

Original model [0] on site

Process model [17] on site

Final model [30] on site

7. DESIGN PROPOSAL

7 DESIGN PROPOSAL

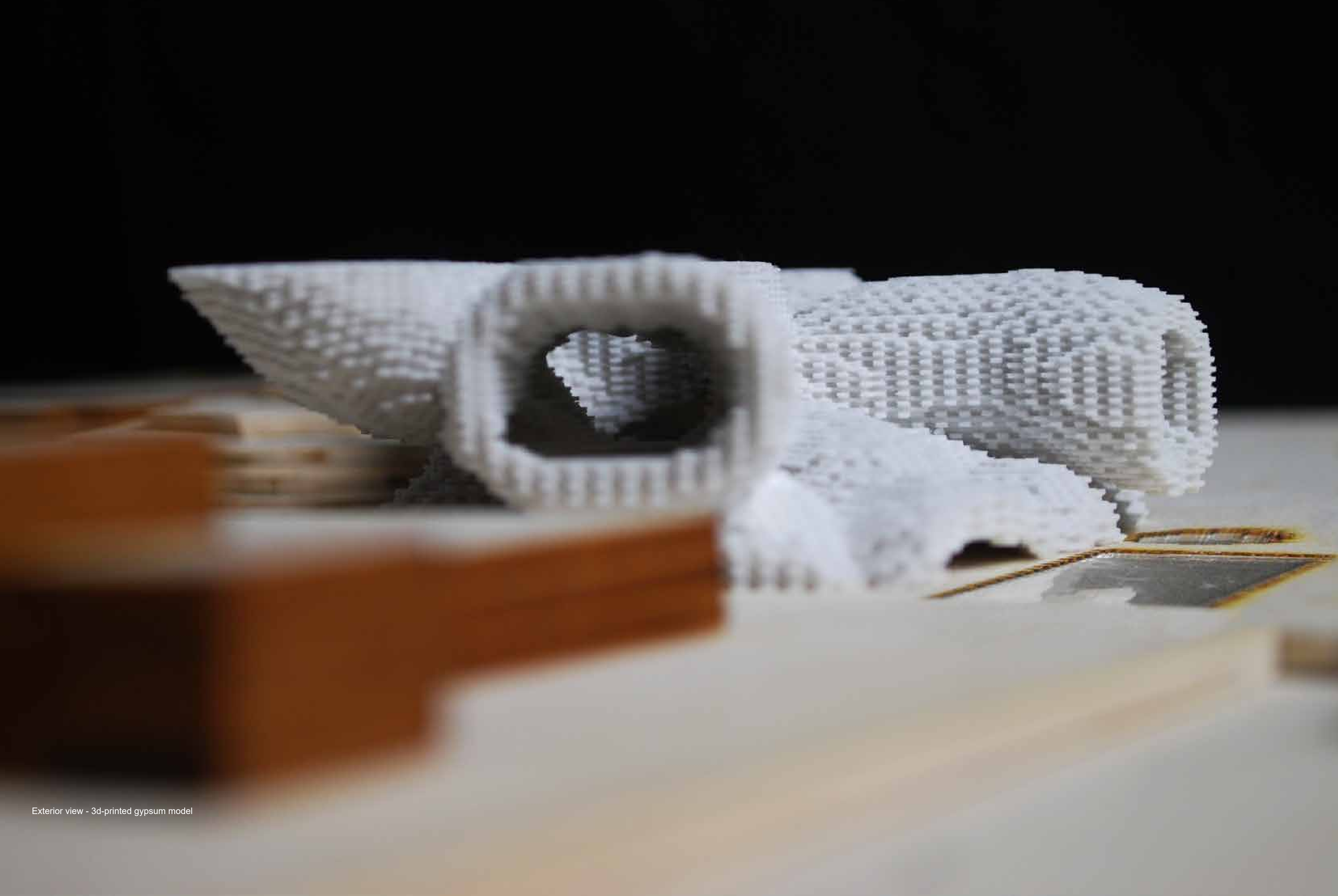
The design proposal is the last step in a series of experimental investigations. Hence, the purpose is to manifest the design process and architectural design ideas in one object, rather than showing construction documents and visualizations for a final design proposal.

The representations at the following pages has a low voxel resolution, if nothing else is stated, where each voxel corresponds to 10 times the size of a standard brick. Yet, some areas have been highlighted with a higher resolution and level of detailing to give more realistic idea of the spatial experience. The reason for tuning down the resolution is that it today is not possible with an ordinary computer to handle the amount of data that is required for modeling and visualizing a more realistic representation.

The driving architectural concept has been to fit main functions, such as pools, jumping tower, slider etc., within the voids of the global shape, while secondary functions, like stairs, corridors, toilets etc., is planed within the walls. The consequence of this in combination with previous steps in the process is a mazelike structure with flowing spatial sequences.

The shapes of the pools are supposed to blend in to the overall structure, but there is also a logic to their shape and size so that they correspond to 25m or 50m pools. The sports administration suggests that a new central bath shall include two 50m pools and two 25m pools (Malmryd, 2016)

7.1 EXTERIOR MODEL



Exterior view - 3d-printed gypsum model

7.2 INTERIOR MODEL

Interior model

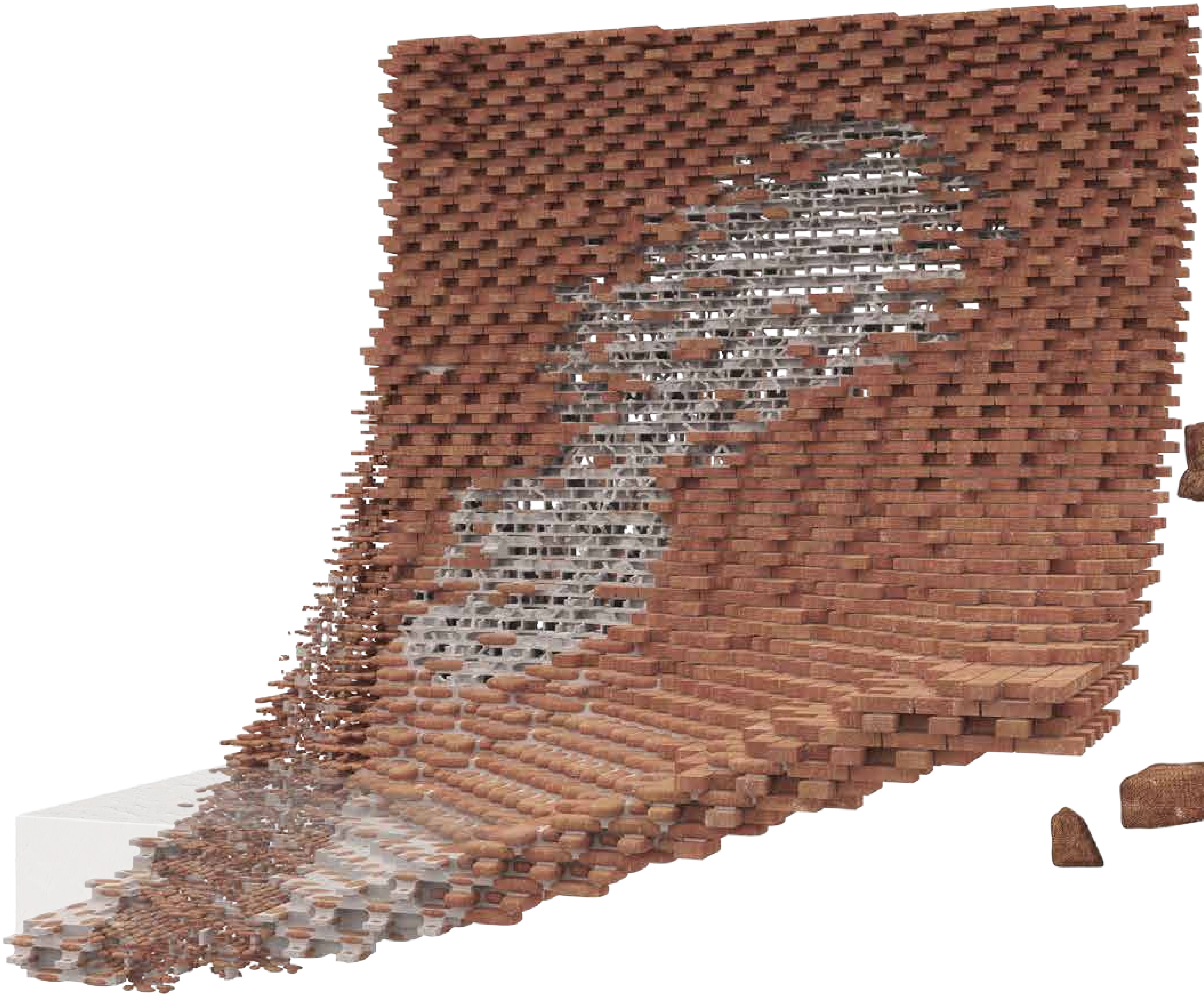
7.3 SITE

Site, Valhalla IP 1:1000

7.4 INTERIOR PERSPECTIVE

Low-res voxel interior perspective from entrance floor

7.5 MORPHING BRICKS

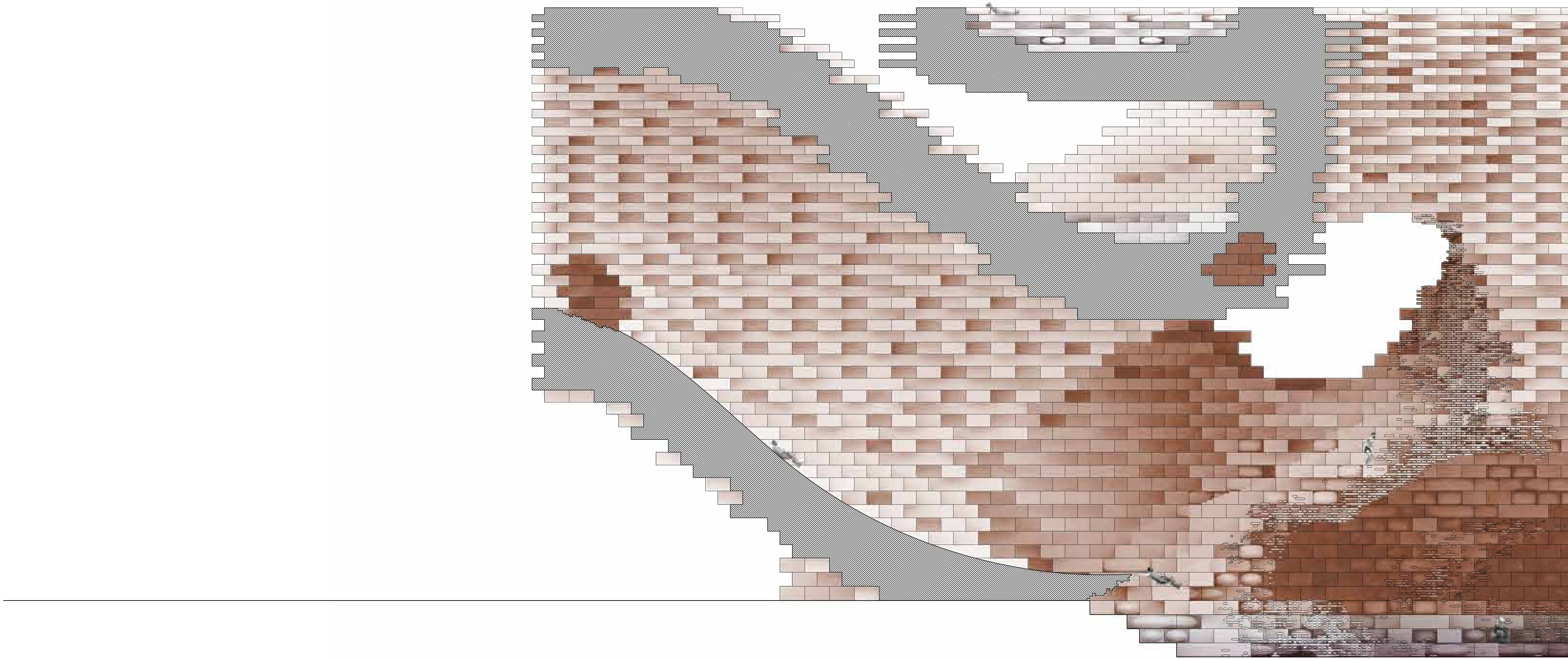


High-res voxel section cut

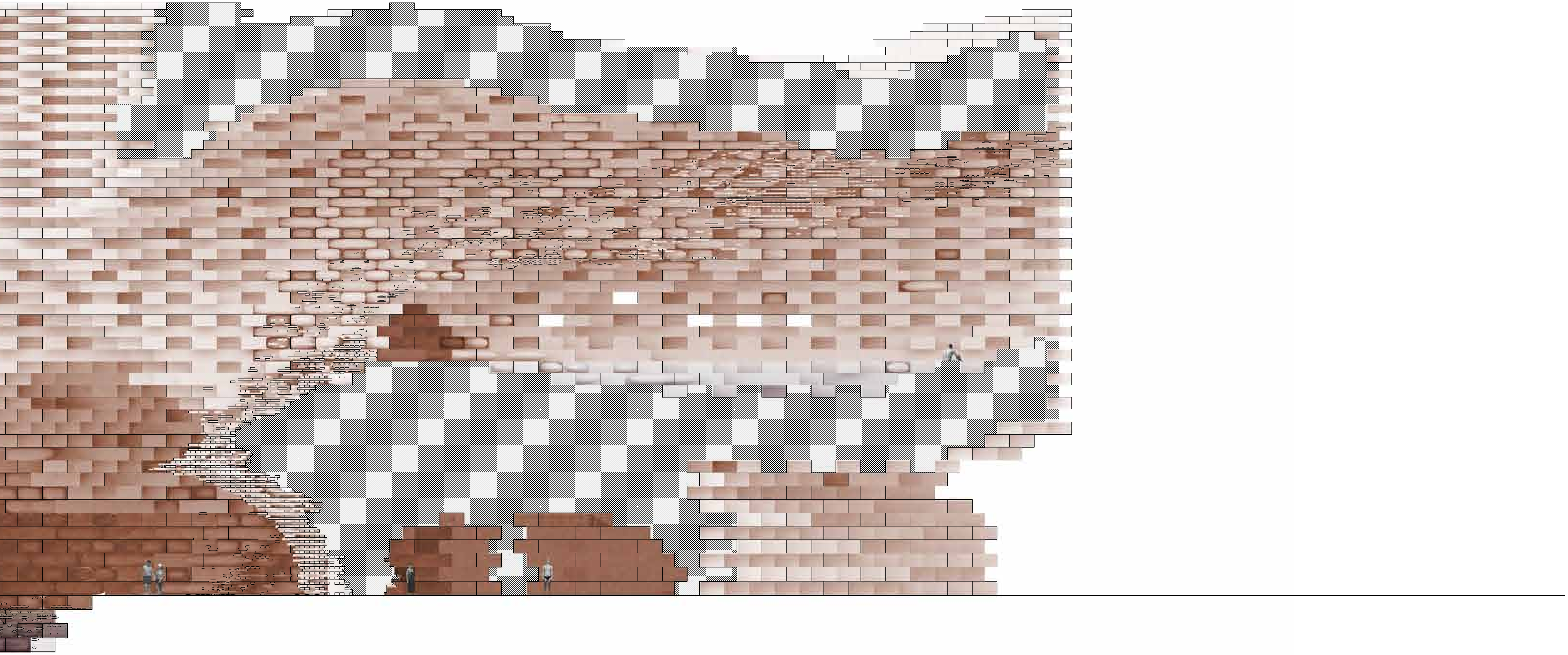

MORTAR STRUCTURE - BRICK WASHED AWAY
SUBDIVIDED
PATTERNED
SUBDIVIDED AND ROUNDED
Rounded

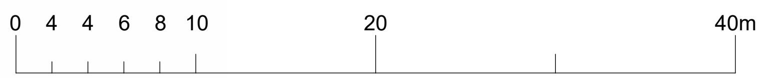
7.6 SECTIONAL DRAWINGS

The sectional drawing is represented with voxels that corresponds to 10 times the size of a standard brick, but some areas has been highlighted with brick representations. Other features that is visualized is the gradual shift of voxel/brick height that corresponds to the building height but reversed, and in some areas, rounded voxels in areas close to the pools. The purpose with rounded bricks is to create a more comfortable bath situation.



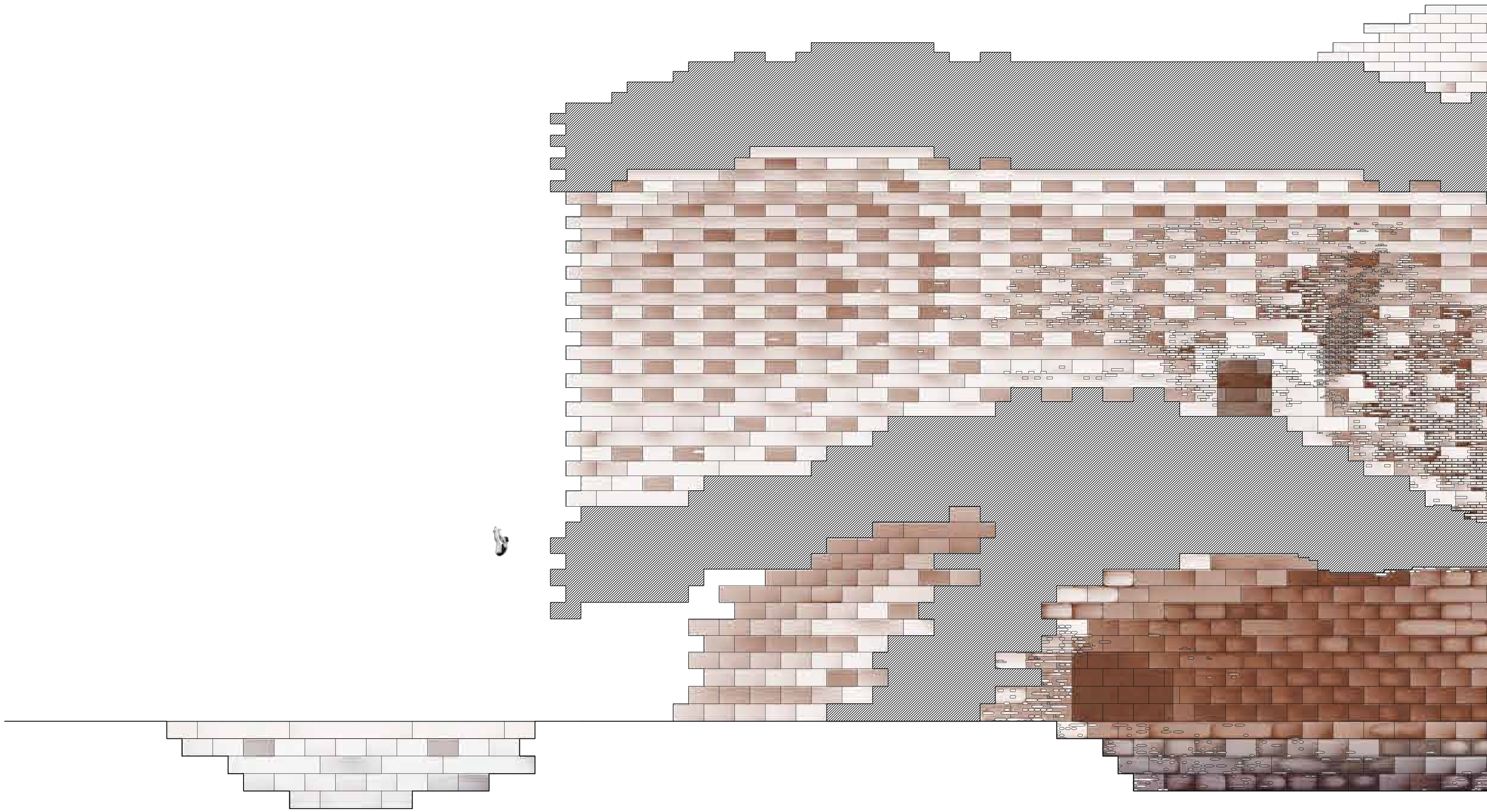
SECTION AA 1:400



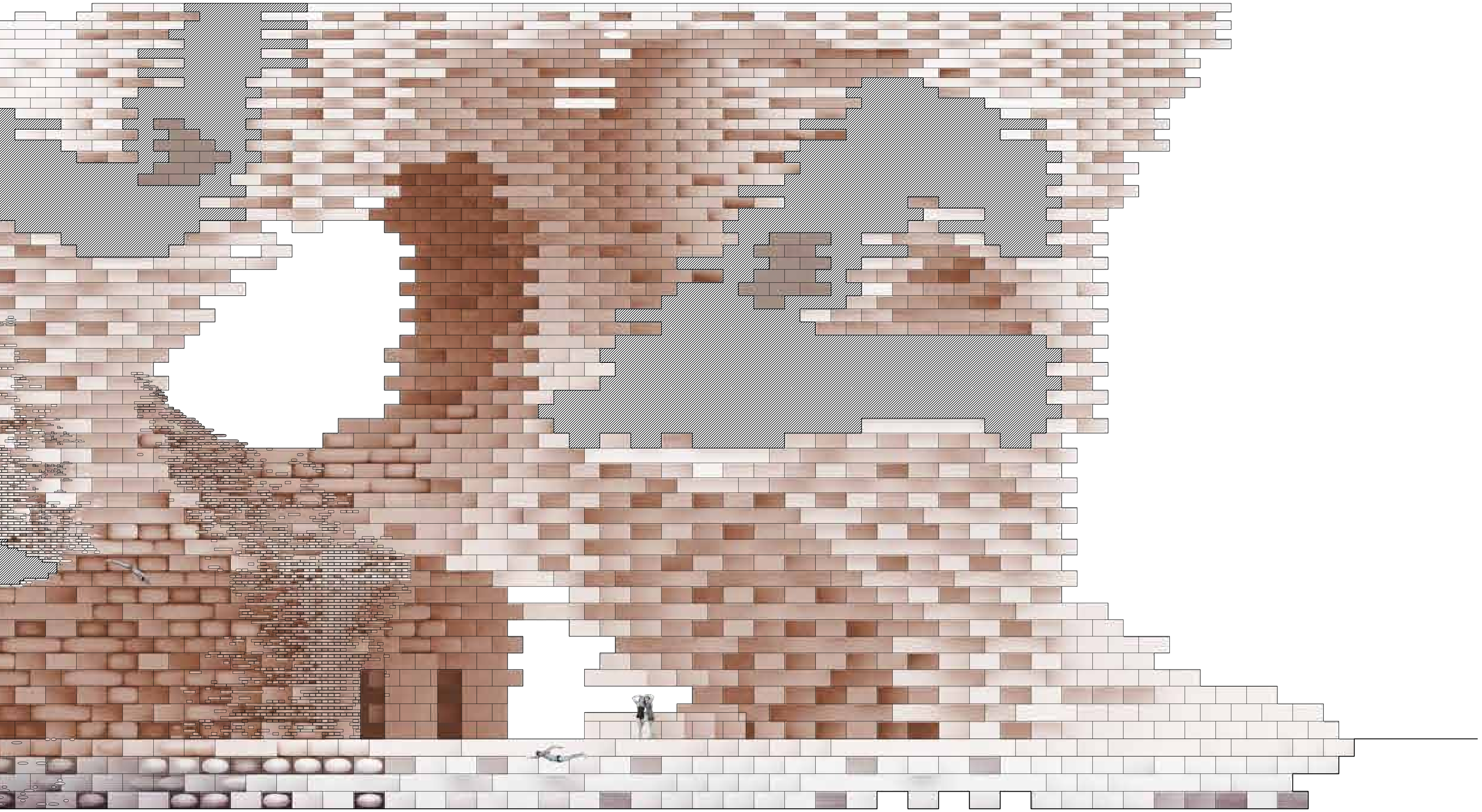

0 4 4 6 8 10 20 40m

7.6 SECTIONAL DRAWINGS

The sectional drawing is represented with voxels that corresponds to 10 times the size of a standard brick, but some areas has been highlighted with brick representations. Other features that is visualized is the gradual shift of voxel/brick height that corresponds to the building height but reversed, and in some areas, rounded voxels in areas close to the pools. The purpose with rounded bricks is to create a more comfortable bath situation.



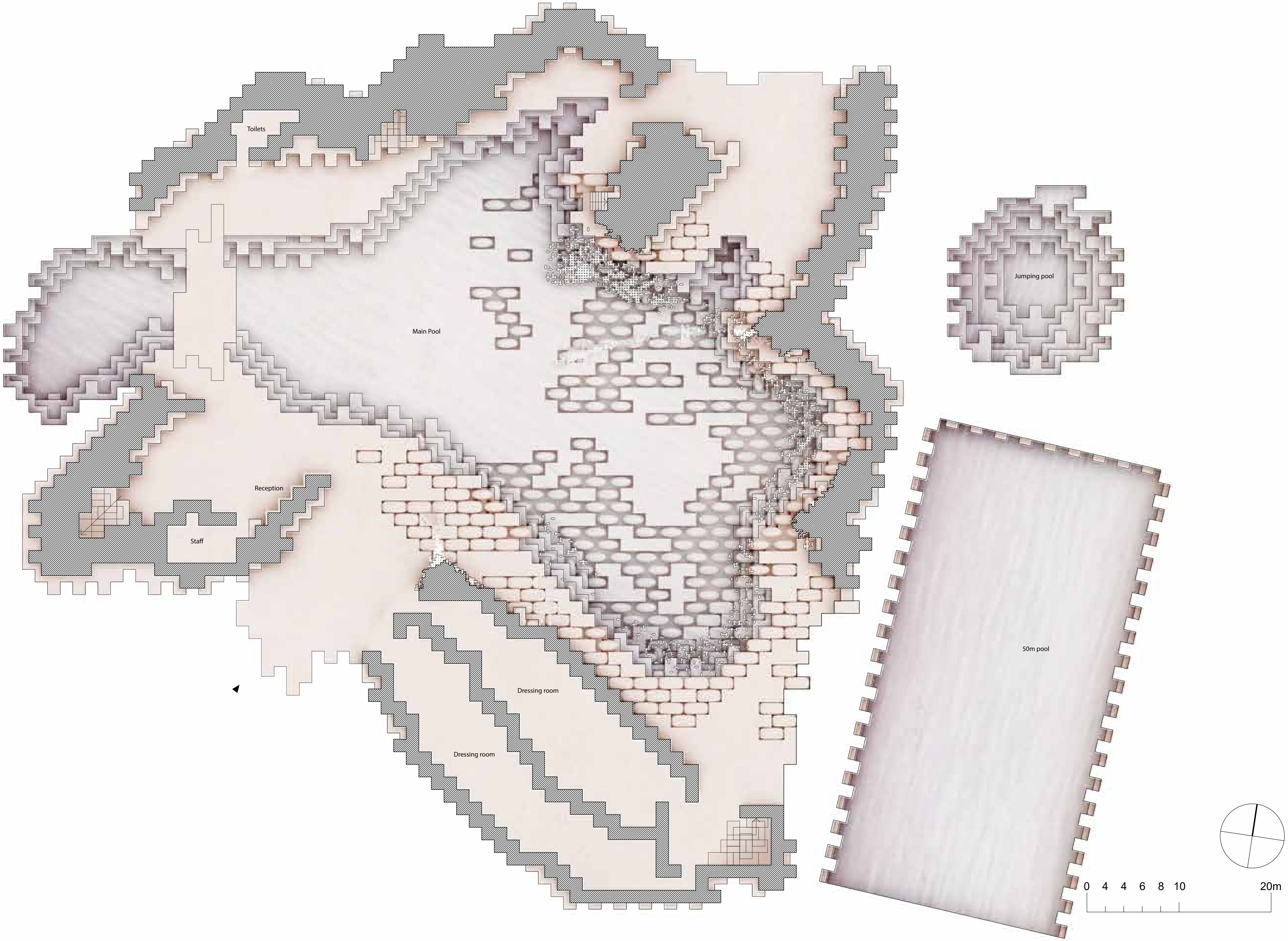
SECTION BB 1:400



0 4 4 6 8 10 20 40m

7.7 FLOOR PLANS

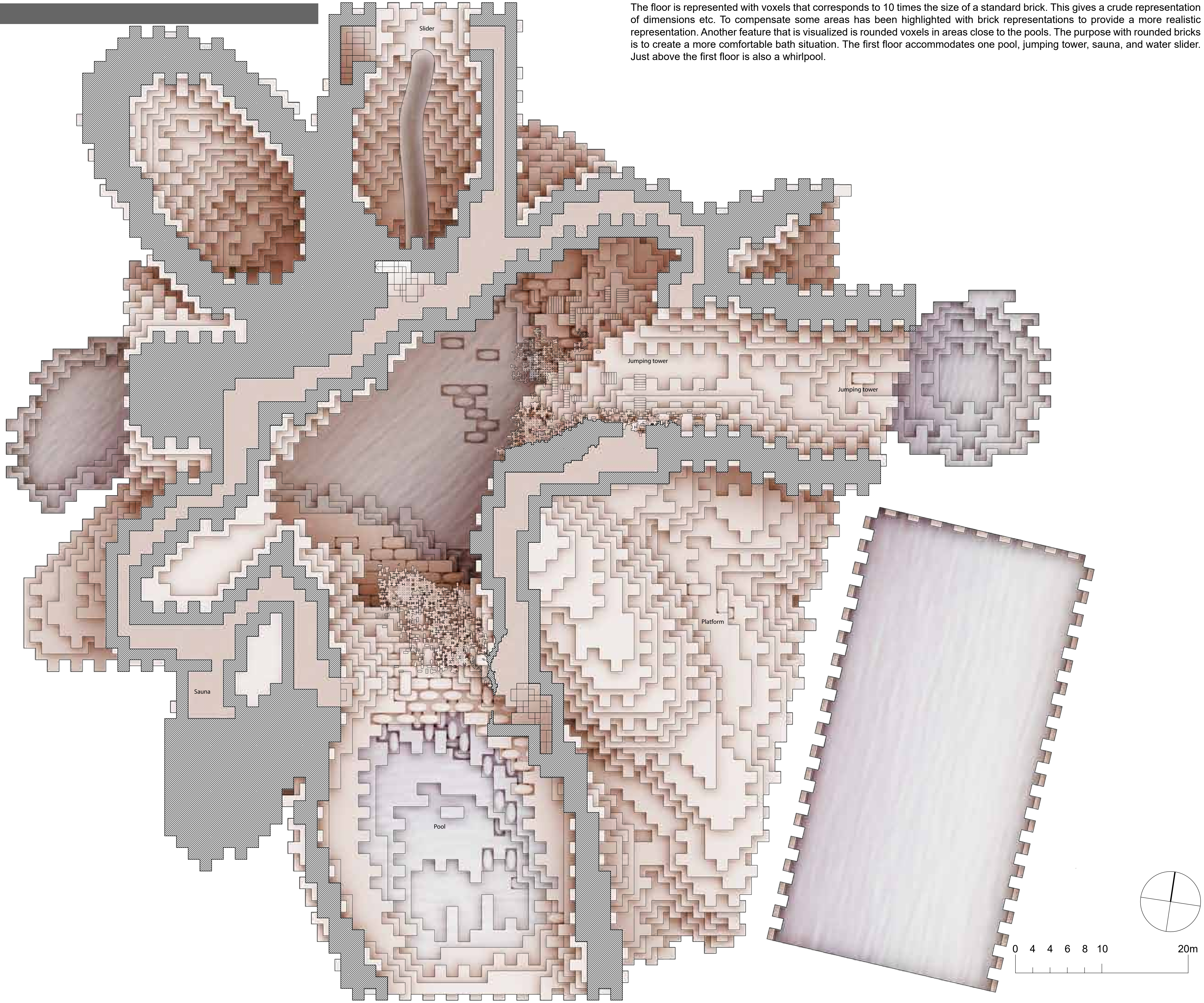
The floor is represented with voxels that corresponds to 10 times the size of a standard brick. This gives a crude representation of dimensions etc. To compensate some areas has been highlighted with brick representations to provide a more realistic representation. Another feature that is visualized is rounded voxels in areas close to the pools. The purpose with rounded bricks is to create a more comfortable bath situation. The entrance floor accommodates the main pool, changing rooms, reception, staff room and toilets. There are also two outdoor pools.



ENTRANCE FLOOR 1:400

7.7 FLOOR PLANS

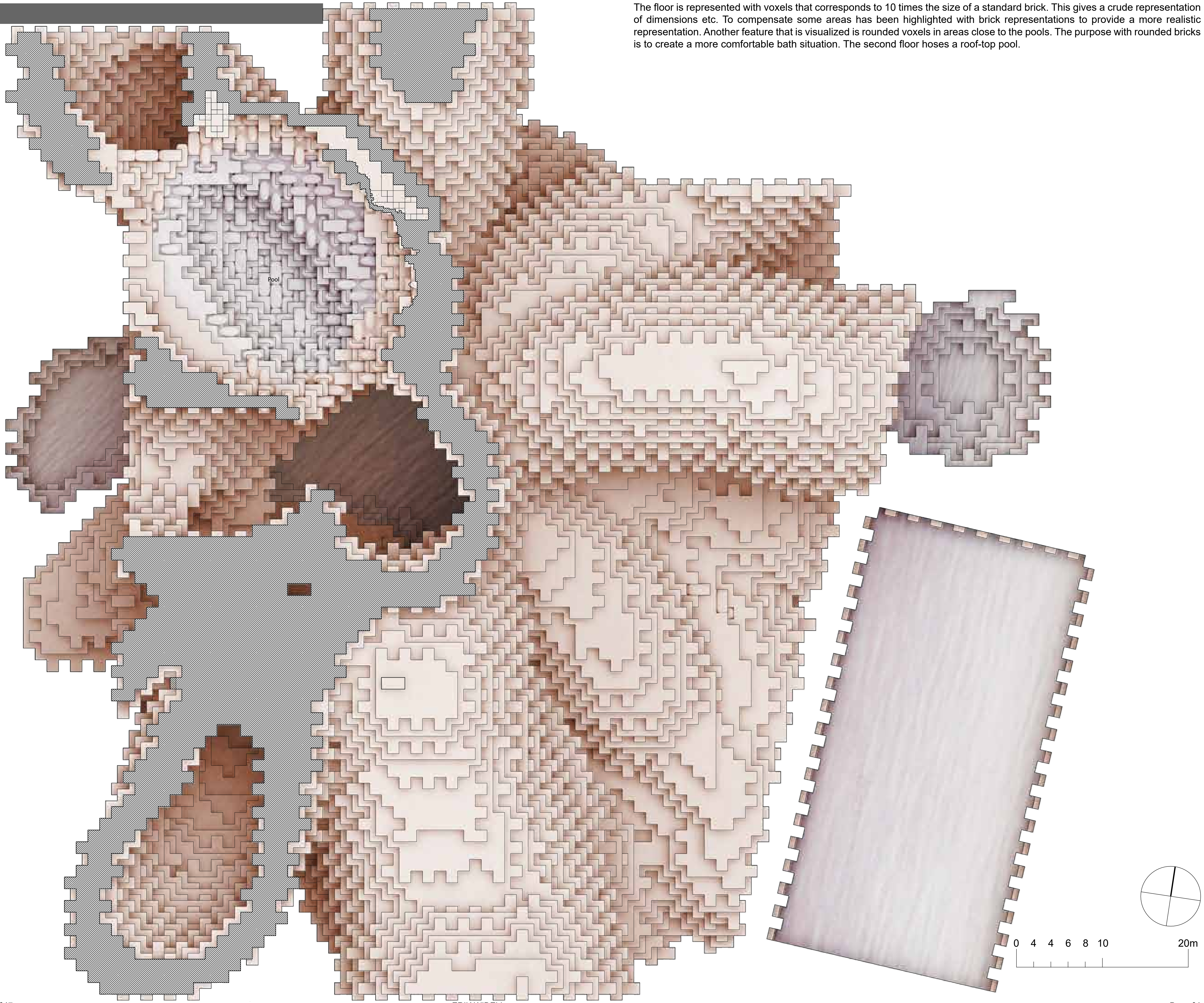
The floor is represented with voxels that corresponds to 10 times the size of a standard brick. This gives a crude representation of dimensions etc. To compensate some areas has been highlighted with brick representations to provide a more realistic representation. Another feature that is visualized is rounded voxels in areas close to the pools. The purpose with rounded bricks is to create a more comfortable bath situation. The first floor accommodates one pool, jumping tower, sauna, and water slider. Just above the first floor is also a whirlpool.



FIRST FLOOR 1:400

7.7 FLOOR PLANS

The floor is represented with voxels that corresponds to 10 times the size of a standard brick. This gives a crude representation of dimensions etc. To compensate some areas has been highlighted with brick representations to provide a more realistic representation. Another feature that is visualized is rounded voxels in areas close to the pools. The purpose with rounded bricks is to create a more comfortable bath situation. The second floor hoses a roof-top pool.



SECOND FLOOR 1:400

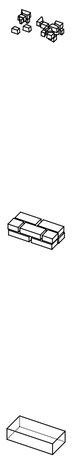
8. DIGITAL MANUFACTURING

8 DIGITAL MANUFACTURING

The ability to manage complexity in geometric shape, spatial organization and building material was limited before the digital revolution because of orthogonal structures in the building process, as Tedeschi (2014) notes. Digital manufacturing creates a direct link between the designer and the final geometry. For this project it is suggested to send coded instructions to 3d-printers and robots. Drawings will merely serve as complementary aids.

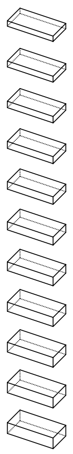
8.1 BRICK PROPERTIES

Based on chapter 2, Grammar and chapter 4, Scale and resolution, a collection of techniques was chosen in order to create variations and ornamental expression.



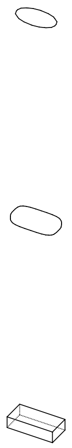
Subdivision / Resolution shift

shift in brick resolution to create a variation that corresponds to the curvature of the global shape



flatness

flatter bricks at the top to express the height difference in the building

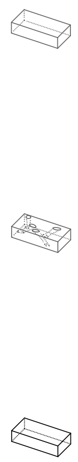


Roundness

An initial proposal was to combine a structure where the bricks are aligned with the shape, close to the pools and a more jagged structure, further away from the pools. Due to geometrical issues a better solution appeared to be to keep the jagged structure everywhere, but to make the bricks rounder the closer they are to the pools. The purpose is to create a more comfortable bath situation.

patterned

To create a sense of intimacy, some bricks will be patterned. This occur in areas where a higher level of intimacy may add value to the spatial experience, for example adjacent to a big opening in the structure, where people might want to sit down for contemplation and relaxation.

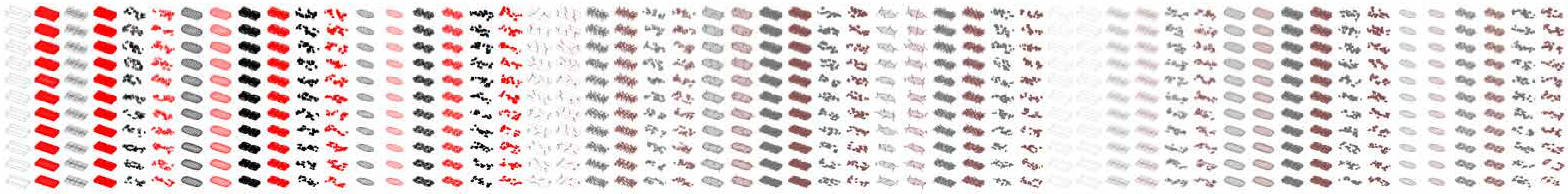


Transparency

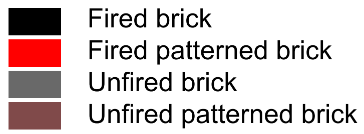
transparency, that is windows etc., is achieved by replacing some normal bricks with unfired bricks that will be pressure-washed away after the mortar has dried. To achieve a gradient, some of these bricks will be made with voids so that mortar can flow within the brick.

8.2 BRICK CONFIGURATIONS

Since each brick/voxel is assigned with a series of properties a large number of different configurations is achieved. The current setup means that there are 594 possible configurations (3*11*3*2*3).



All possible brick configurations



8.3 PRODUCTION METHOD AND DIGITAL INPUT

Each bold number correspond to the same position in the diagram at the facing page. The columns below the number displays the related settings. These coded instructions constitute the link between the 3d-model and the built geometry, and follows each element from raw material to assembly.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
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2	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75	0,75
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2	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65	0,65
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2	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
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2	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
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2	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
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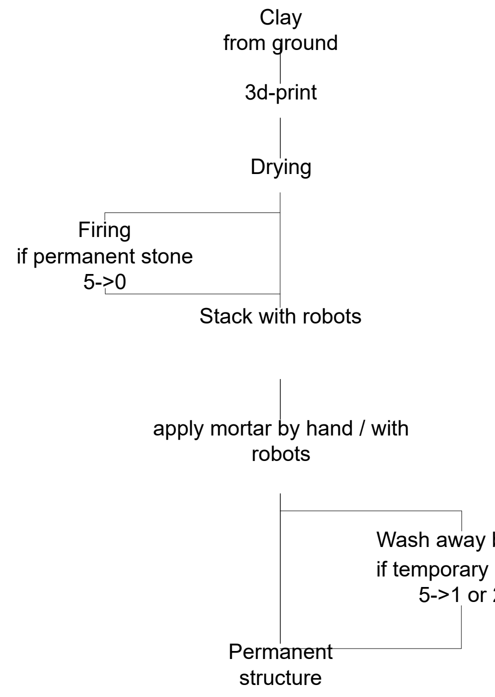
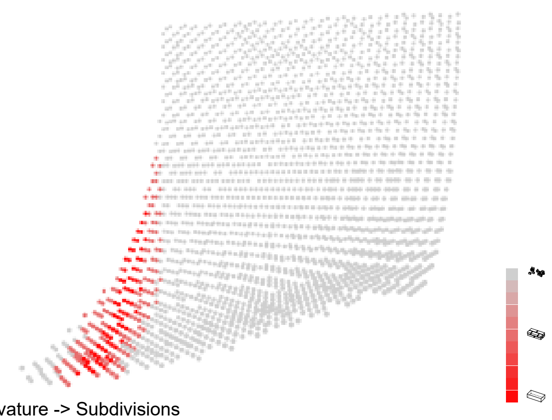


Suggested Production process

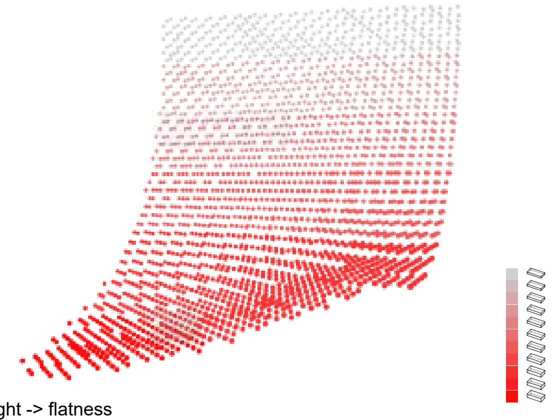
1 -> subdivisions, 1=Subdivided once, 2=Subdivided twice
2 -> Height, 1=Predefined height..., 0,5=50% height
3 -> Roundness, 0 = straight, 1 = Rounded edges, 2= Round
4 -> Pattern, 0=not patterned, 1= patterned
5 -> type, 0=fired brick, 1=unfired void brick, 2=unfired brick

8.4 SHAPE ANALYSIS / ASSIGNING BRICK PROPERTIES

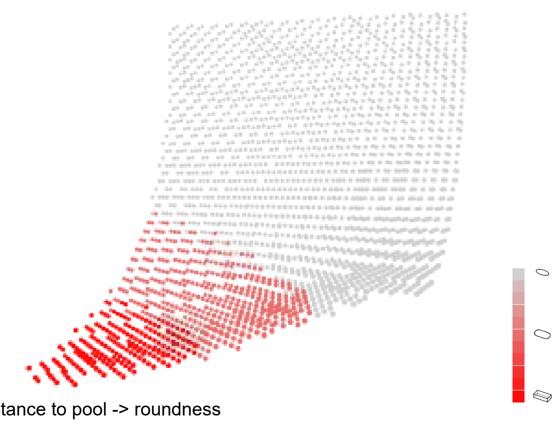
The diagrams display gradual transformations of morphologic bricks/voxels, and how the transformation depends on physical and manually defined properties of the shape. The upper row shows a high-res section cut while the bottom row shows a low-res global shape. A great advantage is that parametric fine tuning allows for gradient changes. It is also possible to replace, add or remove any properties. Apart from giving characteristics to the design, the idea is also that the properties will guide the visitor through the mazelike structure.



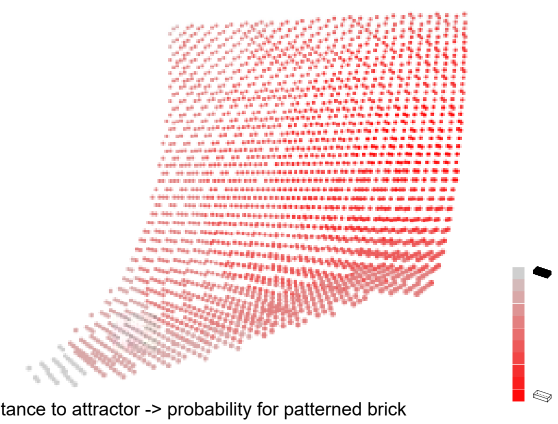
Curvature -> Subdivisions



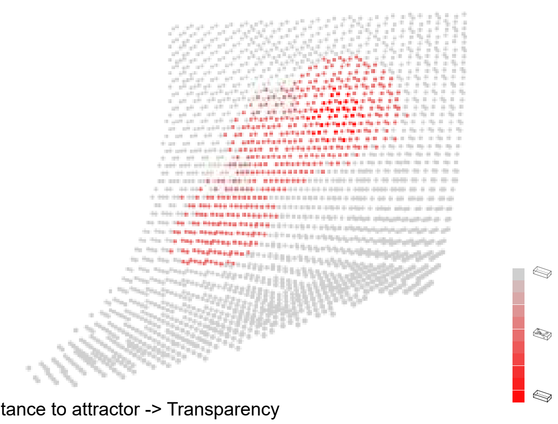
Height -> flatness



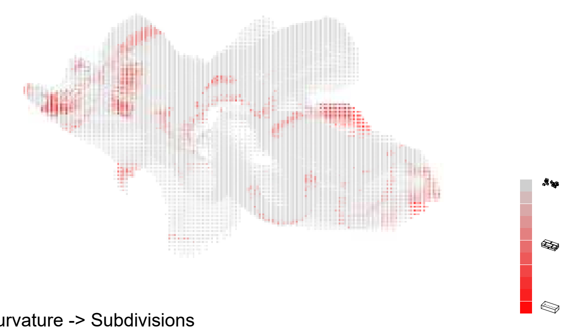
Distance to pool -> roundness



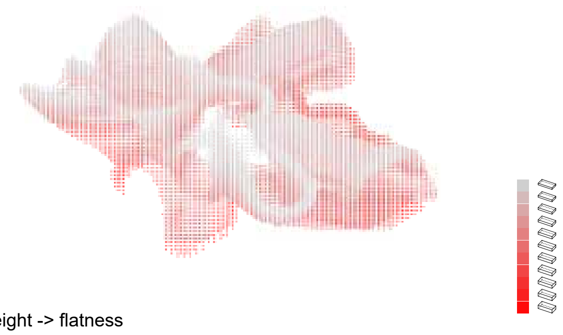
Distance to attractor -> probability for patterned brick



Distance to attractor -> Transparency

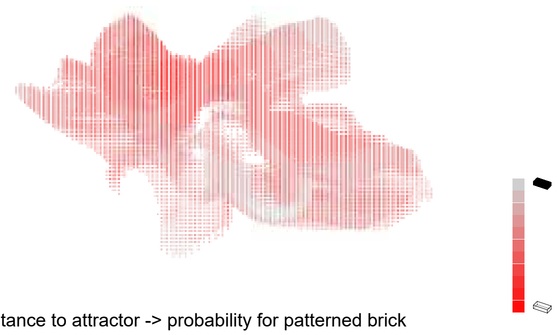


Curvature -> Subdivisions

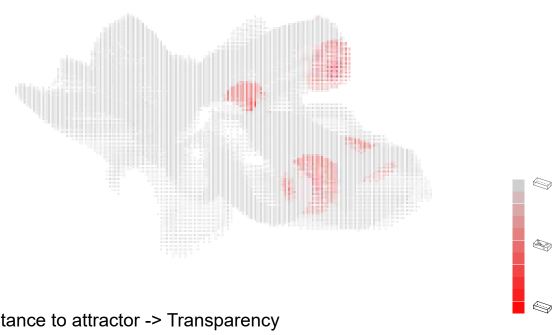


Height -> flatness

Distance to pool -> roundness



Distance to attractor -> probability for patterned brick



Distance to attractor -> Transparency

9 DISCUSSION

9. DISCUSSION

The conclusion of the thesis is that craftmanship in digital brick architecture may be achieved through an iterative, experimental and integrated design process with consideration to feasible construction and design methods and part to whole relationship. The part to whole relationship is with advantage treated with voxelization. For representation of the global geometry the resolution may be lowered to the point where the essence of the geometry is preserved and where the amount of data is manageable. A higher voxel resolution that corresponds to the size of an actual brick is feasible for representing details. The downside with the low-res approach is that the representations may show dimensions that doesn’t necessarily corresponds to their actual dimension in the analogue world. The benefit however of using voxels as a mean to model brick architecture is that there potentially will be a stronger relationship between the part and the whole. In a near future, when the computers have higher capacity, it is fair to assume, that there will not be a need to tune down the resolution, meaning that the use of voxels as a mean for digital brick modeling will be even more useful.

The result of the project is a design proposal for a bath house, but the thesis also provide a design methodology. The methodology can be interpreted in four ways:

1. an algorithm and modeling procedure with various voxel resolution.
2. A design procedure for brick architecture, that follows the described steps in the thesis.
3. A design procedure, similar to the one that has been described, but tweaked to suit another material or context.
4. A three step procedure: define, evaluate and evolve, where the design process guides every next iteration.

The development of the bath house followed the 4th interpretation. This was a cumbersome process, which meant that less attention could be given to the design proposal, than if the steps taken had been given from the start. In the spirit of craftmanship suggested future challenges is about refinement of methodology, the techniques and the object.

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APPENDIX - SCRIPTING AND MODELING PROCEDURE

0.

Rhino:
Define layers and geometries:
GH-input/
start_point
curve_for_generating_geometry
void_curve
solid_curve
Solid_Brep
Void_Brep
3d_Domain
subdivided_3d_domain
Brep_round_attractor
Pt_craft_attractor
Pt_transparency_attractor

1.

Grasshopper:
Run script (1-3)
1: Setting up brick geometry and domain for positioning
2: Define geometry
3: Bake positioning points

2.

Grasshopper:
Run script (4-6) twice (mortar between = false AND mortar between = true):
4. Branching points into layers depending on bonding pattern
5. Analyze shape and assign properties
6. Bake bricks with assigned properties in separate layers

-> Output (mortar between=true):
01_Brick
01_Brick_craft
01_Brick_erode
01_brick_holes_erode
01_hole_makers

-> Output (mortar between=false):
01_mortar
01_mortar_erode

3.

Grasshopper:
Run script (7) on objects in 01_Brick_craft)

-> Output:
02_Brick_craft

4.

Rhino:
01_brick_holes_erode -> MeshtoNURB

Grasshopper:
Run script (8) Bake_hole_stones

-> Output:
02_Brick_holes_erode

Rhino:
Duplicate layer 02_Brick_holes_erode, including objects. Rename new layer to 03_Brick_holes_erode

5.

Rhino:
Duplicate layer 01_Brick_erode, including objects. Rename new layer to 02_Brick_erode
02_Brick_erode-> MeshtoNURB, delete mesh

6.

Rhino:
01_mortar->meshtoNURB, BooleanUnion, offsetsrf inwards (rounded), delete inputs, delete small parts

7.

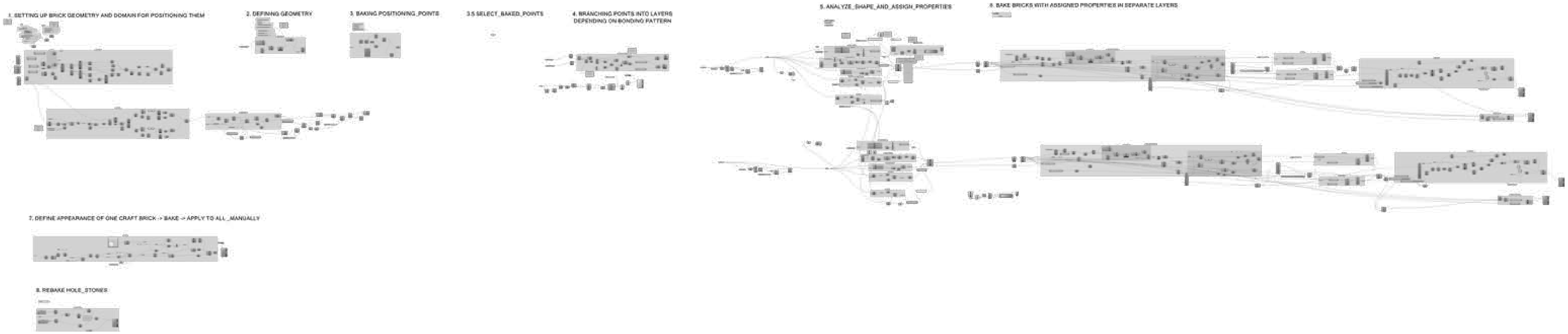
Rhino:
01_mortar_erode->meshtoNURB, BooleanUnion, offsetsrf inwards (rounded), delete inputs, delete small parts

8.

Rhino:
Booleandifference 01_mortar_erode - (02_brick_erode + 03_brick_holes_erode), delete layer 02_bricks_erode and 03_brick_holes_erode

9.

turn on layer 01_mortar, 01_mortar_erode, 03_brick_holes_erode, 02_brick_erode



Grasshopper script

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