ATELIER OF SOUND

Lis Ejdemo

Master thesis spring 2024

Examiner: Mikael Ekegren

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Chalmers School of Architecture

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ACEX35 Master thesis direction: Building Design and Transformation

ABSTRACT

This thesis investigates the interaction between architecture and sound, it addresses how sound is perceived within a spatial invention and during its travel through it. The project presents and explore different methods to influence sound waves by design, with the aim of tailoring the auditory experience. Through a multidisciplinary approach encompassing architecture, acoustics and phenomenology, the study seeks to answer the question: How can architecture influence, or modify, sound through the understanding of space, material and construction in a building dedicated for live performances of music?

The investigation delves into two segments, materiality and form. It seeks to demonstrate the impact of each segment within the realm of acoustics and identifies tools to manipulate sound through thoughtful design and selection of material. To evaluate the impact of these segments, a study was conducted by measuring simulated sound in 3D-models. The outcome of the study identified optimal forms and materials for each space of the project.

The architectural invention is situated at Sjöbergen in Gothenburg, located near the art museum Röda Sten. The rocky terrain, slow-paced river, and proximity to the city center present unique challenges and opportunities.

The building's design-narrative revolves around a central axis, serving as a backbone that leads visitors through a sequence of spaces, each offering different atmospheres. From the intimate spaces of narrow corridors to expansive openness of concert halls, the architectural transition unfolds. Moving down in the building the contrast between the light concert hall and the dark one reveals. Continuing out in the nature the visitor moves alongside the cliff and arrives to the amphitheater, the third and last space for music.

The outcome of this thesis project unveils the relationship between sound and space. It critically reflects on designing without awareness of the sonic experience and highlight the responsibility an architect has on affecting the human behavior in the built environment.

Keywords: Acoustics, phenomenology, sound, music

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PART I

Introduction

PURPOSE, AIM & PROBLEM DESCRIPTION

The thesis aims to explore how sound is experienced when it exist and travels in a building. It will investigate how an architect can design with the sound experience in an early stage, instead of using absorbing add on materials in a late stage of the design phase. It also evokes the lack of consensus between the acoustics and aesthetics in spaces dedicated for music and sound. This manifests often in dark spaces with technical solutions in focus rather than the qualities of space. Therefore will the thesis touch upon how building aesthetics in terms of materiality, proportions, geometry and rhythm affect building acoustics. As hearing is one of the seven senses and therefore will the thesis also touch upon the field of phenomenology.

THESIS QUESTION

How can architecture influence, or modify, sound through the understanding of space, material and construction in a building dedicated for live performances of music?

DELIMITATIONS

The project will not investigate acoustics in a general matter but rather focus on how the design of a building affect how the sound travels and exist within a space. The research will not dig deep in the realm of physics but rather put light on how the architect can affect sound with the simple tools of design, more specifically by form and material of a space.

READING INSTRUCTIONS

The report is divided into three parts. Part I introduce the project by its theory, part II presents the architectural invention and part III consist of a discussion that concludes the work.

BACKGROUND

The thesis contributes to the research of how acoustics, architecture and experiences of senses all affect each other.

The thesis is positioned in the context of acoustics. From an architectural field it will investigate how spatial configuration affect the experience of sound. The thesis shed light on the importance of design spaces with the understanding of acoustics in mind in an early stage and not as an add on at the end of the design phase. Does the shape of the space and its materials affect the sound? If so, why and how? The result of the master thesis will unveil what forms and materials to aim for and which to avoid in a space for music events.

Sound is an important part of how the human body interact with the room. The ear can localize how big a room is, if someone else is in it or on its way entering. In fact - each encounter with architecture is a rich interplay of the senses; the dimensions of space, material and scale are measured by the eye, nose, ear and skin. To understand the experience of a space the aspect of phenomenology within the field of architecture is crucial. Juhani Pallasmaa writes "The way spaces feel, the sound and smell of these places, has equal weight to the way things look."

An architect's primarily task is to design qualitative buildings. Many aspects of an architect's profession involve visible solutions, such as composition of volumes, plan drawing and material palettes. Something that affects the experience of the building, yet remains invisible, is its sound. Something that seems like a good idea in a plan drawing may not translate as good in practice due to the question: how does it sound?

DICTIONARY

Acoustics
The scientific study of sound. (Cambridge Dictionary, n.d.)

Absorption coefficient
A value that is used to evaluate the sound absorption efficiency of materials from 0 not absorbed to 1 fully absorbed. (BAUX, 2020)

Decibel (dB)
A value of sound pressure. It represents the pressure of a sound relative to a reference value. Decibel is often described as sound level. (BAUX, 2020)

Hertz (Hz)
Stands for sound frequency, in other words, it represents the speed at which a sound vibrates. The speed of the vibrations determines the pitch of the sound. Human hearing spans from 20 to 20 000 Hz. Lower frequencies include bass notes while higher frequencies include sounds like bells and cymbals. (BAUX, 2020)

Sound
Something that you can hear or that can be heard. (Cambridge Dictionary, n.d.)

Sound transmission index (STI)
A measure of speech quality in a room. Value from 0, bad to 1, excellent. A number of factors influence speech intelligibility, the science based on the following 8 parameters: (BAUX, 2020)

- The speech level
- Frequency response of the channel
- Non-linear distortions
- Background noise level
- Quality of the sound reproduction equipment
- Echo (reflections with delay > 100ms)
- The reverberation time
- Psychoacoustic effect

Noise
A unwanted, unpleasant, or loud sound. The main difference between a pleasant sound and a noise is how the vibration is perceived by the individual. (Cambridge Dictionary, n.d.)

Phenomenology
The study of phenomena and how we experience them. (Cambridge Dictionary, n.d.)

METHOD THESIS PROJECT

In the beginning of the thesis workflow the primary focus was on gathering information of the site, theory and materials. The phase involved the collection of theoretical foundation, exploring phenomenology and acoustics. It aimed to find the backbone of the architectural invention and building its narrative and character. The theory investigations spanned through different scales from a spatial perspective, room configuration and flow, down to the details of chosen materials. Conclusions was sought through built reference projects, digital software as well as model explorations. The investigation searched both tangible and intangible aspects. Further on was the understanding of these key elements profited one another and overlapped. In this phase site explorations and analysis was made, especially regarding existing sound.

The design phase concentrated on translating the discoveries made in the previous phase to a form. The design did undergo experiments of how the invention interacted with the site as a whole as well as the bodies occupying it. Investigations was made until the building answered to the expectations and needs of the site, program, users, concept and theoretical backbone. The investigation involved trials in plan, section, elevation as well as material explorations.

The presentation phase was dedicated to collect and summarize the layers of the project, formulate its narrative and character. This resulted in sharpening the arguments of the choices made during the process. This phase was also about curating the finished drawings and models, ensuring its coherence and clarity of answering the research question.

METHOD ACOUSTIC INVESTIGATION

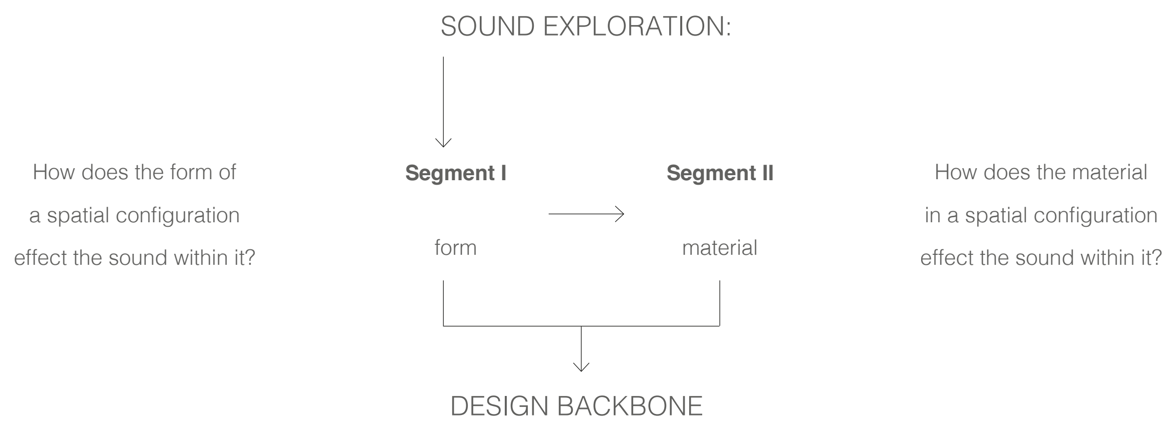
The acoustic research will mainly take part in the first phase of the thesis workflow. Subsequently it will be tested as a design during the second phase.

The core of the project is to explore how sound is experienced when it exists and travels in a building. To seek answer to the thesis aim digital software will simulate sound in 3D models and conclude the results in numbers and sound scenarios to listen to. The statistics was compared and results was conducted. The software used is named Treble Technologies.

The acoustic research has been divided into two segments to simplify the process. One of them is form and the other is material. The thesis will begin with the investigation of how the form of the spatial configuration effect the sound within it and the following research will be focus on the other segment, material. Answering the question of how the material in a spatial configuration effect the sound within it. The result from both segments have been the design backbone of the thesis project.

The chosen values is measured in Speech Transmission Index (STI). According to Baux (2020) STI is a measure of speech transmission quality. STI is measured in a value from 0 to 1, where 0 is bad and 1 is excellent.

In a playhouse, concert hall and theater the value recommended is around 0,62 (Baux, 2020).



THEORY, PHENOMENOLOGY

“The way spaces feel, the sound and smell of these places, has equal weight to the way things look.” states Juhani Pallasmaa in the book the eyes of the skin (1996). Every interaction with architecture unfolds as a symphony of sensory experiences. The eye, nose, ear and skin measure the dimensions of space, materiality and scale. Pallasmaa means that senses are crucial to fully understand the experience of a space.

On the topic of phenomenology Peter Zumthor writes in the book Atmospheres (2006) that interior environments functions as expansive musical instruments, projecting sound as well as capturing and enhancing it. This phenomenon is shaped by the unique forms of each room and the surfaces of the materials present within, as well as how these materials are utilized.

Zumthor continues and describes the beauty of contemplating a building as it takes shape and envisioning it bathed in stillness. Striving to craft a structure into a peaceful place. Visions arise about the sounds that will fill the space as people move through its corridors and when the conversations fill the space. Some buildings offer noteworthy acoustics, almost like a welcoming melody signaling that within those walls a sense of comfort can be established. (Atmospheres, 2006)

Steen Eiler Rasmussen states that the light in a building provide us with a visual impression, offering insights into its form and materials. Similarly, the sound it mirrors also play a role in our perception of its form and materials. Various room shapes and materials generate different reverberations, adding layers to the auditory experience and influencing our interpretation of the space. (Experiencing architecture, 1959)

Fig1. Swiss Sound box pavilion, Peter Zumthor, 2000

“Can architecture be heard?

Most people would probably say that as architecture does not produce sound, it cannot be heard. But neither does it radiate light and yet it can be seen.

We see the light it reflects and thereby gain an impression of form and material. In the same way we hear the sounds it reflects and they, too, give us an impression of form and material.”

- Steen Eiler Rasmussen

Experiencing Architecture, 1964

THEORY, ACOUSTIC

To incorporate acoustics into architectural design, it is essential to comprehend the nature of sound. What is sound? How does it work?
BAUX AB (2020) writes that sound is produced when something vibrates. In the realm of physics, the vibrations transform into sound waves, characterized by regions of high and low air pressure. As these sound waves reaches the ear and travels down the ear canal they vibrate the eardrums at an equal resonance. Then the vibrations are converted by the bones of the inner ear to nerve impulses, subsequently conveyed to the brain for analysis.

To manage sound in a closed indoor environment goes beyond locating and stopping its source. There are instances where the sound can be unavoidable or even essential, for example the sound of a coffee machine in a cafe or people talking and laughing in a bar. To control the sound its behavior or direction must and can only be influenced once it has set in motion. Sound waves outdoor travel freely in straight lines, while sound waves indoor react uniquely to various obstacles it hits. It can be walls, furniture or people. The sound wave can bounce off, maneuvering around or change direction as it moves from one obstacle to the next.

To grasp the principles of sound control it is essential to understand the behavior of sound when it travels in an enclosed space. Six different and common ways are the following:

Absorption
When a sound wave encounters an object or material and it absorbs the sound. The sound wave transforms into heat energy within the absorbing object or material. The extent of absorption depends on the thickness and composition of the material.

Diffraction
When a sound wave travels through a slim opening, like a doorway, it spreads out. It explains how individuals in one room can be able to clearly hear someone speaking in another room.

Diffusion
When a sound wave encounters an object or material a scattering phenomenon can occur and the wave spreads out in various directions. The specific way the sound diffuses depends on the characteristics of the surface. When it is hard to localize the sound source too much diffusion can be the reason.

Reflection
When a sound wave hits an object or surface reflection occurs. The wave rebounds and bounces back. This phenomenon is most evident in spaces with sleek and hard materials like stone. The consequence can be echo or amplified sound which can create an environment that feels excessively noisy.

Refraction
Is when a sound wave bends as it travels. The wave changes in both direction and speed depending on the properties and temperature of the object or material. So called "shadow zones" are the result of refraction, in those sound becomes inaudible despite the source being visible to the listener.

Transmission
When a sound wave travel through a material and is transferred to the other side, for example when you hear a neighbor in another apartment. The amount of transmission depends on how effectively the material block sound.

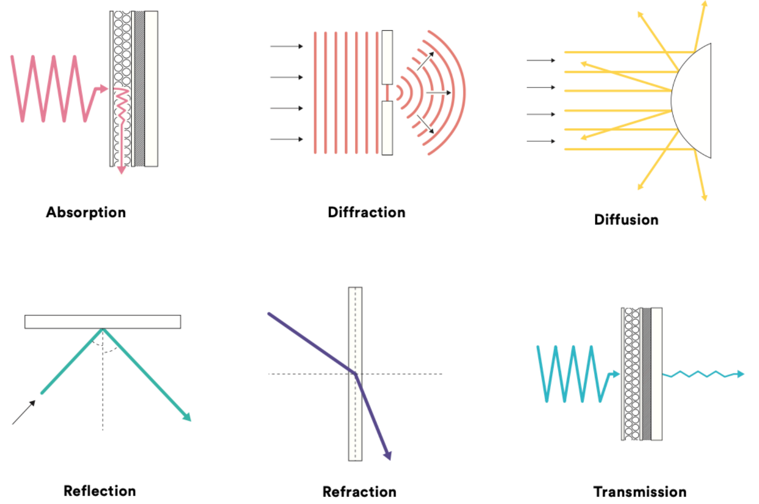


Fig 2. The fundamental of sound control, BAUX, 2020

TOOLS TO SHAPE THE ACOUSTIC ENVIRONMENT

The aim of acoustic solutions is to improve the sonic environment of a space and thereby enhance its intended functions, according to Baux (2020). Acoustics solutions can be broadly categorized into two types: soundproofing and treatment.

Soundproofing primarily focuses on preventing sound from either escaping the space or entering it. Soundproofing requires the incorporation of mass, as it is the fundamental element of preventing sound traveling through a medium to another.

On the contrary, acoustic treatment aims to refine and optimize the sound within a space to enhance clarity and therefore provide a superior sonic experience for the listener. It is designed to affect the dynamics of how sound waves move within the space. The acoustic treatment can distribute the sound waves direction or focus on absorbing them.

Maximizing the overall acoustic experience can be accomplished through these four tools:

Absorb
Materials with porous treatment absorb and capture sound waves leading to reduced sound reflection in a space. The materials are applicable in ceilings, floors, walls or integrated as a part of the furnishing. Important to note is that the goal is not always about adding as much absorbers as possible, it its rather about having the optimal quantity of absorbent materials determined by calculating the ideal reverberation time.

Block
The prevention of sound travel is achieved by incorporating barriers between the source of sound and the receivers in a space. These barriers may manifest as walls or big and tall furniture. It can also be about isolating a noise source, like a machine, by constructing a separate room for it.

Cover
Introducing additional sound can veil the existing sound in a space. The goal is to make it more challenging for the brain to pick up clear fragments of sound or conversation, enabling individuals to stay focused on their intended activities, for example work tasks. The additional sound sources can be music played though a loudspeaker or water pouring in a fountain.

Diffuse
By incorporating objects or materials with textured or uneven surfaces the sound is scattered in varied directions. The aim is to enhance the quality of the sound by reflecting and evenly spreading it. This means that when the sound reflects and re-enter the space it does not rebound in the original direction.

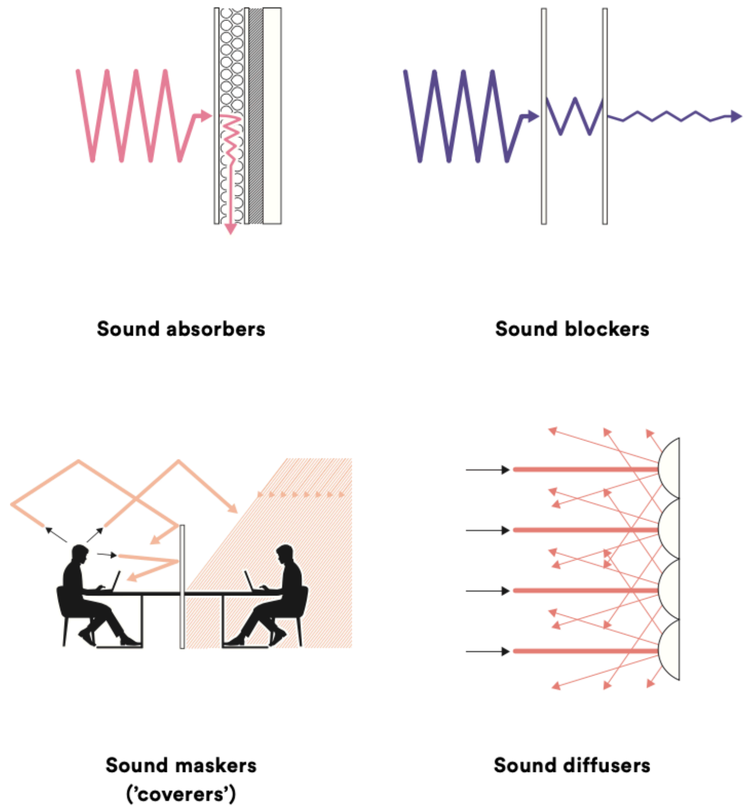


Fig 3. Types of acoustic treatment, BAUX, 2020

ACOUSTIC EXPLORATION

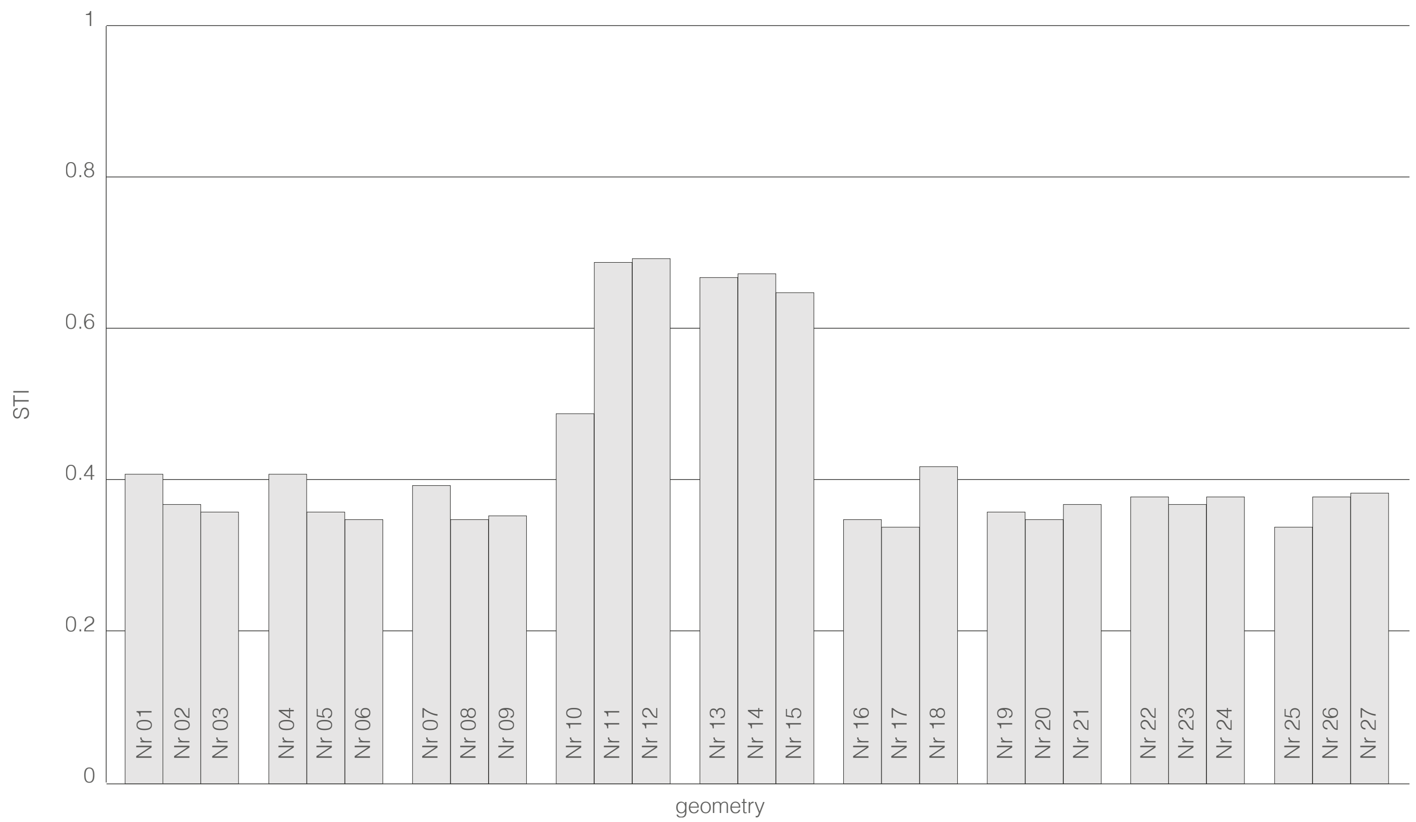
Seeking answer to the aim of the thesis an acoustic exploration has been conducted. The method used is manifested at page 15 whereas the following diagrams reveal the answer of the exploration. The analysis of the answers found will be carried out on page 68, Discussion.

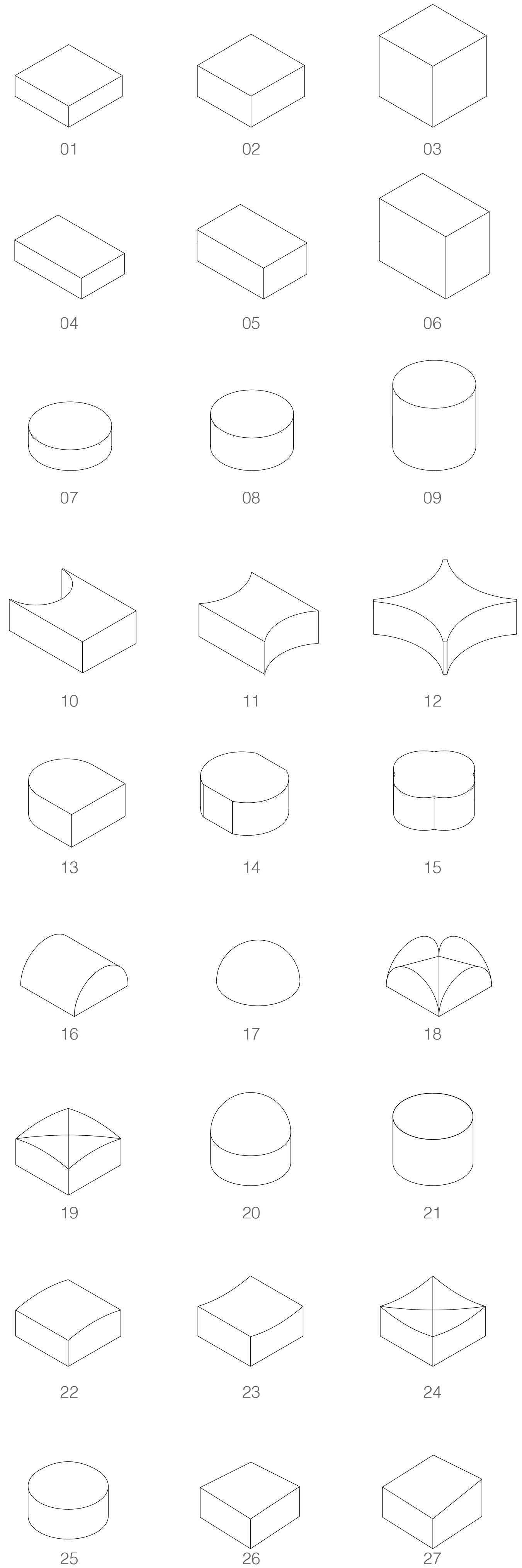
The sound is calculated with Speech transmission index (STI) from 0 (bad) to 1 (excellent). Measured at Noise criterion 25 dB.

In the first part the results from segment I, form, is presented. They reveal that forms 11 to 15 was approximately 30% better than the rest of the tested forms.

In the second part of the study the results from segment II, material, is presented. The numbers show that of the three chosen materials, concrete, wood and textile, incorporation of textile makes the value improves by 25%. This has to do with the absorption coefficient that is better for fabric than for wood and concrete.

Segment I - form

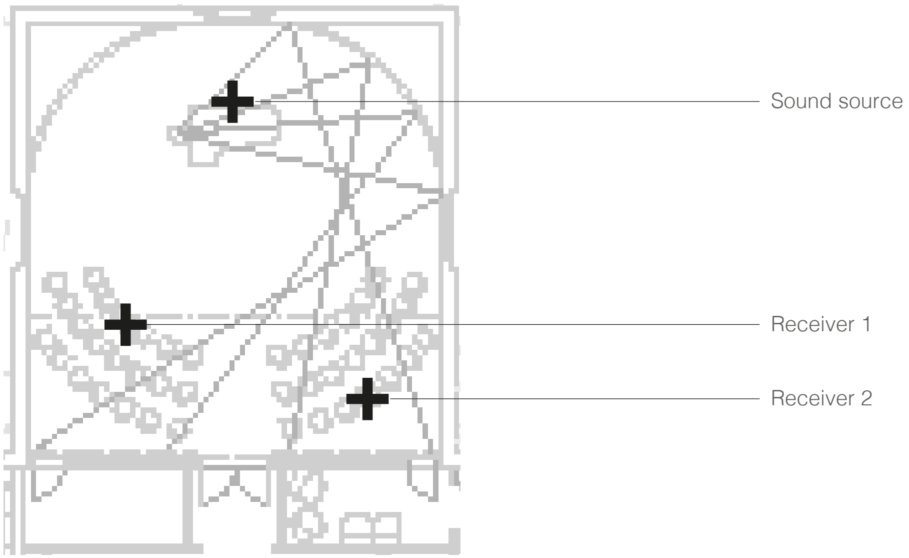




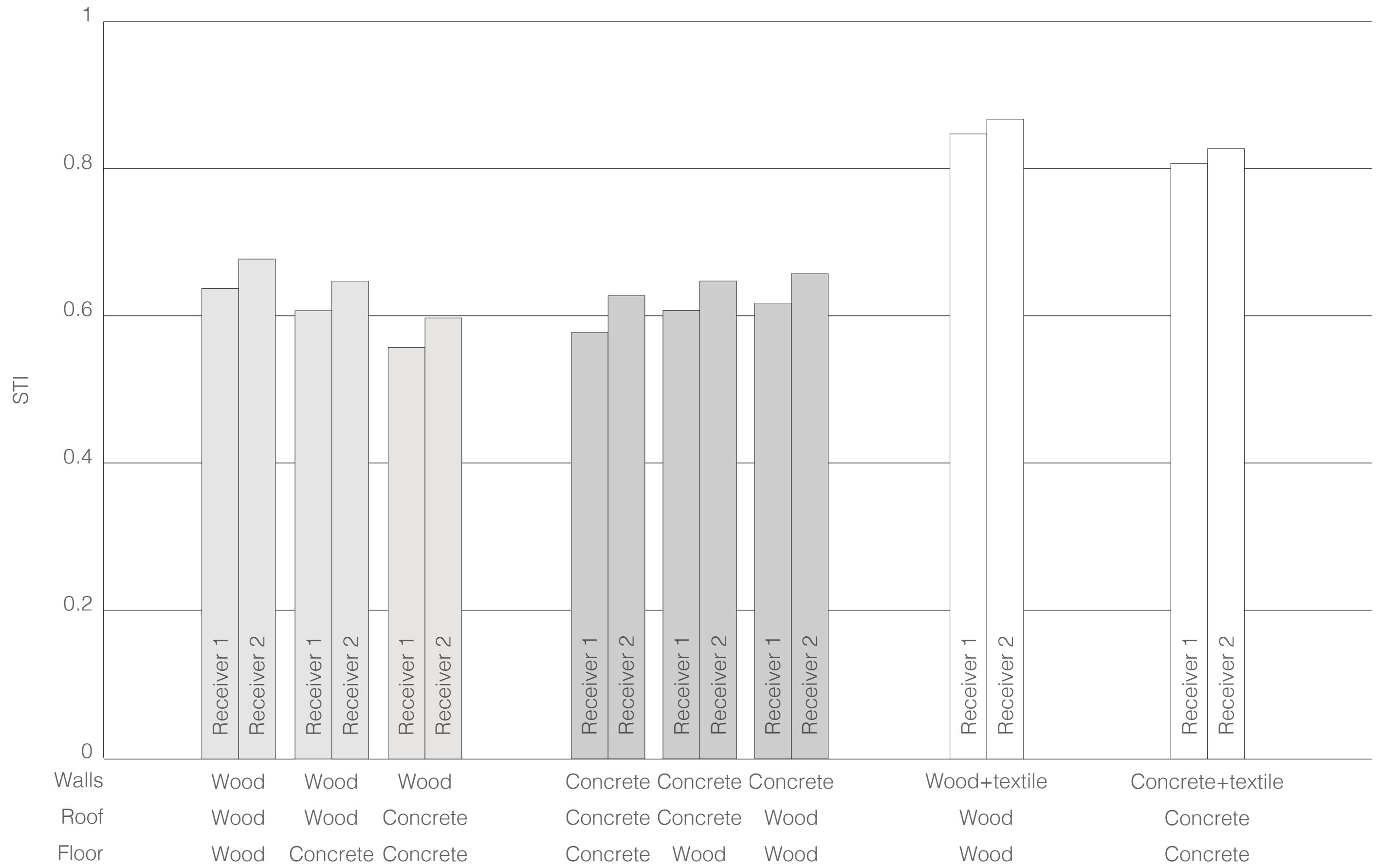
ACOUSTIC EXPLORATION

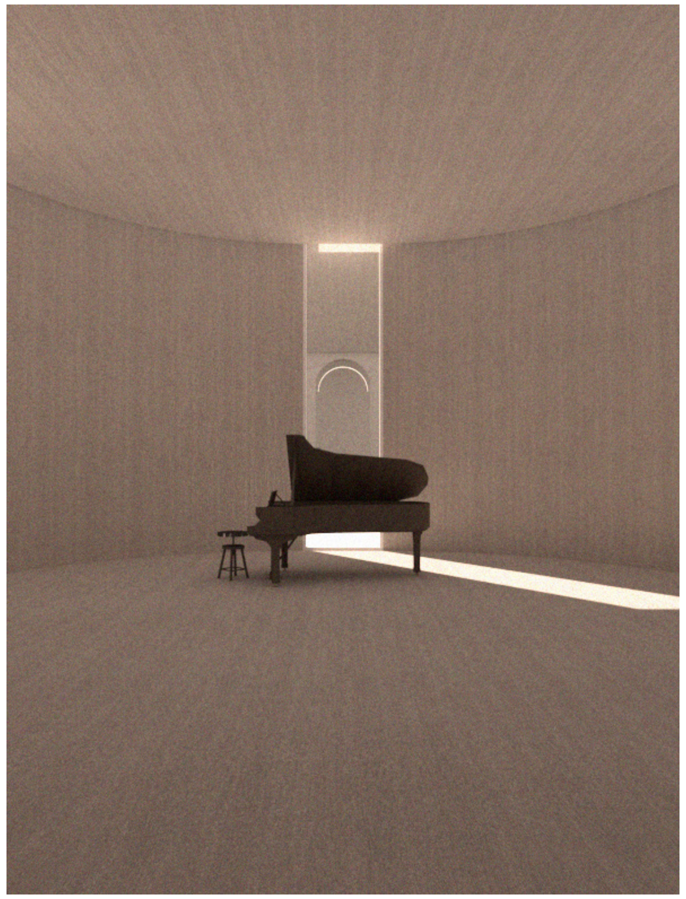
The absorption coefficient at 1000 Hz is the following: wood 0.08, concrete 0.08, concrete flooring 0.02 and fabric 0.46.

Measure points:



Segment II - material





PROJECT REFERENCES

Chapel of Sound and Chapel of Music are two buildings reviewed as references. They are relevant in terms of scale as well as program since both functions as buildings for live performances of music.

Chapel of Music, to start with, is made by Vector architects and is located in Japan. The position of the audience, seated as a circle around the sound source is an interesting observation but the most thrilling part of the building is its space underneath the hall. A room just for listening to the music, but not seeing it. According to its construction detail this is successful due to sound transmission tubes.

The other reference, Chapel of sound, is made by OPEN architecture and is located in China. This building is an amphitheater since it lacks a roof. The walls of the building has a cave- like formation and since the walls are not perpendicular to each other, the formation creates a good acoustic environment.

Fig 4. Listening hall. Chapel of Music, Vector Architects, 2023

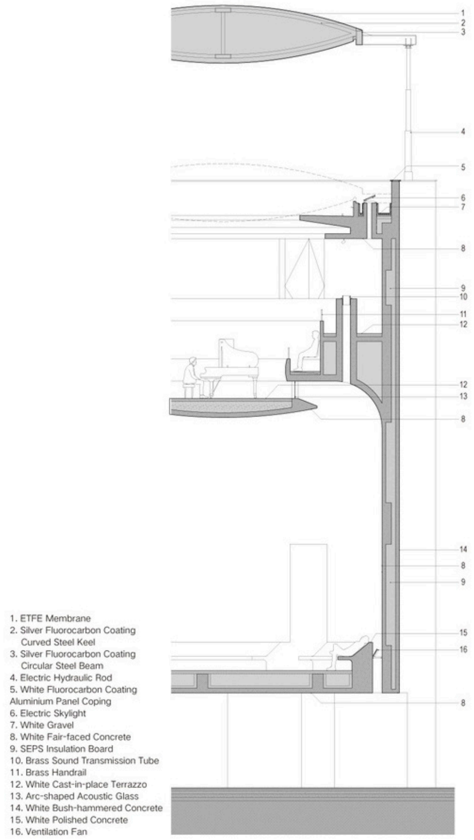


Fig 5. Acoustic detail. Chapel of Music, Vector Architects, 2023

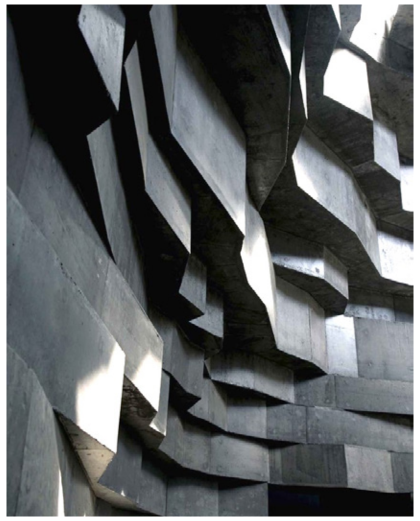


Fig 6. Walls in concert hall. Chapel of Sound, OPEN Architecture, 2021

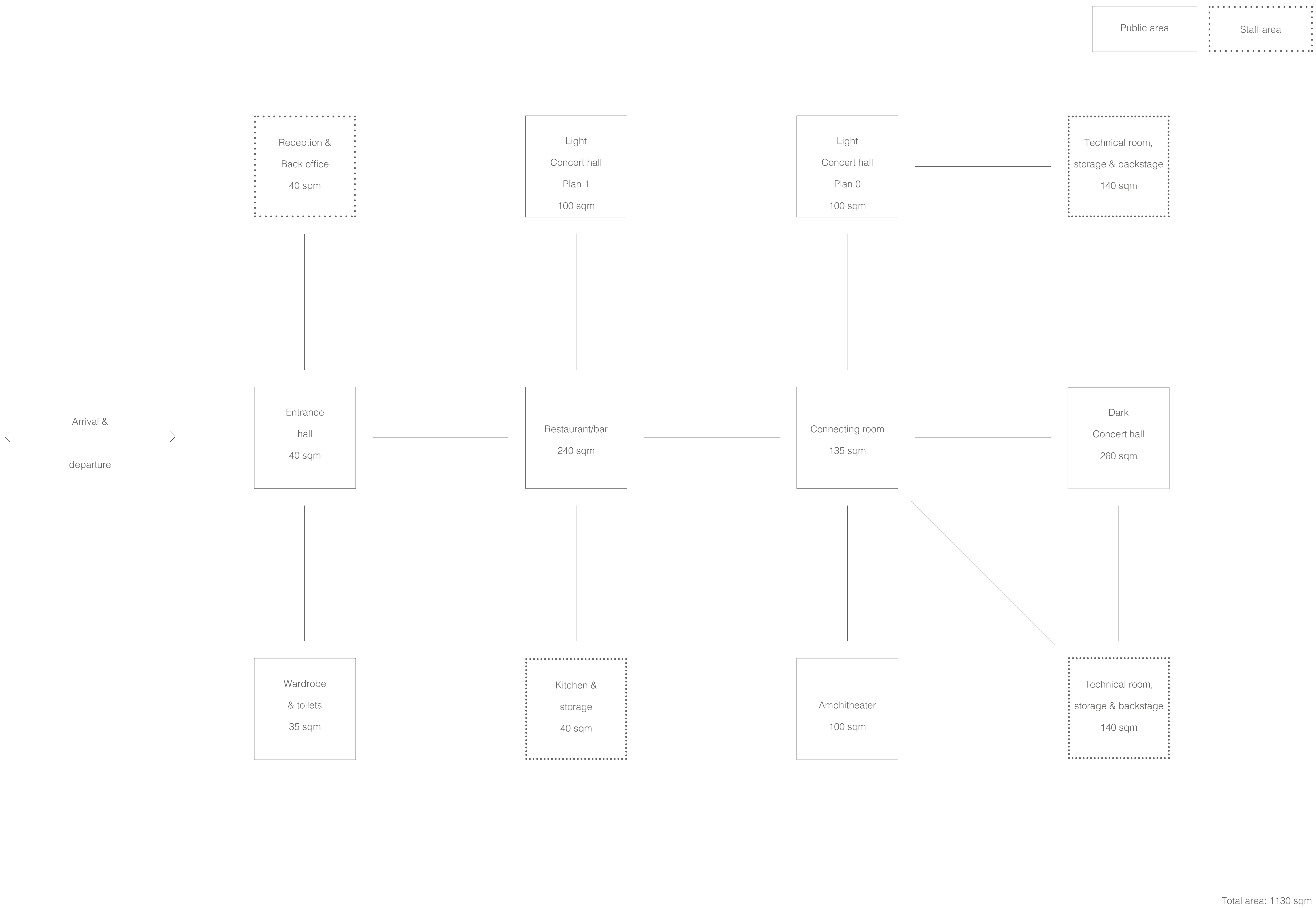
Fig 7. Sand casted concrete element. 35 Green Corner Building, Studio Anne Holtrop, 2020

Fig 8. Exterior design. More than a House, Xavier Corberó, 1935

Fig 9. Material palette. Chapel of Music, Vector Architects, 2023

PART II

Proposal


Public area
Staff area
Reception &
Back office
40 spm
Light
Concert hall
Plan 1
100 sqm
Light
Concert hall
Plan 0
100 sqm
Technical room,
storage & backstage
140 sqm
Arrival &
departure
Entrance
hall
40 sqm
Restaurant/bar
240 sqm
Connecting room
135 sqm
Dark
Concert hall
260 sqm
Wardrobe
& toilets
35 sqm
Kitchen &
storage
40 sqm
Amphitheater
100 sqm
Technical room,
storage & backstage
140 sqm
Total area: 1130 sqm

CONTEXT OF THE PROJECT

The chosen location for the invention is called Sjöbergen and is situated in Gothenburg on the west coast of Sweden. The site has a view over the port inlet of the city and adjacent to the Röda Sten art museum. Despite its proximity to the city center, the site is a bit hidden.

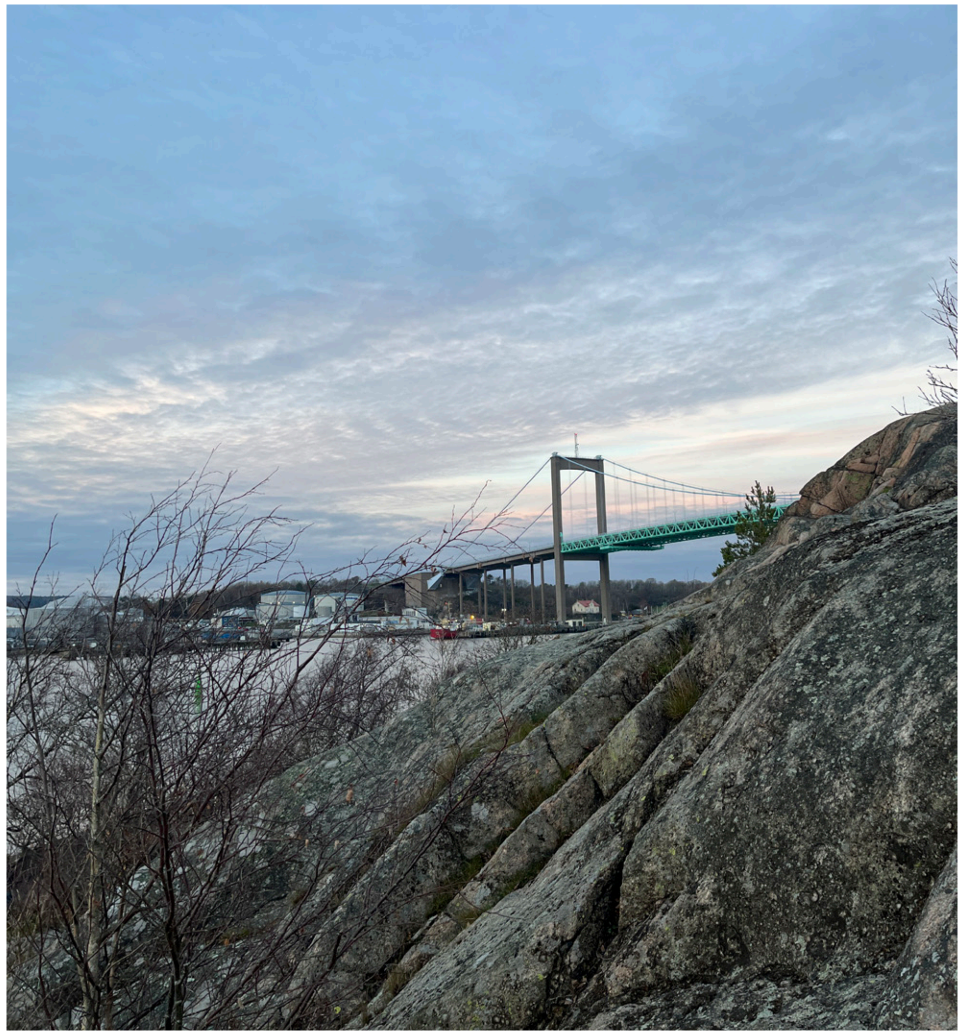
The nature at the site consists of primarily rocks and the river that moves by in a slow pace. The topography is steep which makes it possible to locate the invention a bit higher up, with the view towards the sea and the harbor, which is important for its history and cultural heritage of Gothenburg. In the evening sun the site bathes in warm light, creating a harmonious atmosphere during the building peak hours of activity.

The building will open up towards south, west and north to enhance the view, light and sound at the site. Big infrastructure nodes are located to the east and therefore will the building have a closed facade in that direction to block the noise of traffic.

The accessibility of the site from the Gothenburg city center is suitable for the buildings program and need. It can be reached in 20 minutes by bike or 30 minutes by public transport, with the final stretch of the journey along the waterfront of the Gothenburg river. As you approach the site, the port inlet lies ahead while the sound of the city appears from behind.

Since the site is located a few meters away from one of the two big bridges over the Gothenburg river the noise of traffic is present. This challenge is addressed throughout the project with well-considered volumetric studies were walls and landscape acts as barriers.

Harbor entrance // west



Älvsborgsbron // east

Rocky surface

Walkway

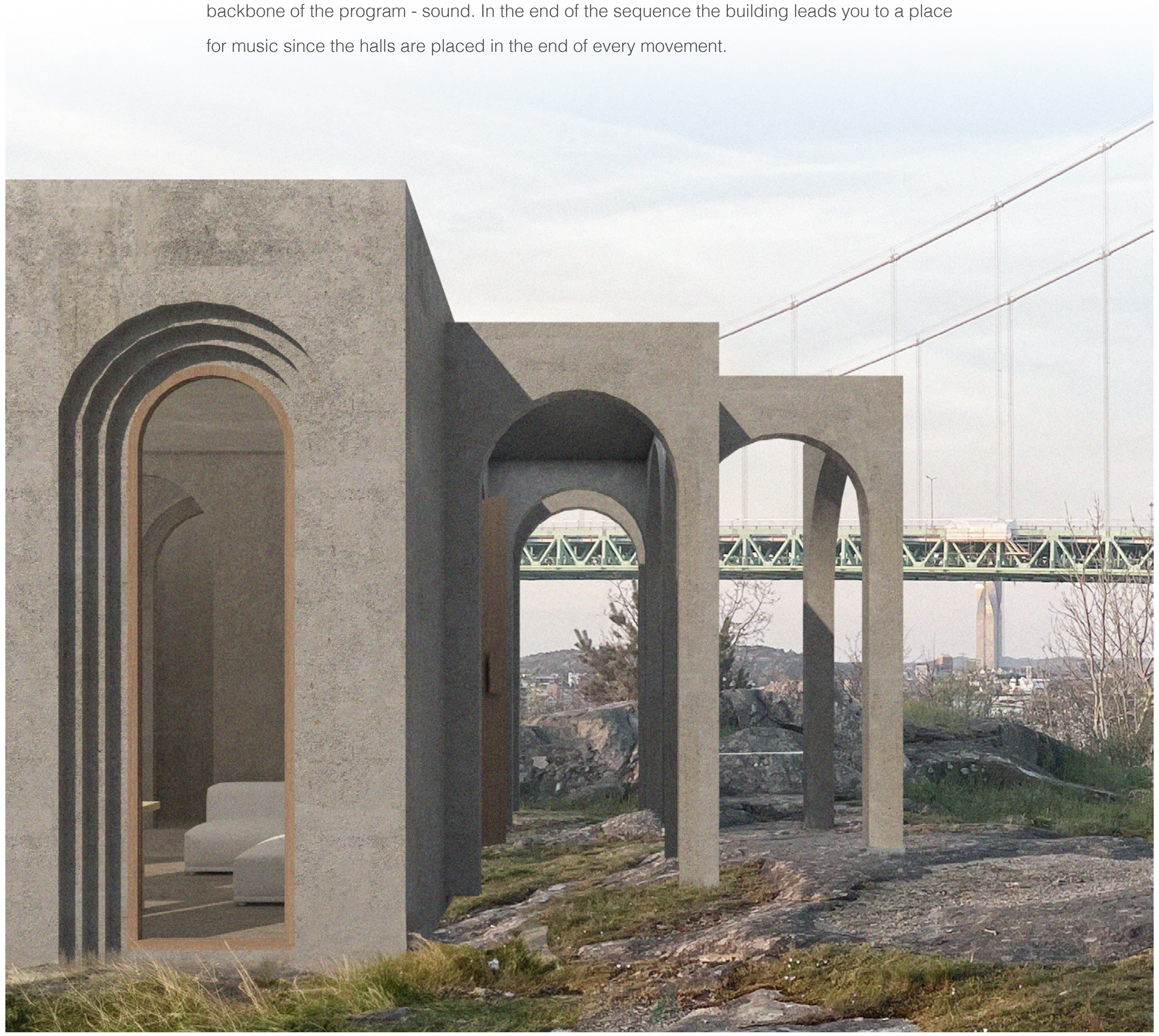
Site plan, scale 1:8000

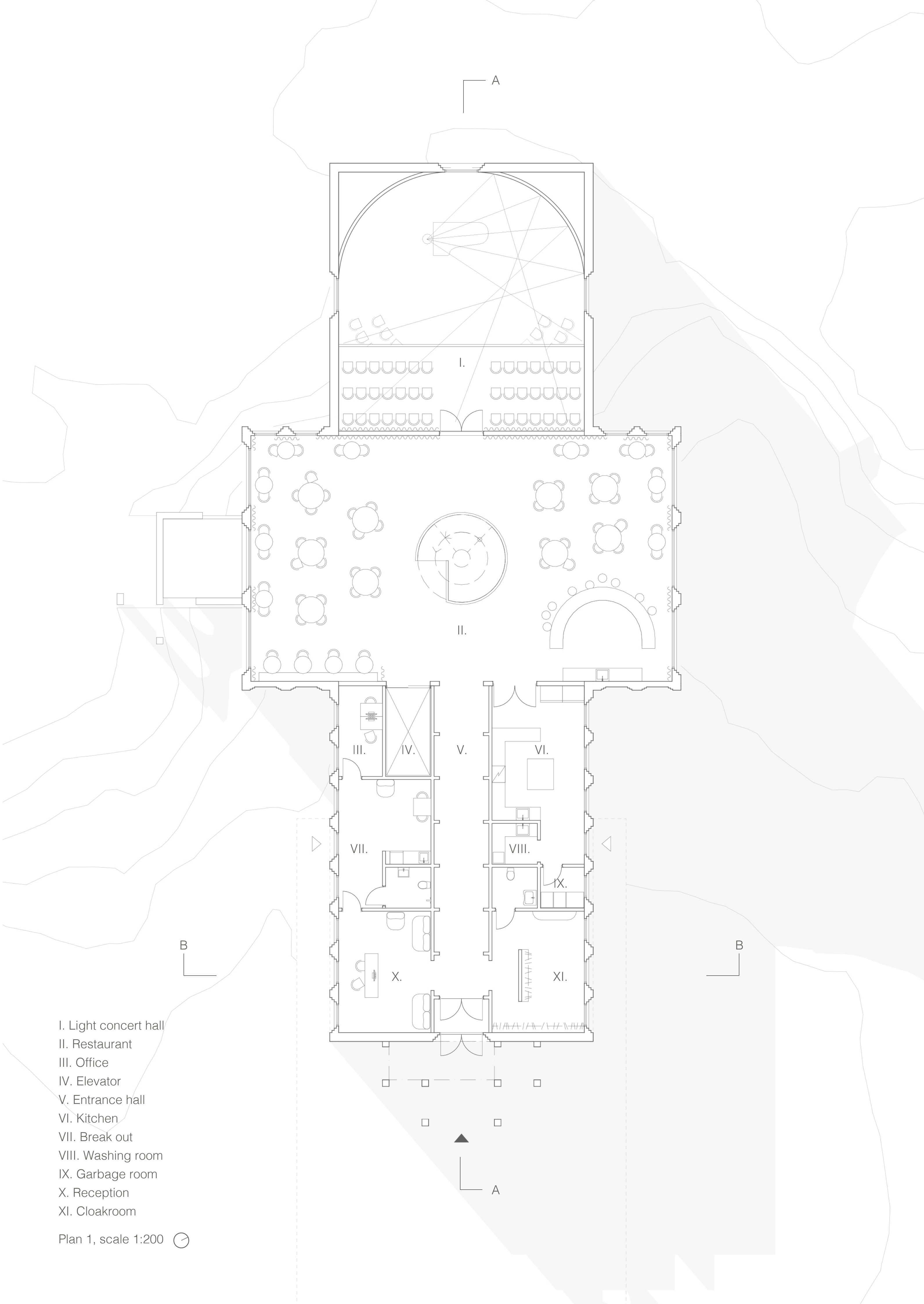
Site plan, scale 1:1000

PLAN 1

When entering the building, you will meet a calm entry space. While moving forward in the narrow corridor, the sound of talk and laughter will increase its sound level and the arches you walk through mark the rhythm of your walking pace. In the end of the central axis you will find the balcony of the light concert hall that has a view towards the port inlet of Gothenburg. The doors to the light concert space are open but closes automatically just before the concert starts, acting as a symbol for when it is time to take your seats. The space of the light concert hall at the entry floor is a room inspired by the reference "Chapel of Music". A space where you can hear the music and enjoy the view, but not the show.

Music is divided into segments but unified by a rhythm. The experience of the building is tuned in the same way. The central axis is the backbone that are guiding you on how to walk through the invention, when to move forward, down or out. The sequence leads the visitor through long narrow corridors followed by big open spaces, a contrast that reveals the hierarchy of spaces. The rooms mark a pace, a transition or are accompanied by the site, always in line with the backbone of the program - sound. In the end of the sequence the building leads you to a place for music since the halls are placed in the end of every movement.

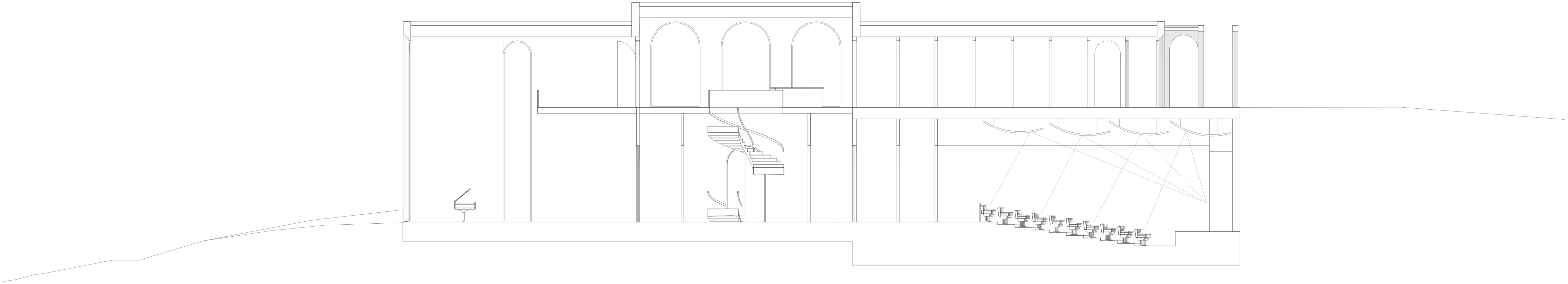




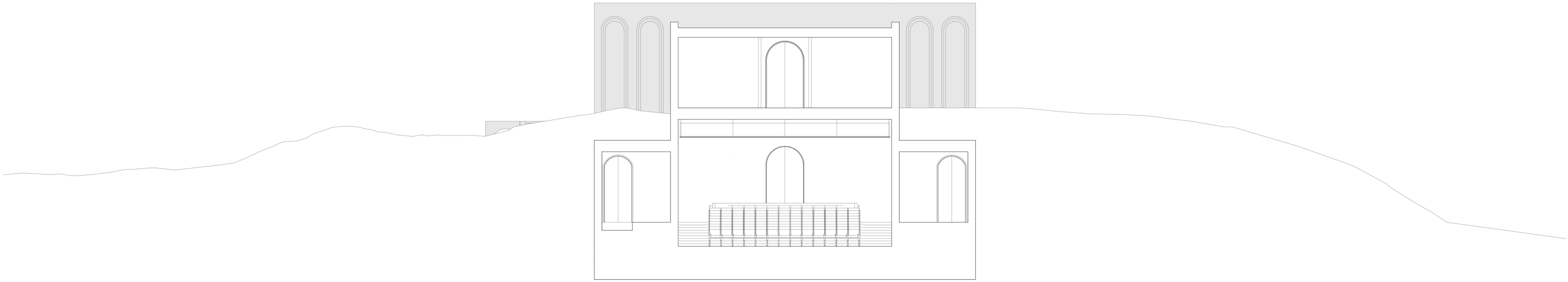
Plan 1, scale 1:200

Interior of entrance

Bar and restaurant



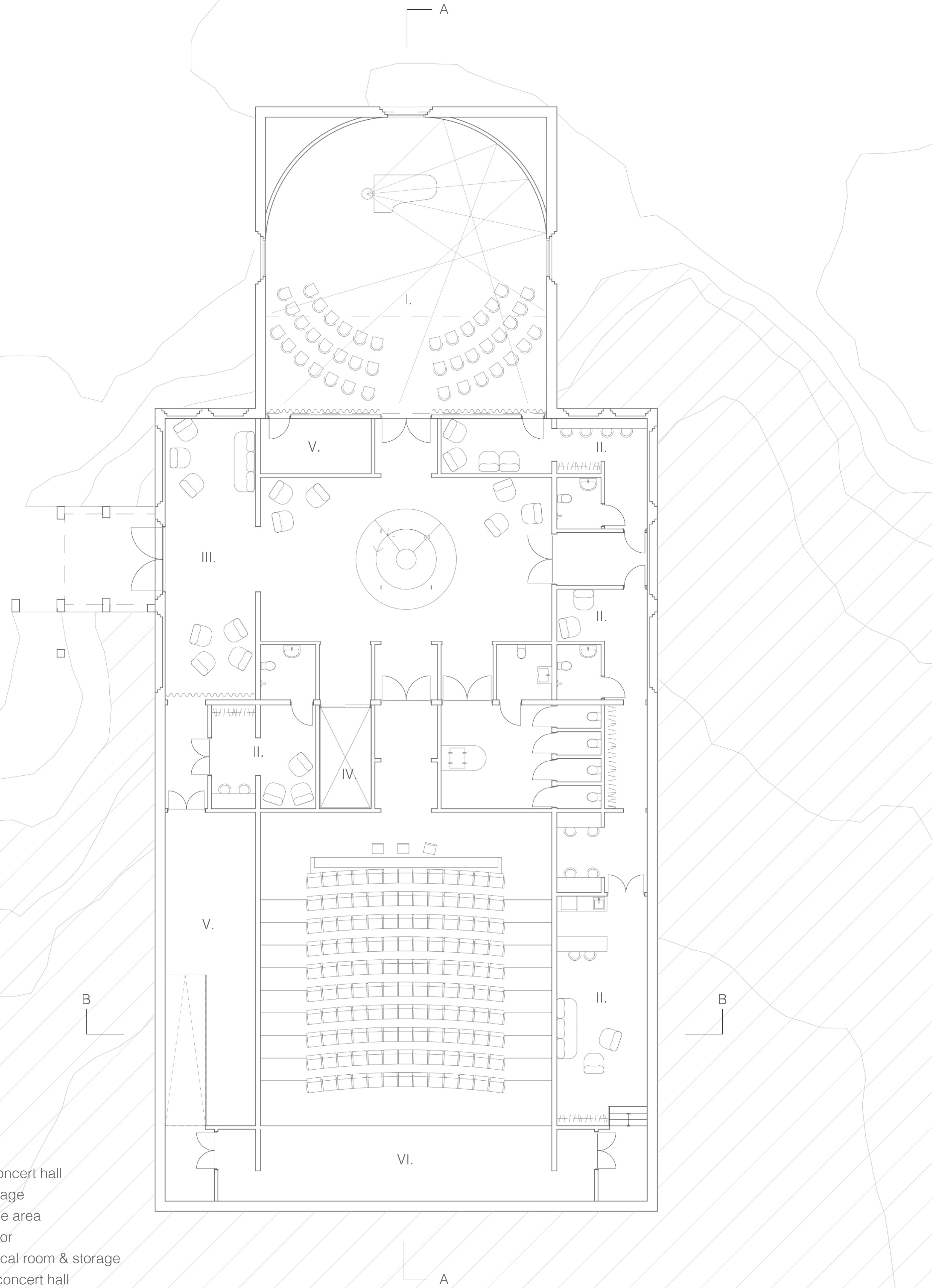
Section A-A, scale 1:200



Section B-B, scale 1:200

PLAN 0

When moving down in the building it reveals all the spaces where the live music take place. You are visually connected to the amphitheater as well as the two indoor concert halls in opposite directions. The two spaces have different characters, one is light and has a view, the other is dark and underneath the ground. The light concert hall has no electronic devices to intensify or support the sound level, the architecture makes it possible for the sound to be distributed and diffused in the right way at the right places. The movement to the dark concert hall continues further down in the building and into the cliff of the site. This space has electronic devices such as speakers and microphones to support the sound. This creates a need for the space to be able to hide installations as well as distributing sound.

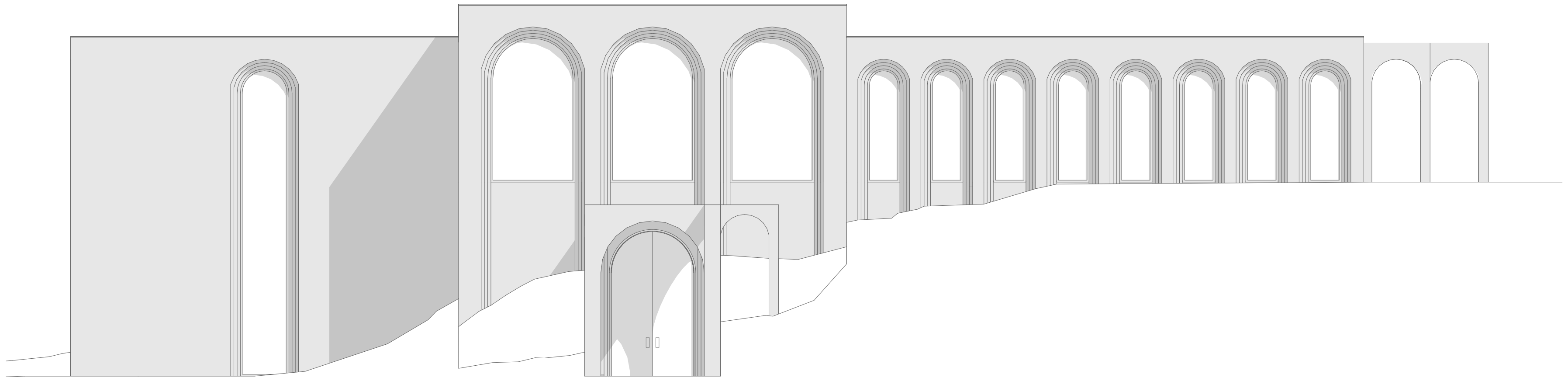


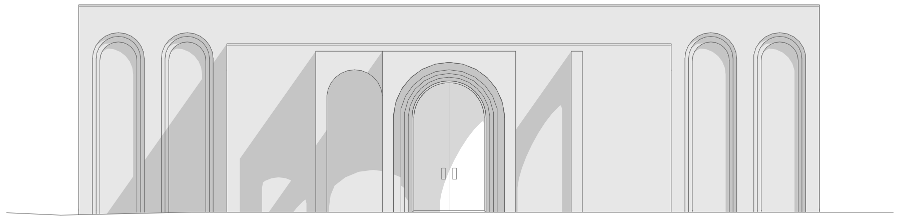
I. Light concert hall
II. Backstage
III. Lounge area
IV. Elevator
V. Technical room & storage
VI. Dark concert hall

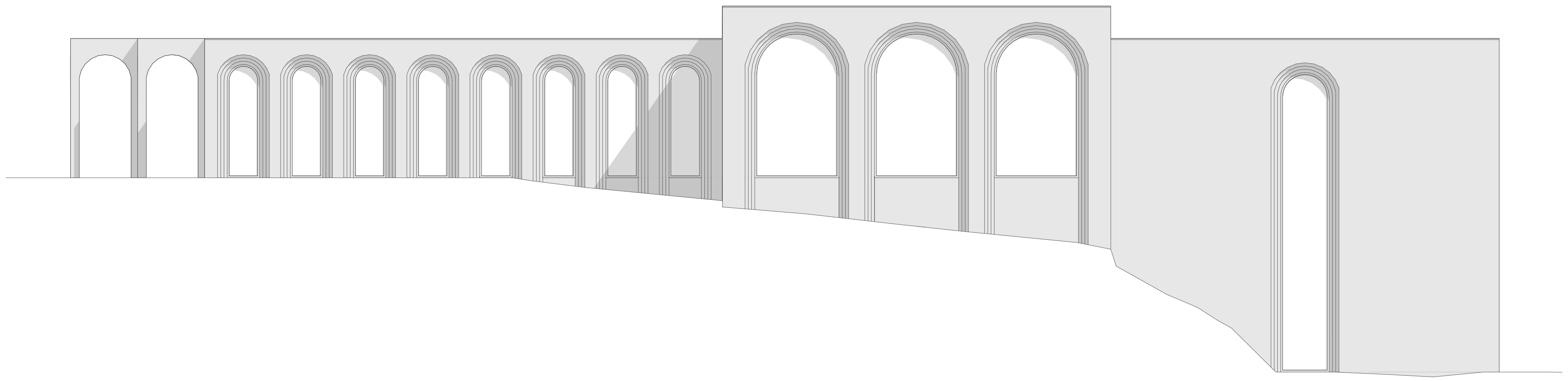
Plan 0, scale 1:200

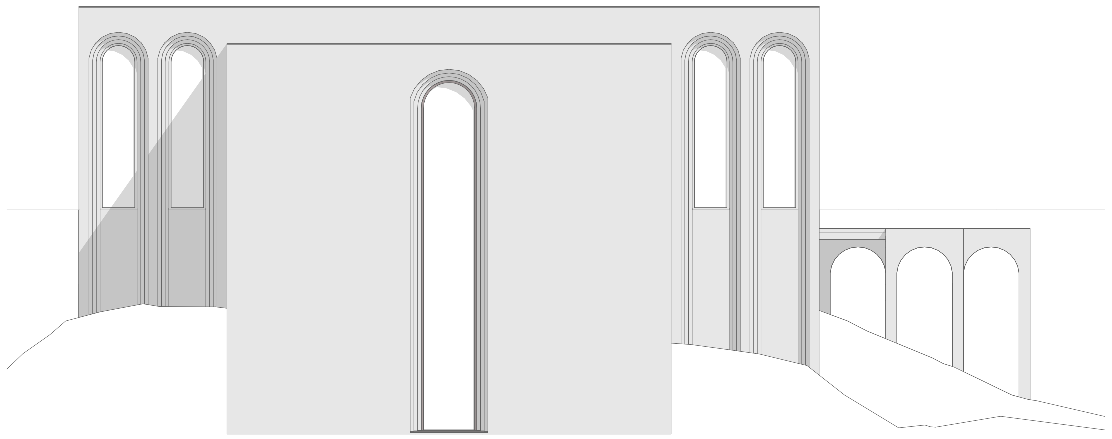
Light concert hall

Dark concert hall



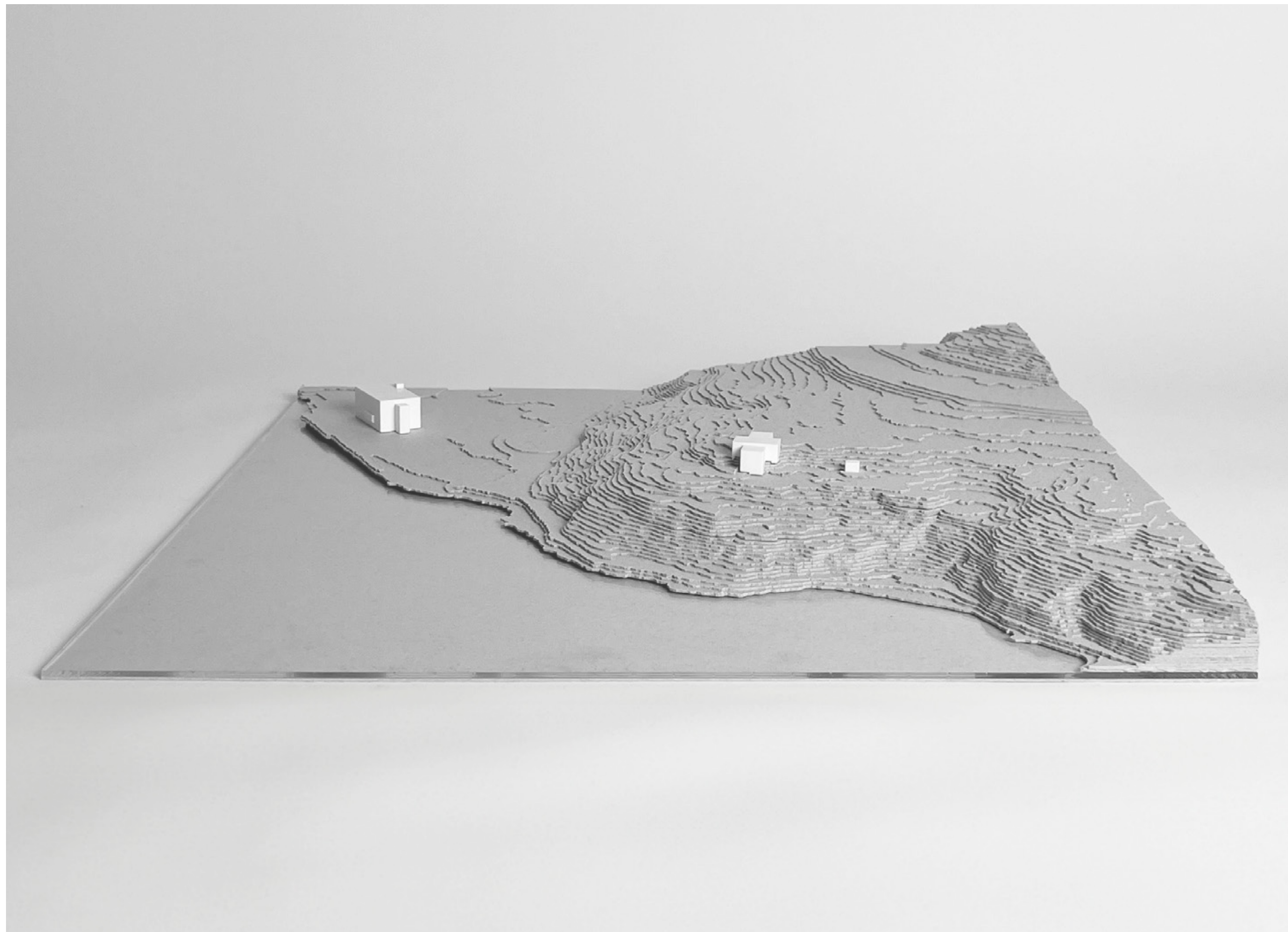


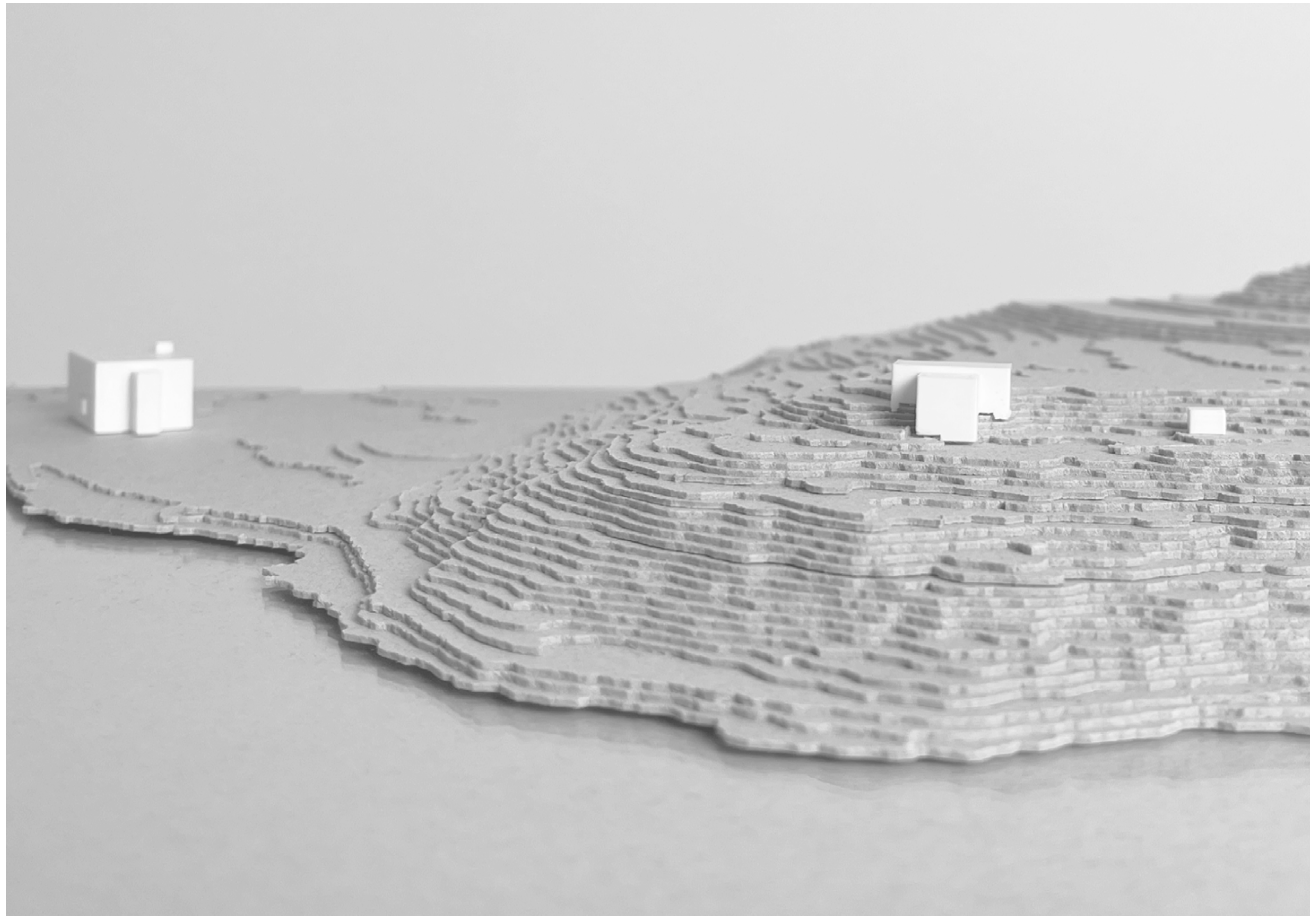




Elevations, scale 1:200

Plan & section, scale 1:300





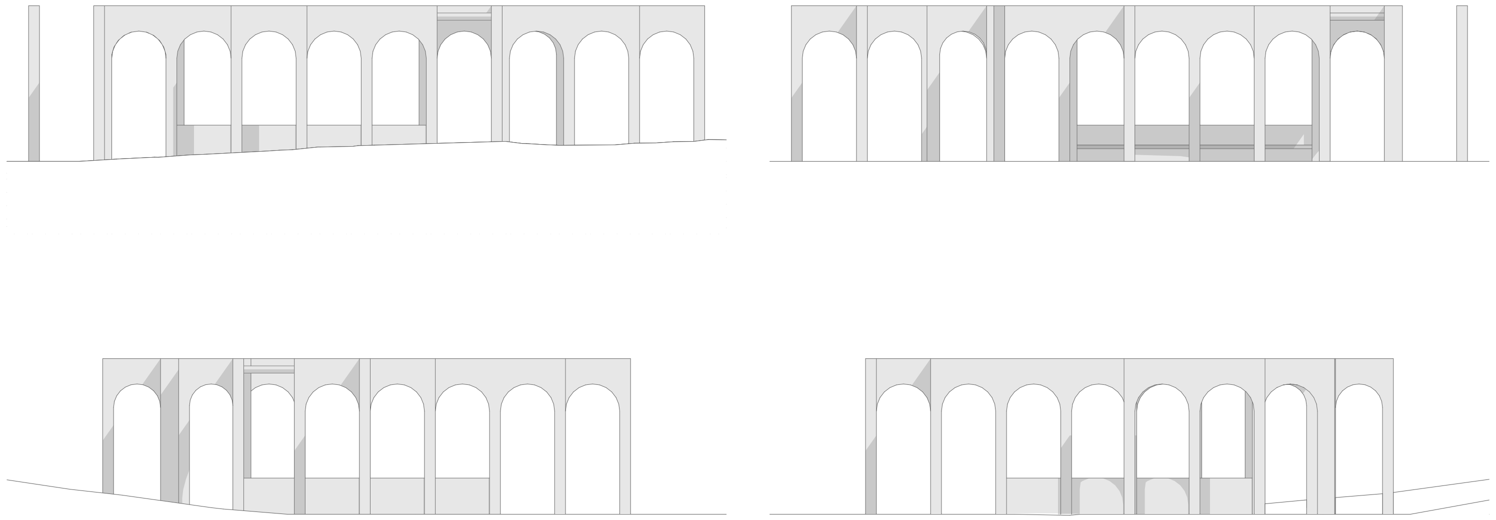
Picture of site model 1:1000

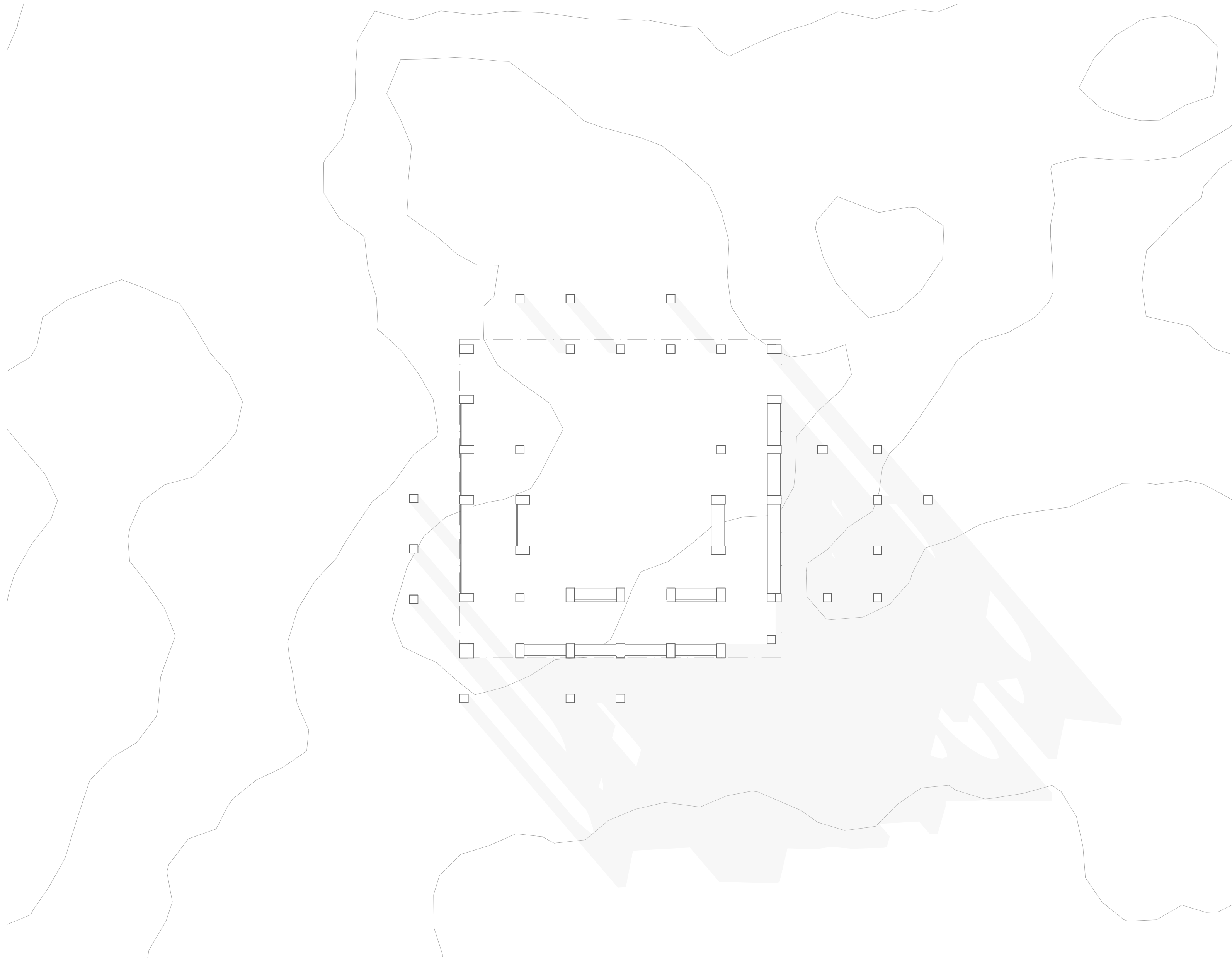
Picture of model 1:200

AMPHITHEATER

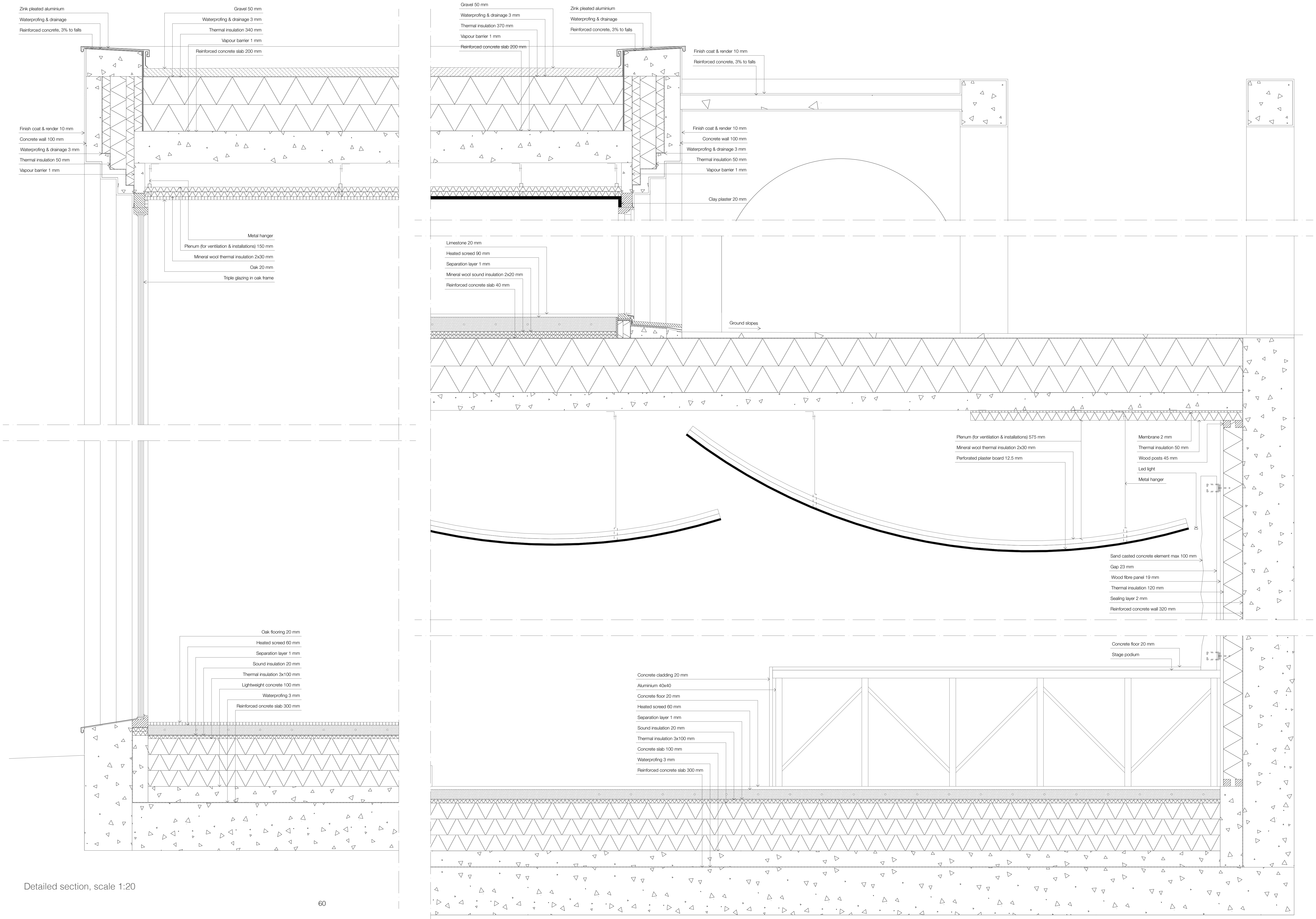
You reach the amphitheater by walking out from plan 0 into the nature along the cliff. The terrain is flat and the ground cover is fully accessible.

The port inlet of Gothenburg with its history and cultural heritage of the town is the backdrop of the event, but its appearance varies depending on the time, weather and season. Making it as a part of the experience listening to acoustic music in the amphitheater when the rain pours down, feeling the breeze pass through when celebrating a wedding in a hot summer day or enjoying a concert in the sunset.





Plan & elevations, scale 1:200

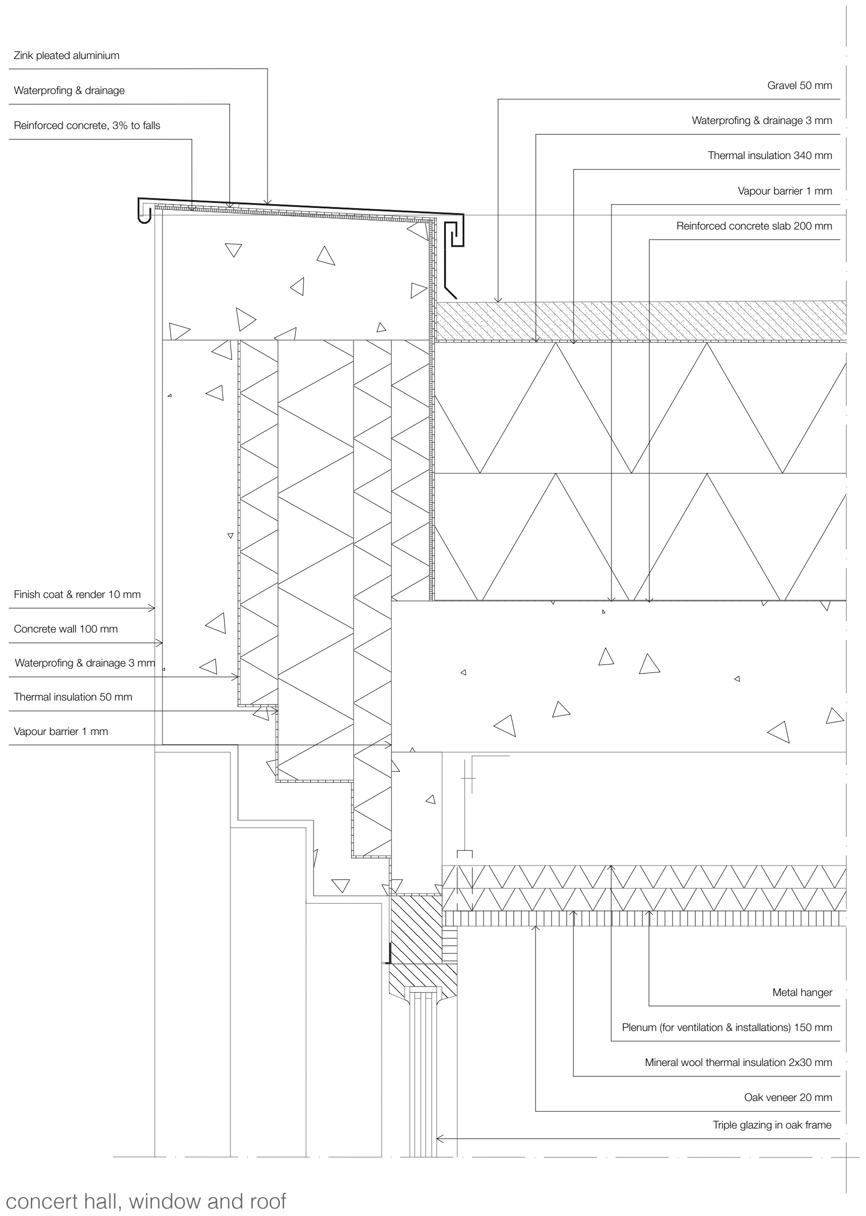


Detailed section, scale 1:20

MATERIAL AND DETAIL

In the detail acoustic solutions has been in focus, such as sound proofing insulation, sand casted elements and plenum in the roof. On one hand for directing the sound waves and on the other hand to hide installations such as electronic devices and ventilation.

The exterior walls are covered in concrete plaster to cover the seams of the concrete blocks and make the building blend into the cliff on the site. The interior walls have a clay plaster, and the flooring are made of limestone. The light concert hall has oakheart in flooring as well as walls and ceiling. Textile covers a part of the walls to absorb sound. The dark concert hall has concrete in floors and walls and grey plasterboards in the ceiling. The dark concert hall has electronic devices supporting the sound and therefore is not the STI and absorption coefficient of such a big importance as it is in the light concert hall.



Light concert hall, window and roof
Highlighted detail, scale 1:10

RELEVANCE FOR SUSTAINABLE DEVELOPMENT

Aspect of time is fundamental in the discussion of sustainable development in architecture. The longer lifetime a building has the better it is to the sustainable discourse.

Therefore has qualitative building methods and robust materials been investigated and used in this thesis project. Materials that can endure friction will be prioritized and the life cycle of a building is thereby considered.

The thesis is designed in a way that makes it sufficient to retouch surface materials instead of demolition and new replacements. It is also preferable from an architectural point of view thus the original character of the building will be kept. The initial material palettes will stay and the life that has taken place in the building will be seen. The thesis project is designed with materials that emphasize the platina of years in use rather than demolition.

Acoustic absorption to investigate are following three materials, fabric, wood and concrete.

BUILDING

ACOUSTIC RESEARCH

Exterior walls
Concrete plaster

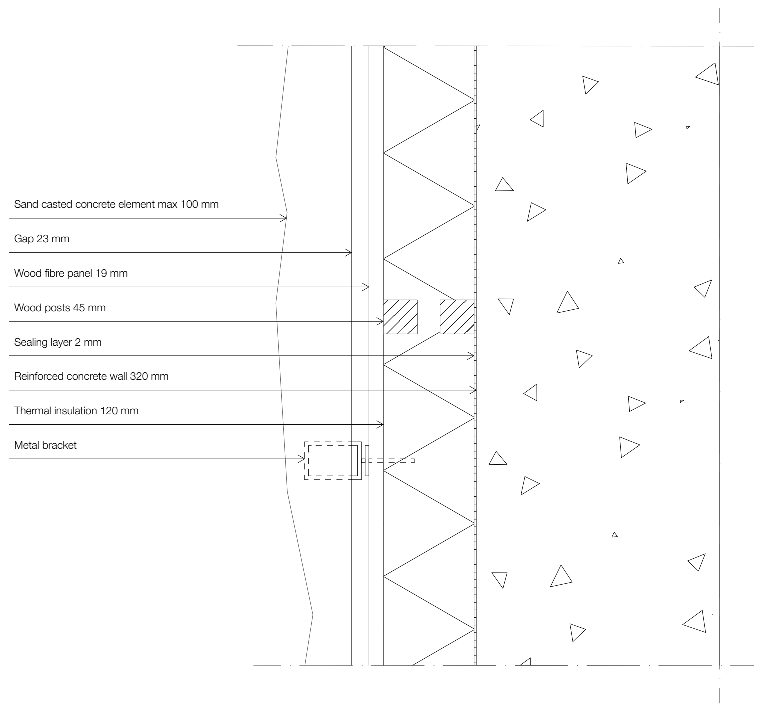
Indoor walls
Clay plaster

Floor
Limestone

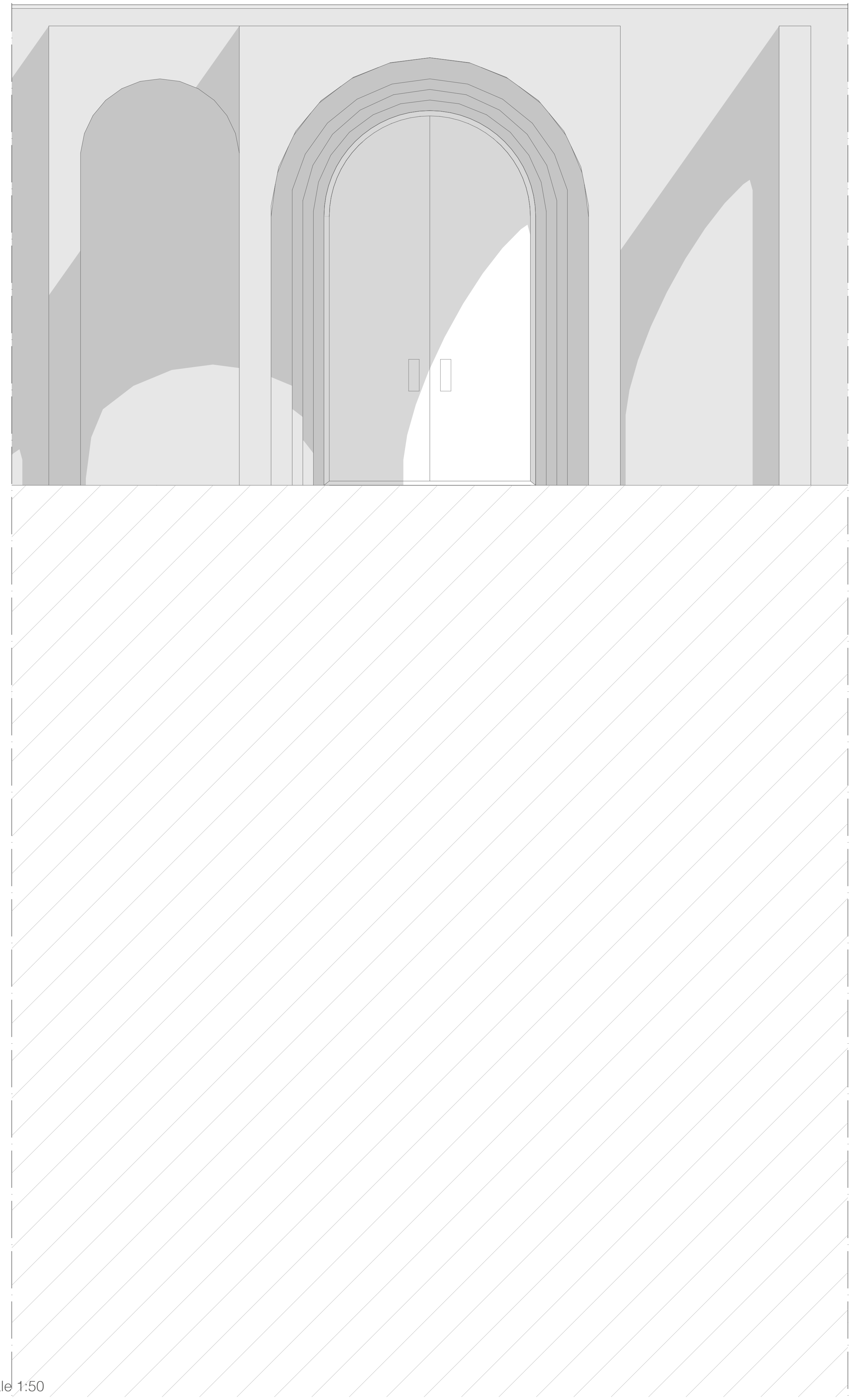
Soft
Fabic

Semi solid
Oak wood

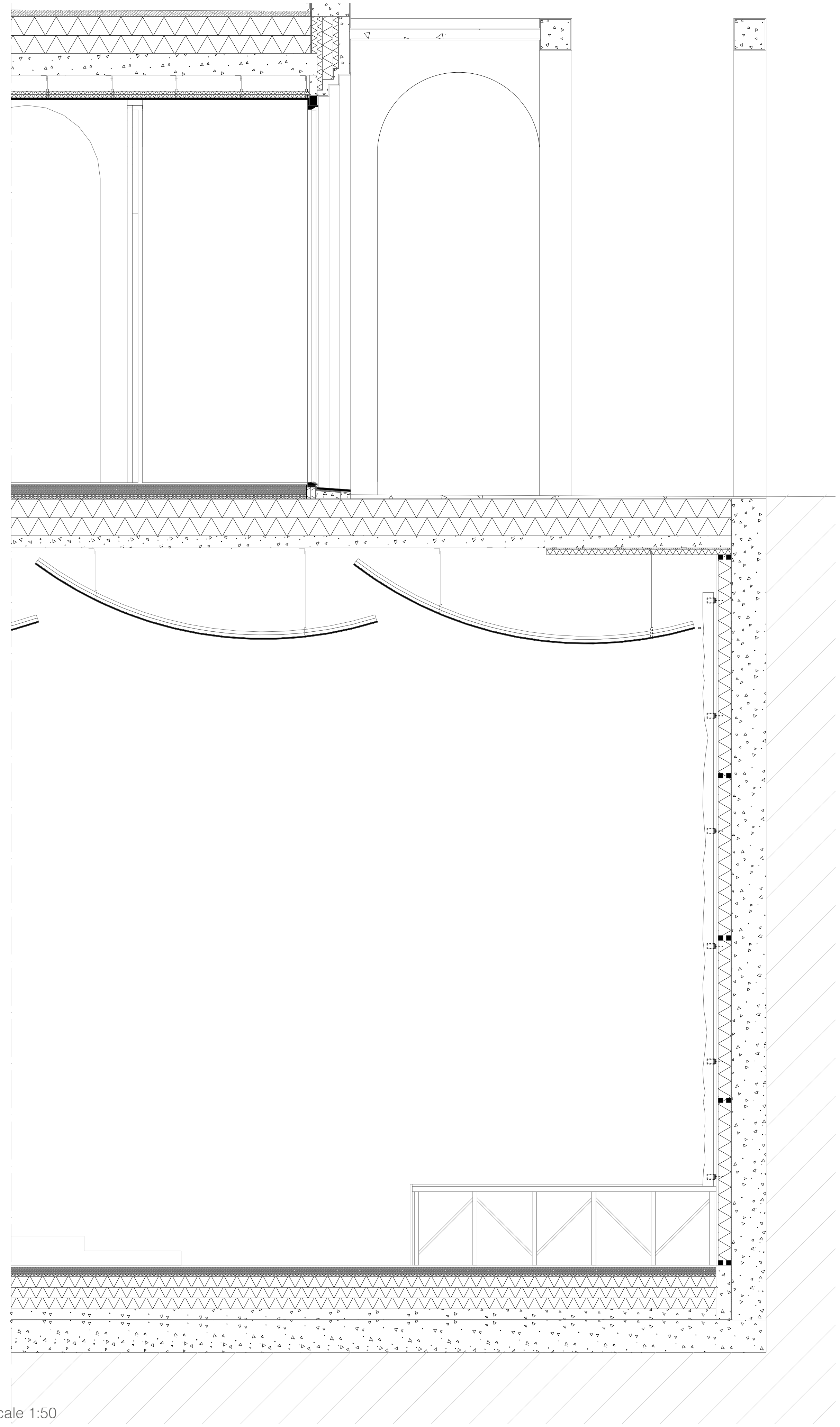
Solid
Concrete



Dark concert hall, wall element
Highlighted detail, scale 1:10



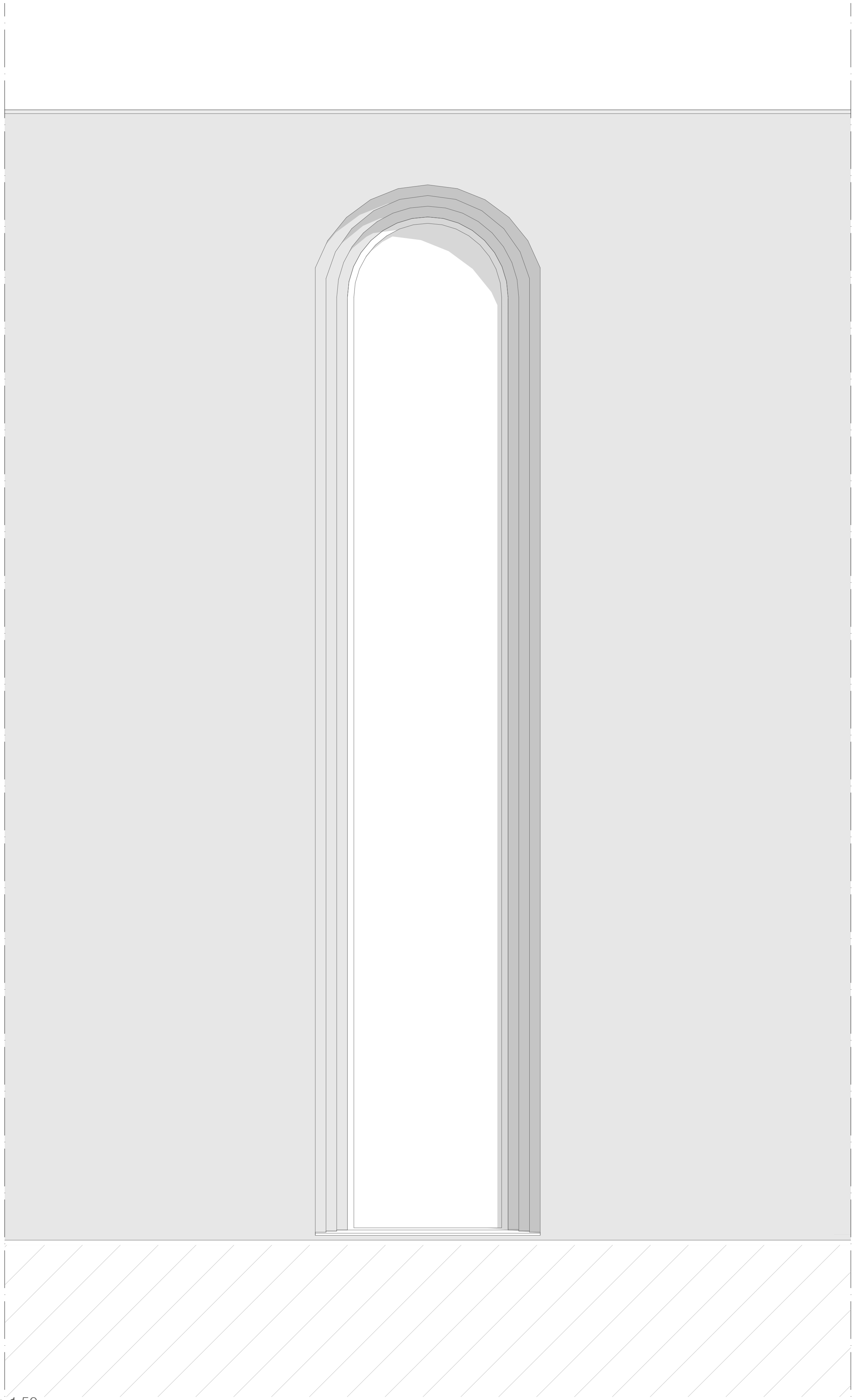
Elevation, scale 1:50



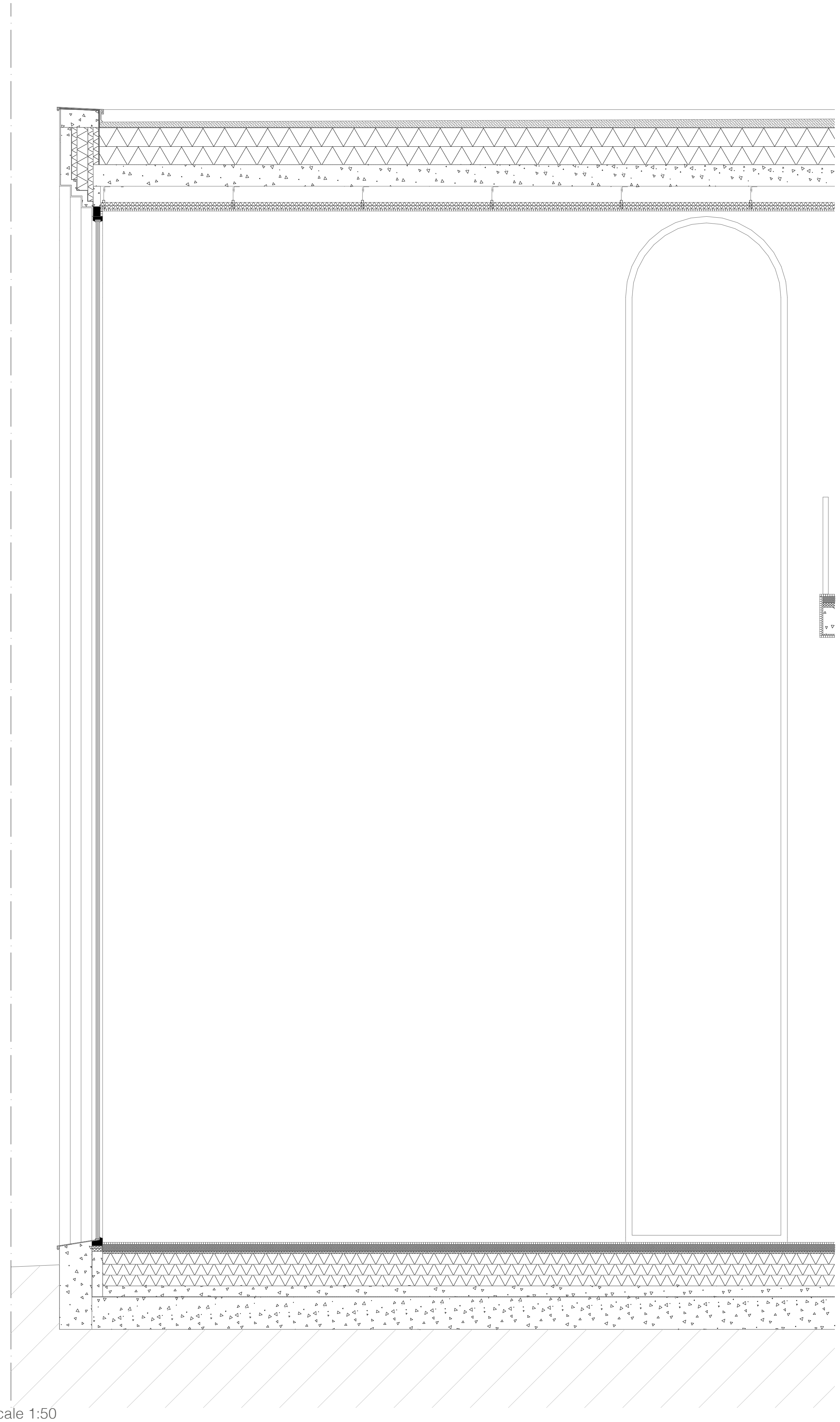
Detailed section, scale 1:50


Picture of detail model 1:20


Picture of detail model 1:20



Elevation, scale 1:50



Detailed section, scale 1:50

PART III

Conclusion

DISCUSSION AND ANSWERS

So, how can architecture influence, or modify, sound through the understanding of space, material and construction in a building dedicated for live performances of music? Since sound travels in air as linear lines consisting of vibrations, they are influenced by the built environment that the sound wave encounters. Grasping how it is affected can be understood by categorizing the phenomena into the two most common ways. Either by absorption, when the energy of the sound wave is absorbed by the material it encounters, or by diffusion, which means that the sound wave is directed in a specific way with the help of design. These two categories align with the two segments of this thesis, form and material, as absorption primarily is achieved by material and diffusion a consequence of form. However, it is important to note that there are exceptions. One example is a regular opening, no material absorbs sound as effectively as openings, as it causes the sound waves passing through it to disappear as long as they do not encounter anything on the other side. In this example, absorption relates to form rather than material.

The problem formulation of the master thesis highlights how acoustics and sound often are incorporated in a late stage of the design phase, which can lead to a dissonance between the original vision and the final outcome of the design. This can either be visible by add-ons to the existing structure or noticeable by getting a negative experience of using the building. An example of this is the Umeå School of Architecture with an open floor plan and material palette making it possible for someone at the top floor to hear someone talking in the entrance at the bottom floor. This can be distracting, especially for students with concentration difficulties. If the design is not in tune with everything you can perceive, not just what you see, the architect has not succeeded. Therefore, this thesis contributes to a debate within the profession to not forget about sound in the design phase, because even though sound waves are not visible, they too affect the buildings character as Pallasmaa argued.

> "The way spaces feel, the sound and smell of these
> places, has equal weight to the way things look."
> - Juhani Pallasmaa
> The eyes of the skin, 1996

In the conducted investigations using 3D modeling and the software Treble Technologies, interesting findings were made. Regarding the first segment, form, it became clear that the primary factor affecting the acoustics of a room is its three-dimensional volume. This means that the larger volume a room has, the longer distance the sound wave must travel before it becomes diffused or reflected, which results in a poorer sound experience. Consequently, rooms with higher ceilings require careful consideration of sound-directing elements or strategically placed sound-absorbing materials.

Another shape that stood out in the study was a completely circular room. By visiting the Meštrović Pavilion by Ivan Meštrović in Zagreb and the Stockholm City Library by Gunnar Asplund an interesting phenomenon was revealed. When the sound source is positioned at the center of the circular room and the listener is standing close to the wall at the outer radius of the circle, it is difficult to perceive any sound at all. If the sound source is located at the outer radius of the circle the sound is clearer. This suggest that even though the listener is closer to the sound source when it is positioned in the middle, it is harder to notify its message.

On the other hand, the study showed that incorporating concave or convex walls within the space can help distribute the sound wave, improving the value by 30% compared to a space with regular straight walls.

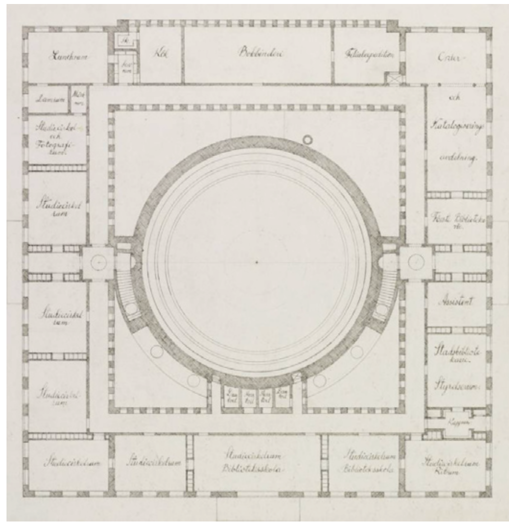


Fig 10. Plan drawing of Stockholm City Library, Gunnar Asplund, 1928

Fig 11. Meštrović Pavilion, Ivan Meštrović, 1938

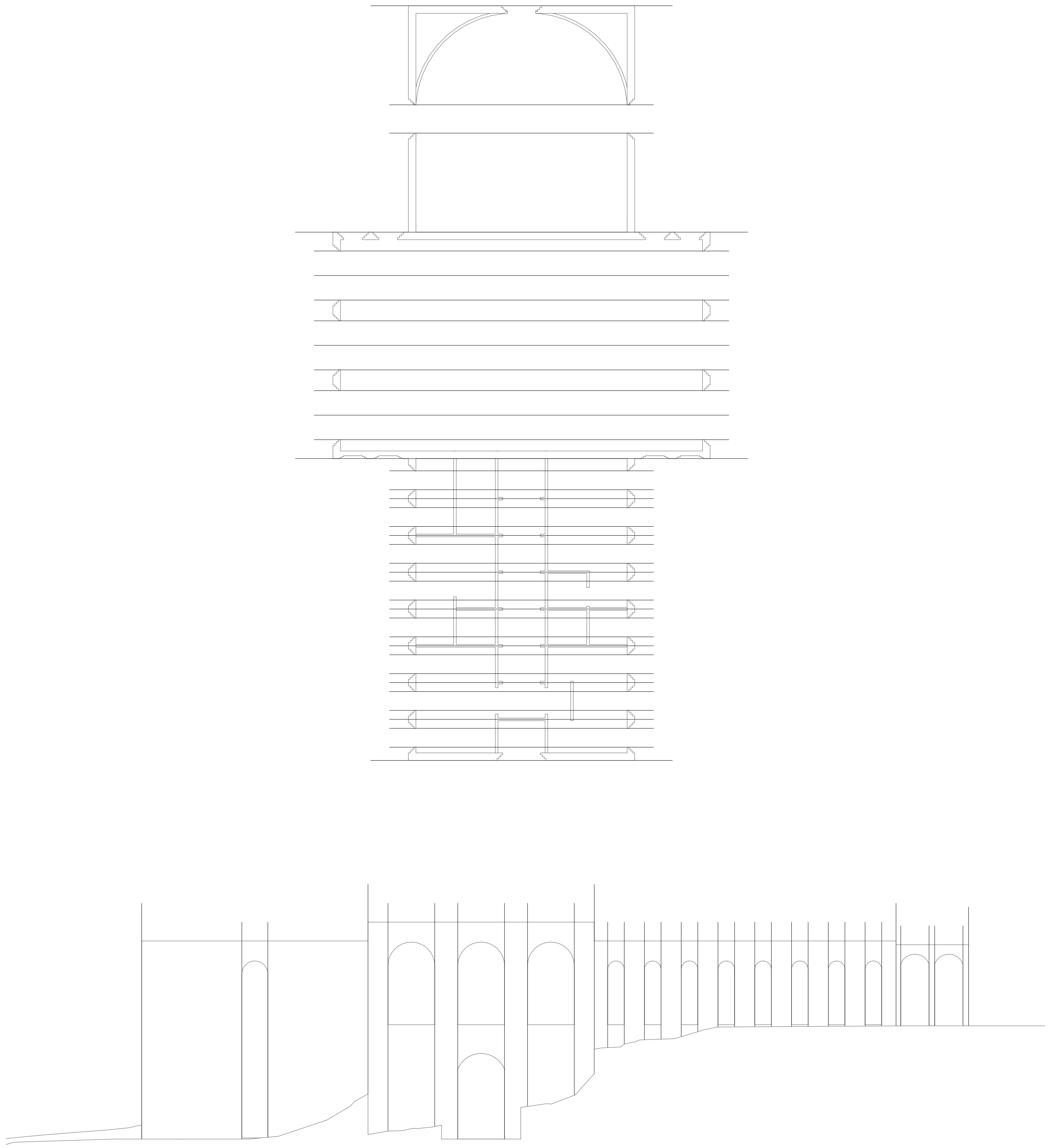
Regarding the second segment, material, it shows that the absorption quality is the most important value. For instance, wood and concrete have more or less the same absorption coefficient, which means that the difference between them is not significant. The higher the absorption coefficient, the more energy from the sound wave it can capture, eventually causing it to become silent. The study showed that the biggest difference is made with materials with components that are composed of porous elements. For example fabric or wood wool. The placement of these materials is also crucial, especially if the intention is to block a sound from one part of a room to another. Generally the bigger quantity of the material the better. For instance, thicker curtains absorb more energy from the sound wave than thin ones. In environments were someone is talking without a amplifier and microphone, in a classroom for example, it is important that the surface around the speaker allows for diffusion. This makes the sound waves spread out and therefore be heard better, while in other parts of the room it may be advantageous for the sound wave to be absorbed to prevent echo. In other words, sometimes it is beneficial for the sound wave to be absorbed, but in other cases, it is preferable for it to be diffused.

To stimulate the visitor's impression in a similar way as music can, the design of the building has been influenced by music. The building elements of void and mass has been orchestrated in a precise way. The buildings proportions and rhythm create an experience that changes while walking through the building. The exterior has windows in different sizes to create a change in the facades rhythm as well as highlighting a hierarchy. The room where the light concert hall is placed has less openings than the other parts of the building, to mark a shift and telling a story that something important for the buildings program is hiding inside.

The amphitheater has a scattering design to not make it formal and therefore create a possibility to host events of different sizes and programs. The roof of the amphitheater is important for its acoustics, making the sound waves reflect to its surface and bounce down to the audience.

The project has challenged the understandings for acoustics and sound in the built environment. It is a complex science connecting physics, engineering and architecture. The thesis has contributed to a wider understanding of acoustics, but also a realization of how much more there is to learn within the field. The investigation has been balancing on what is relevant as a designer to know and what is not.

Since the thesis have been made from an architect student perspective a delimitation has been the lack of scientific calculation behind acoustics but on the other hand, the discussion of where and how acoustics and architecture meets was one of the reasons why the topic was interesting to investigate. The project has never been about physics but rather how an architect can draw with the sound in mind. Departing from the field of architecture acoustics is an important topic that affects the overall experience of a building.



Diagram, Rhythm in plan and elevation

Exterior

STUDENT BACKGROUND

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08.2021 - 06.2024	MSc Architecture and Urban Design, Chalmers Tekniska Högskola
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Cambridge Dictionary (n.d.) Noise https://dictionary.cambridge.org/dictionary/english/noise

SOFTWARE

Treble Technologies https://www.treble.tech

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