



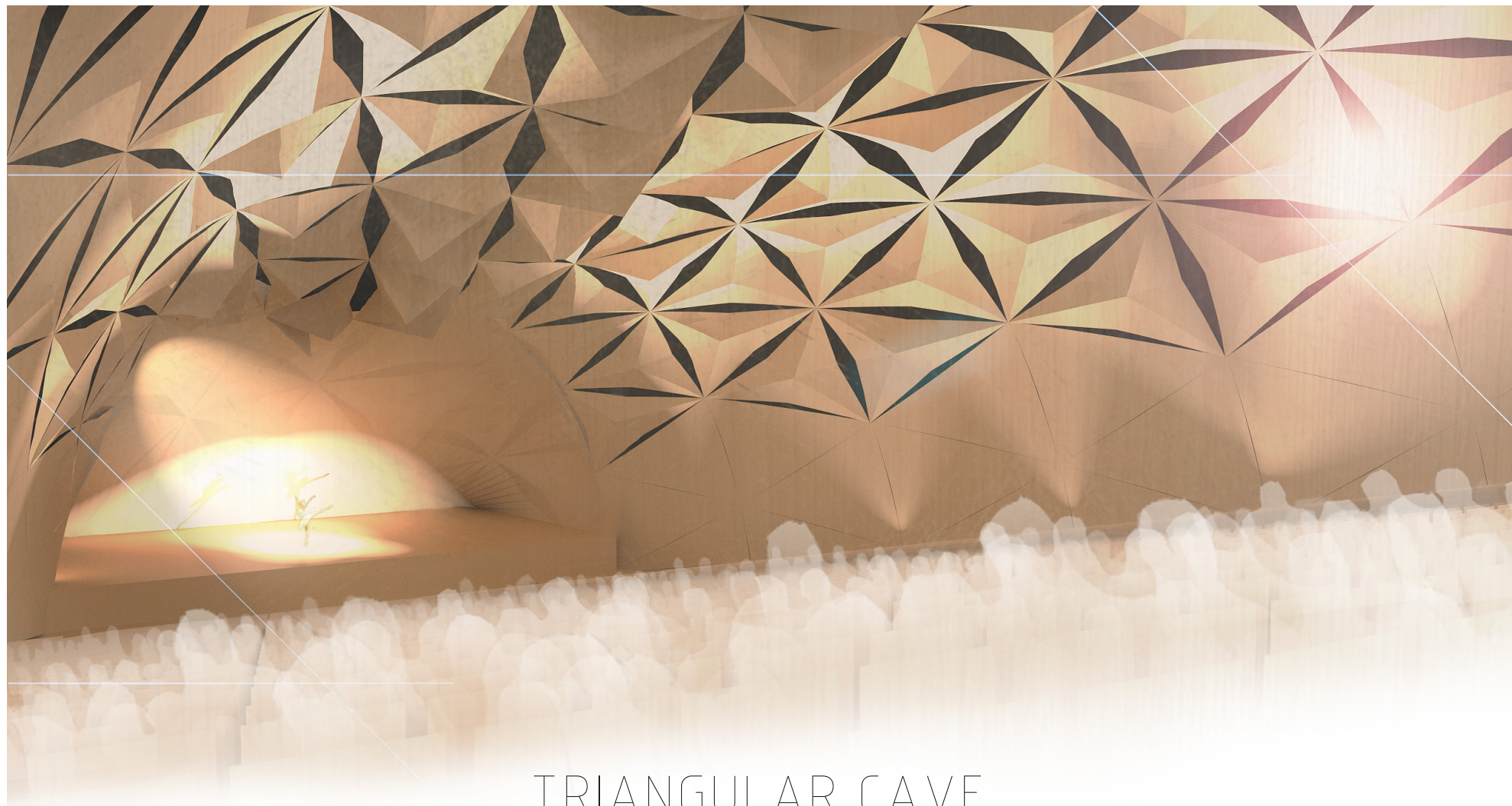
TRIANGULAR CAVE

BACHELOR PROJECT PORTFOLIO, ARCHITECTURE & BUILDING ENGINEERING

ELIN ISRAELSSON with LINNÉA GABRIELSSON and JING ZHENG

CHALMERS UNIVERSITY OF TECHNOLOGY, SPRING 2020

EXAMINER: MORTEN LUND and PETER CHRISTENSSON



TRIANGULAR CAVE

Elin Israelsson, Linnéa Gabriëlsson, Jing Zheng

CONCEPT

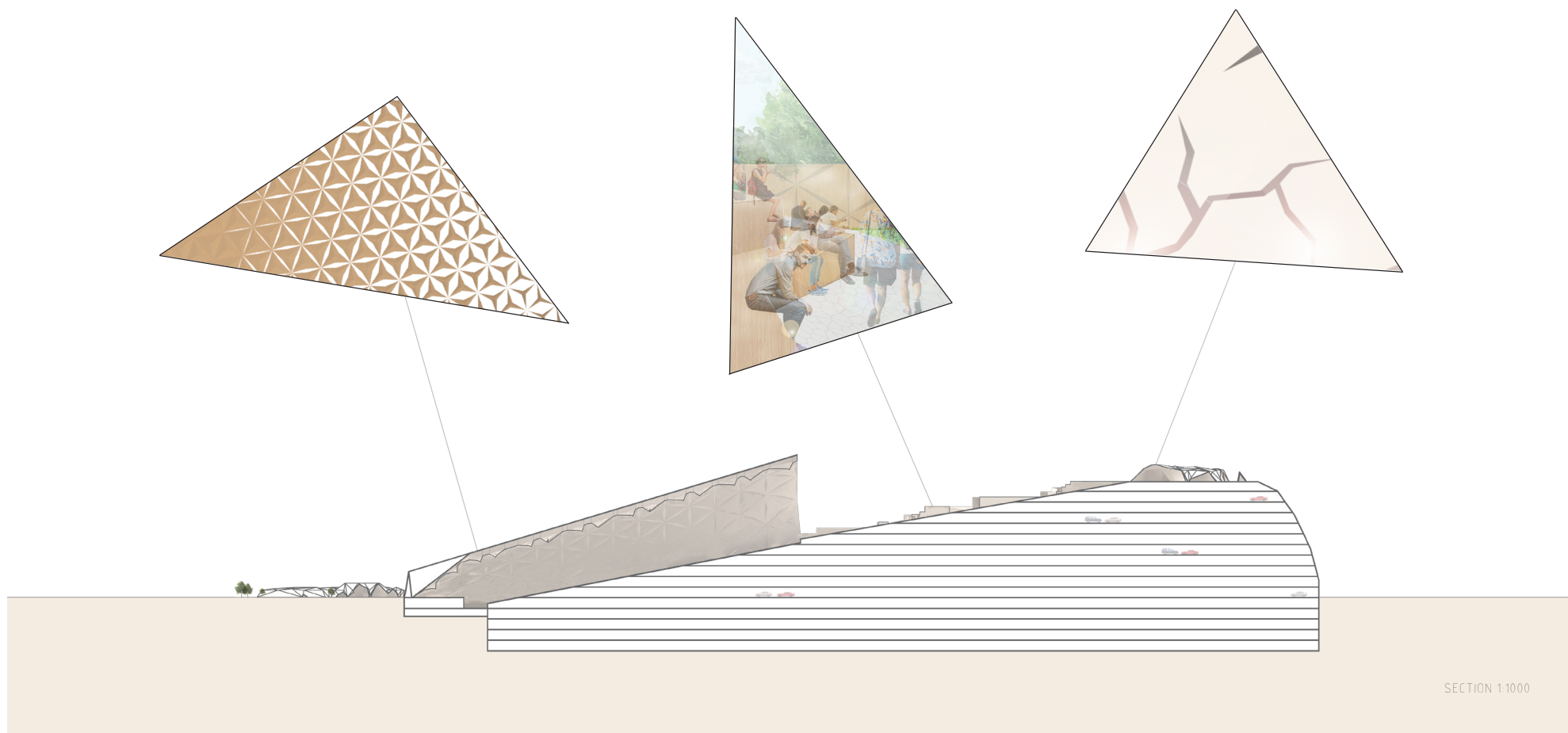
The Triangular Cave is a music pavilion situated in Denver, Colorado. It is designed to accommodate 7000 seated audience members under a spectacular roof, perfect for opera, ballet and theatre. Performances that interest a larger group of people, such as rock and jazz, are possible as well by reason of the open lawn area, accommodating another 18 000 people. The main concept of the project is an abstract cave. This concept is enhanced by the use of triangles in both aesthetic and acoustic contexts. Furthermore, the cracks created in both the buildings and the roof, are important for the plans as well as the acoustics.

ACOUSTICS

The characteristic roof is naturally the centre of attention in the project. It is not only protection from the elements, but also an acoustical profit. The roof consists of adjustable wood triangles that can be angled depending on the performance. When the roof is angled, cracks will appear between the triangles. These cracks will consist of absorbent material that changes the acoustical condition. In that way the amount of absorbent and reflective material can be variable and adjusted to the current performance. Moreover, there will be holes in some of the wood triangles to facilitate hidden loudspeakers.

MOVEMENT

One big aspect of the project has been movement. On your way to your seat you move in and out of cave-like buildings. This creates interesting movement throughout the entire site. The way we experience the triangles can differ depending on the environment, and so, we incorporated the triangles and the movements in different ways depending on the building and its use. We incorporated the triangles to the facades, the corridors, the interior paneling, the sharp landscape and of course the main roof over the stage.



THE ROOF

Different genres of music prefer different listening experiences, which are connected to how the room responds to the sound. Our adjustable roof makes it possible to change the reverberation character of the room. Note: since we are dealing with such a huge room, the air attenuation cannot be neglected. High frequency components will be affected more. To compensate that and further reach a more blended sound effect, resonators targeted at low frequency are considered in the absorbent material.

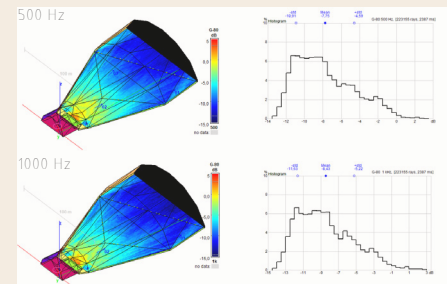
THE FLEXIBILITY

Using simulation, the corresponding reverberation time can be reached by different opening settings of the roof triangles.

Orchestra: 75% wood boards and 25% fiberglass.
Opera: 50% wood boards and 50% fiberglass.
Reinforced music: 30% wood boards and 70% fiberglass.

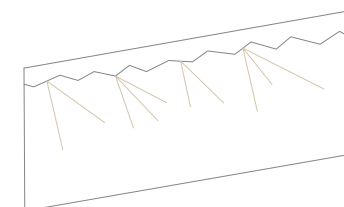
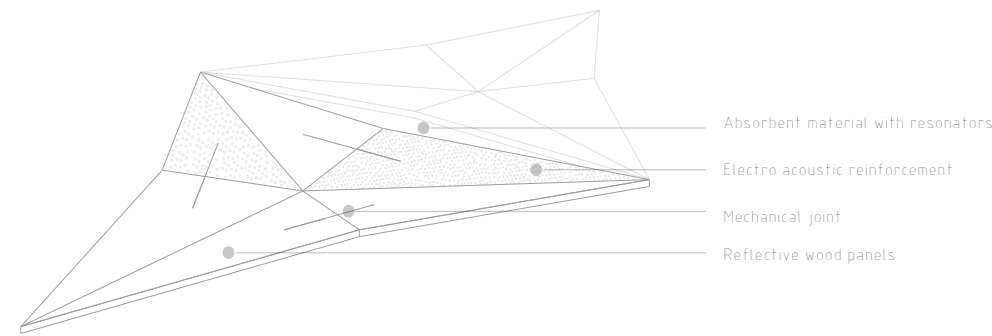
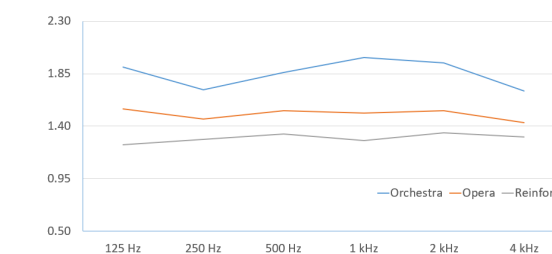
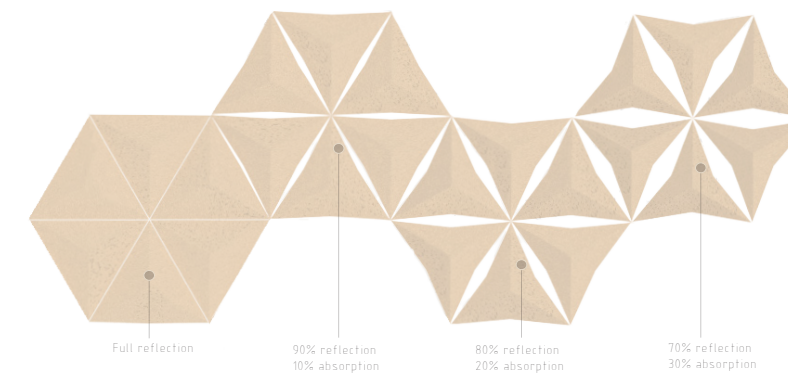
THE ELECTRO ACOUSTICS

Due to the large volume of the room, the sound strength is below target. Therefore, amplification is required. No large main loudspeaker will be used, instead, multiple loudspeakers will be hidden behind the triangles. The delay time and volume are adjusted to match and support the acoustic sound in the room and also keep the aural localization at the stage. This concept will continue to the open lawn area. Here multiple loudspeakers are hidden in the ground in a pewback setting. These loudspeakers will also deliver delayed sound according to the direct sound from the stage.

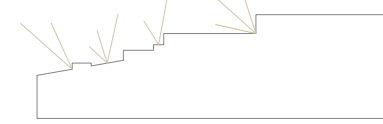


THE CORRIDORS

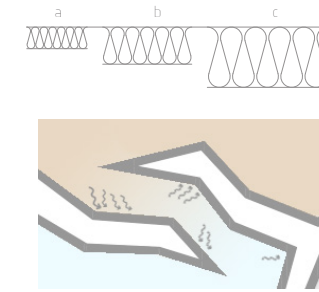
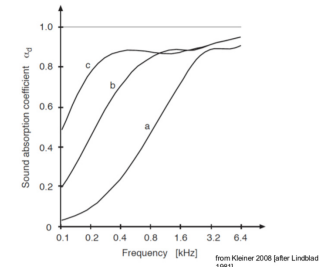
To create a more cave-like experience, the rehearsal rooms are doorless, and the sound is attenuated through a corridor. The corridor will be covered with porous absorbers with gradually increasing thickness. With this configuration, the impedance, especially for the frequency components, will change gradually. In this way, the velocity change would be less intensive. As a result, we could expect a much softer sound at the end of the corridor. To help with this acoustic challenge, the corridors are designed to be extensive and are slightly angled.



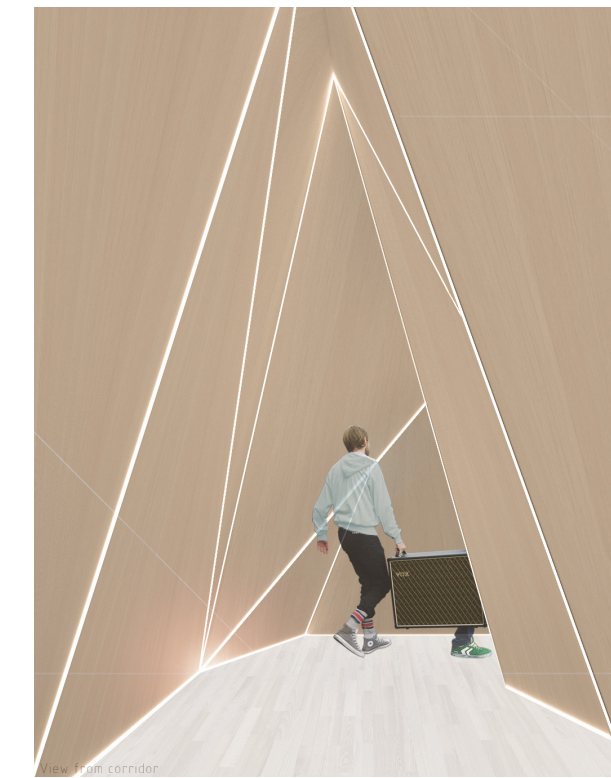
Delayed cluster



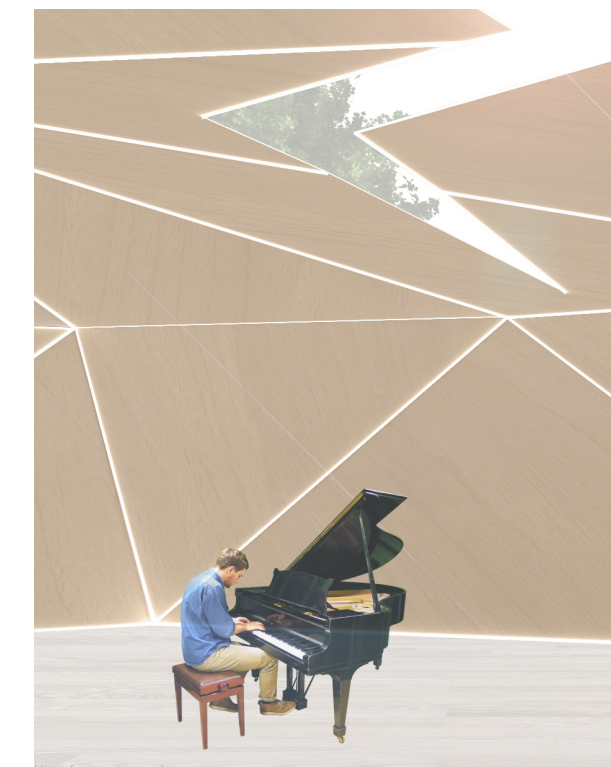
Pewback loudspeakers



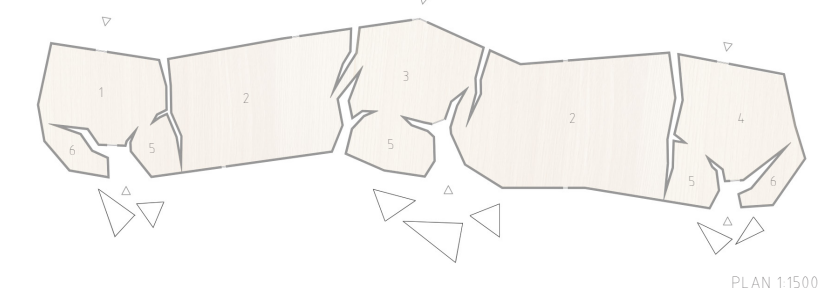
FACADE BACKSTAGE



View from entrance

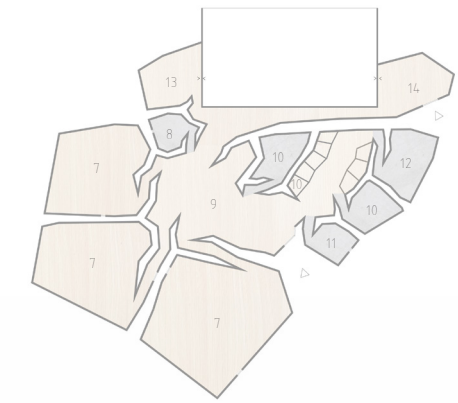


View from rehearsal room



- 1 Left foyer
- 2 Restaurant
- 3 Central foyer
- 4 Right foyer
- 5 Wardrobe
- 6 Restrooms

There are two buildings on the site, one entrance building and one backstage building. The entrance building is situated on top of the parking while the backstage building is placed behind the stage. The stage, seating area and open lawn area are located in the slope between these two buildings.



- 7 Rehearsal
- 8 Green room
- 9 Foyer
- 10 Dressing rooms
- 11 Office
- 12 Mechanical room
- 13 Storage
- 14 Loading platform

Cracks were created to form rooms in the buildings. The cracks, starting at the facade and reaching into the buildings in different directions, maintain the sense of an abstract cave. Moreover, the overlapping cracks facilitate long, slightly angled passages that in combination with a very absorbent material eliminates the need for an ordinary door, further contributing to the cave experience. The windows are likewise created in a crack shape, reaching from the ground to the ceiling.



- Bus stop
- Entrance parking
- Parking exit
- Landscape
- Roof
- Stage
- Loading platform
- Staff parking
- Staff entrance

CONCEPT

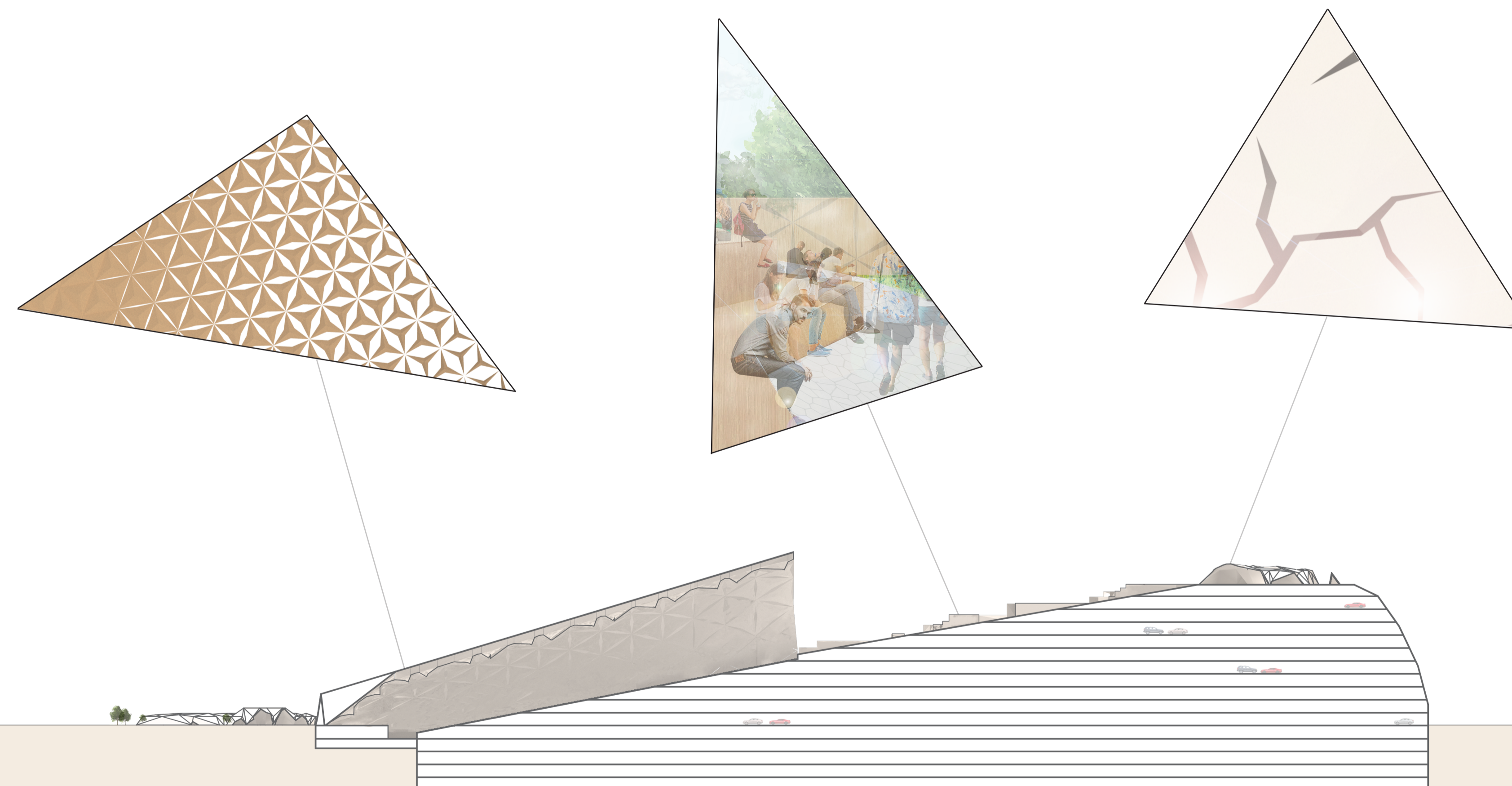
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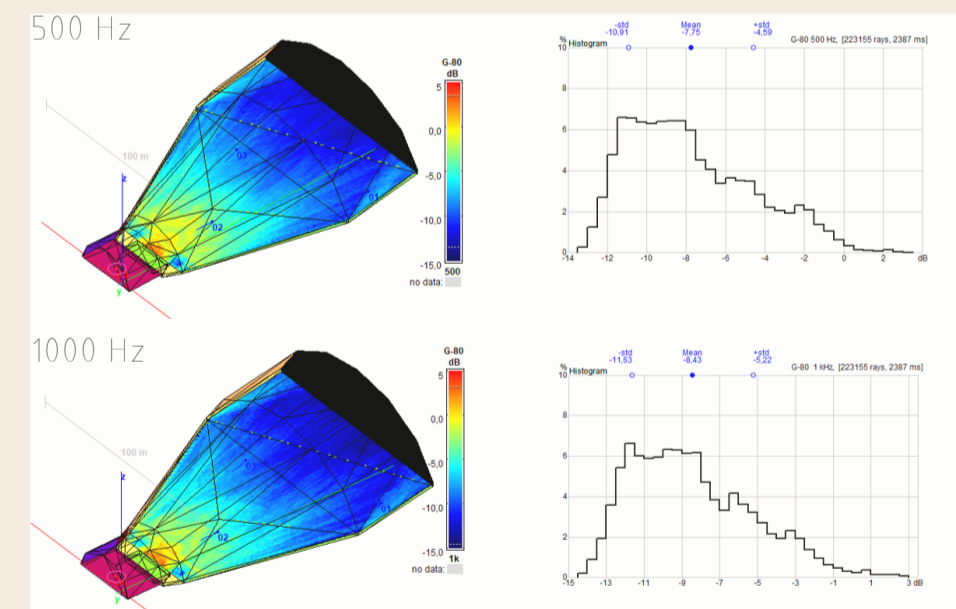
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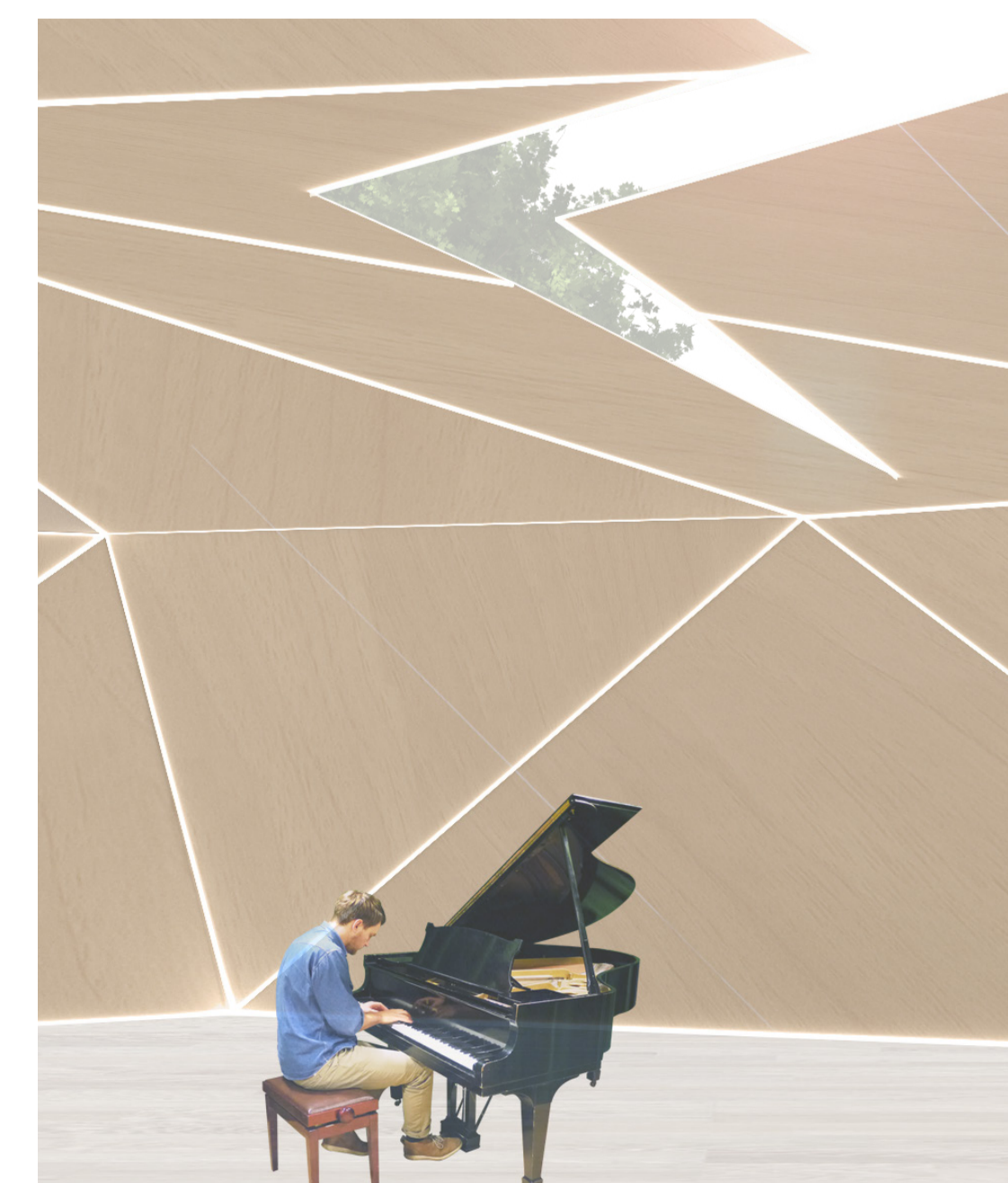
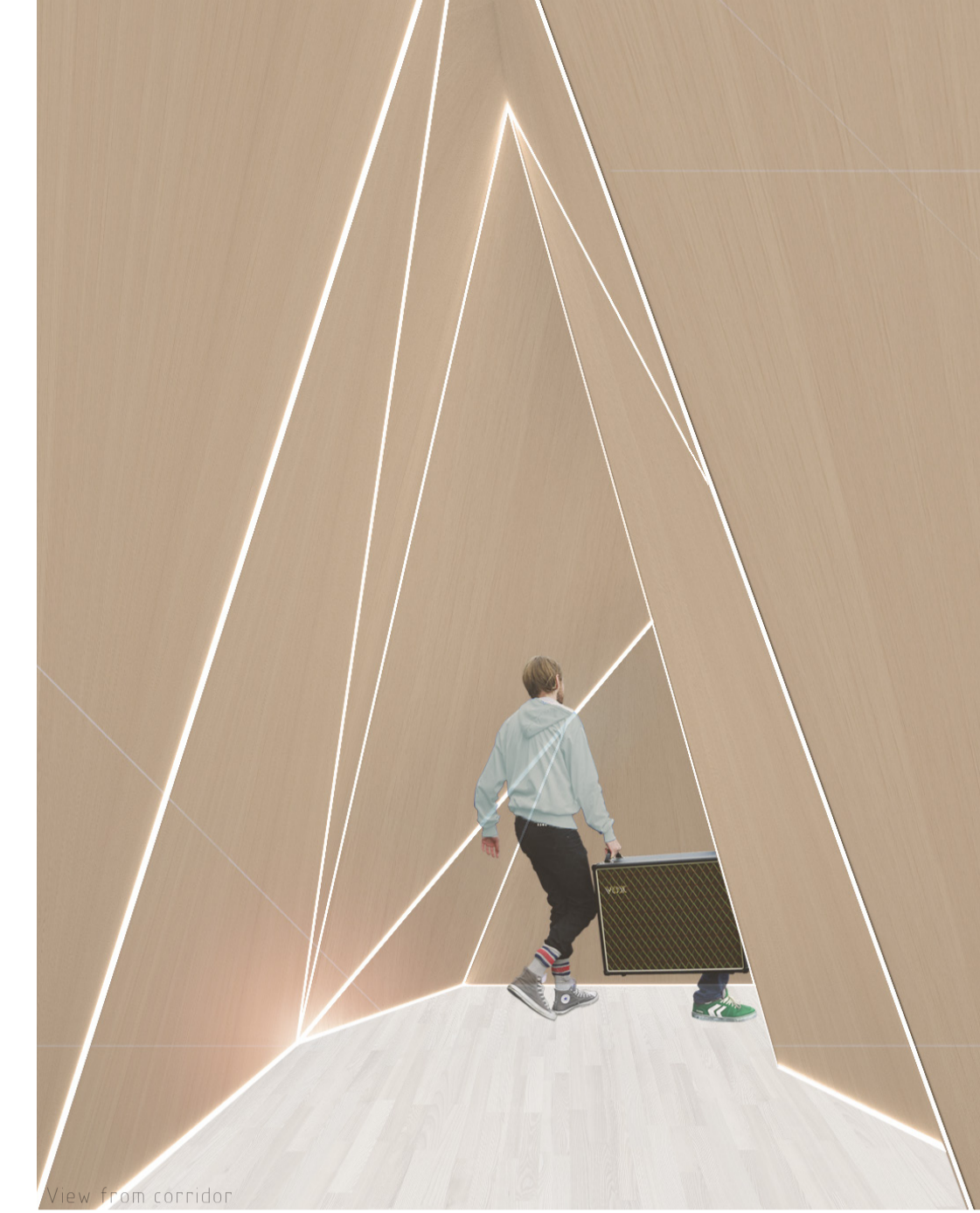
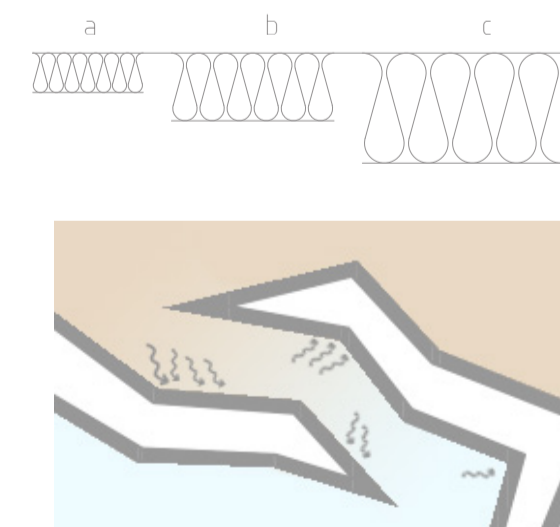
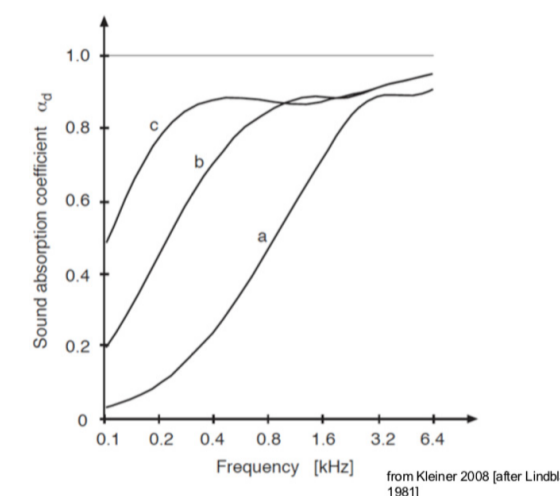
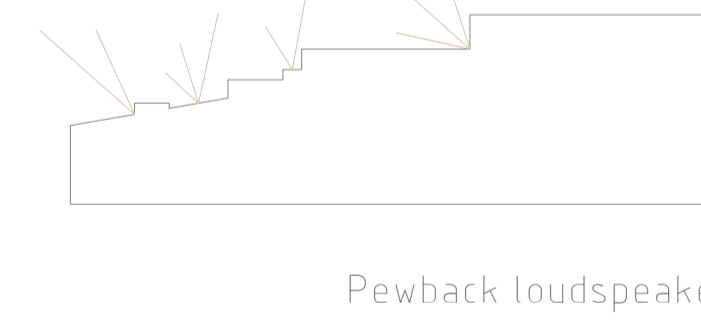
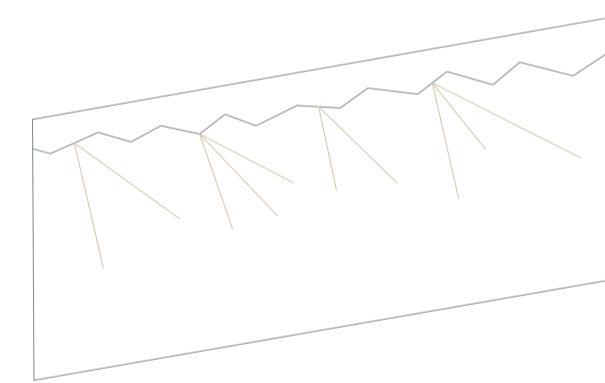
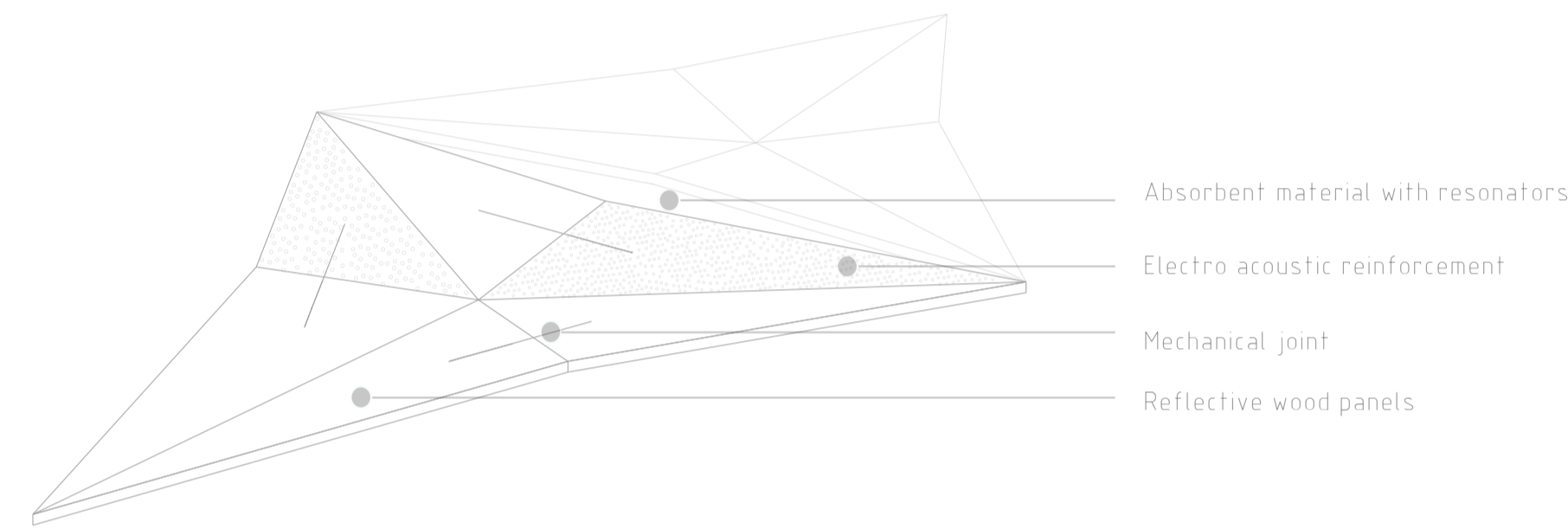
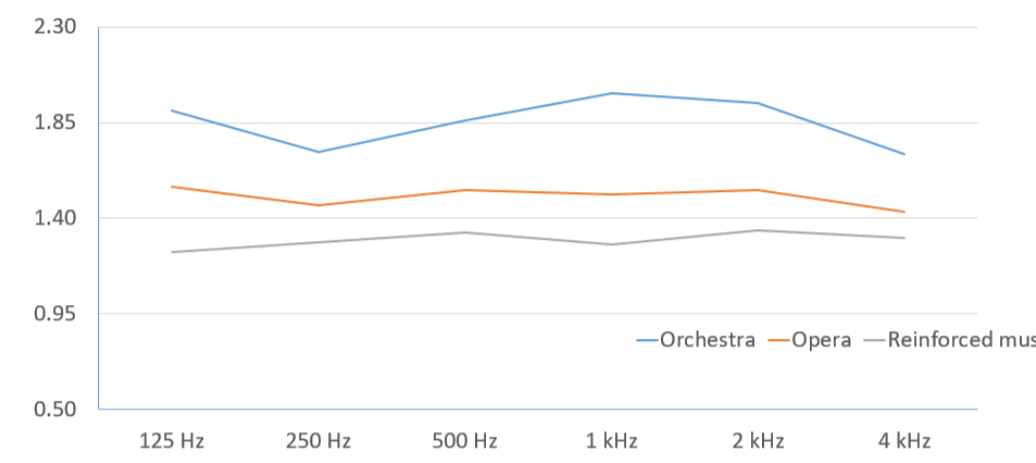
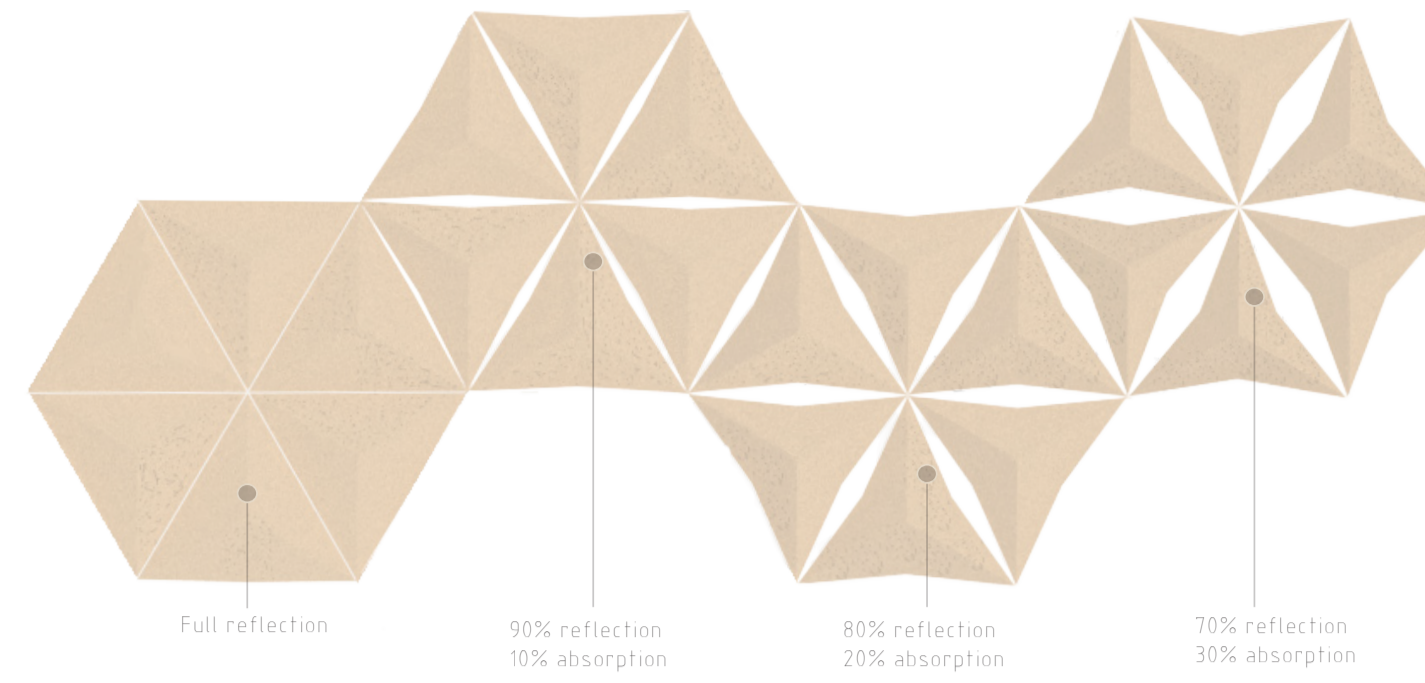
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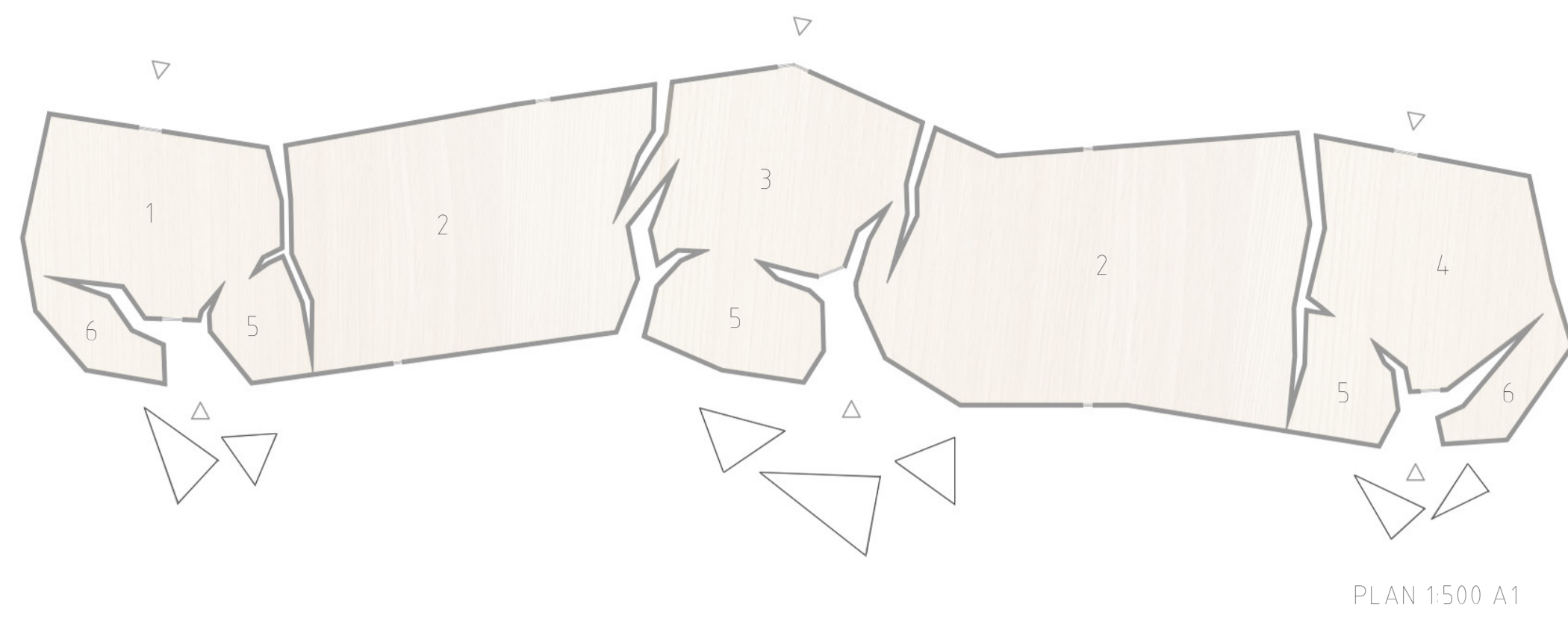
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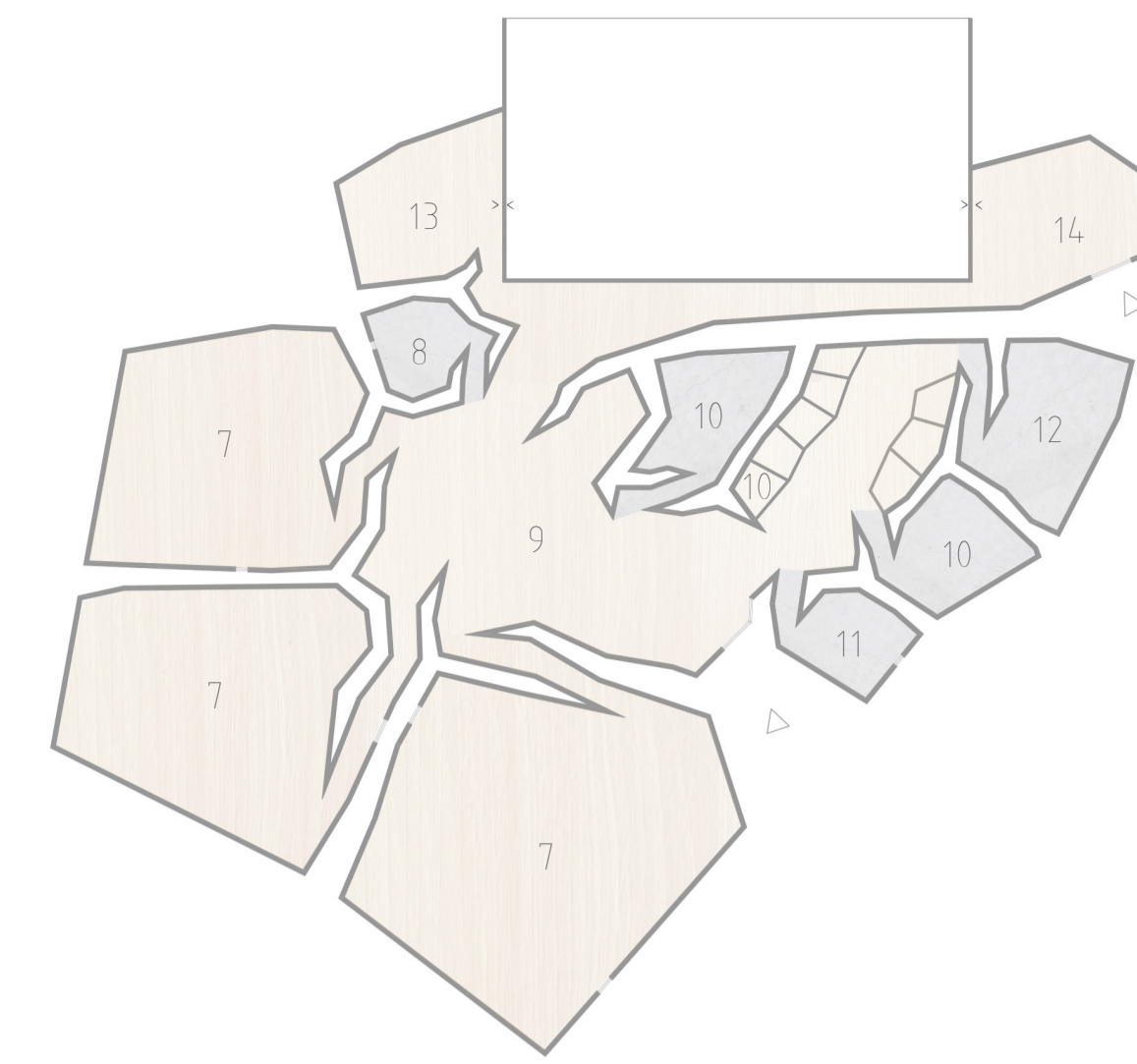




PLAN 1500 A1

- 1. Left foyer
- 2. Restaurant
- 3. Central foyer
- 4. Right foyer
- 5. Wardrobe
- 6. Restrooms

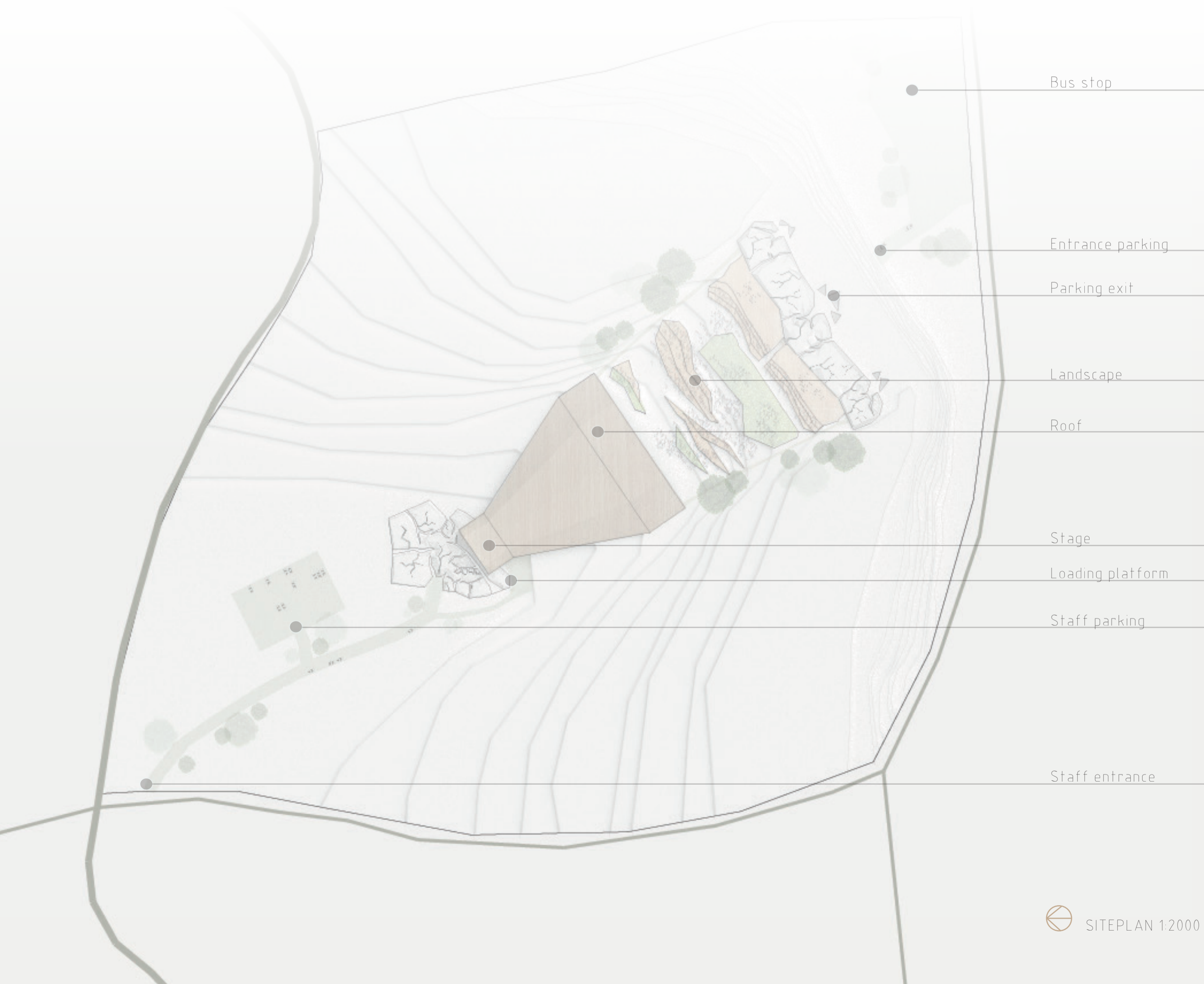
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⊙ SITEPLAN 12000 A1

REFLECTION

Firstly, I am very pleased with the final result of our project. We had a clear concept from the beginning with our triangular adjustable roof and throughout the entire process we worked with these triangles and cracks in one way or another. Since this was such a big concept in our project, I really appreciated when we got the feedback that the triangles and cracks were very convincing and connected the entire area. We used the cracks in different ways in for example the roof and the buildings but still people felt that they belonged to the same family.

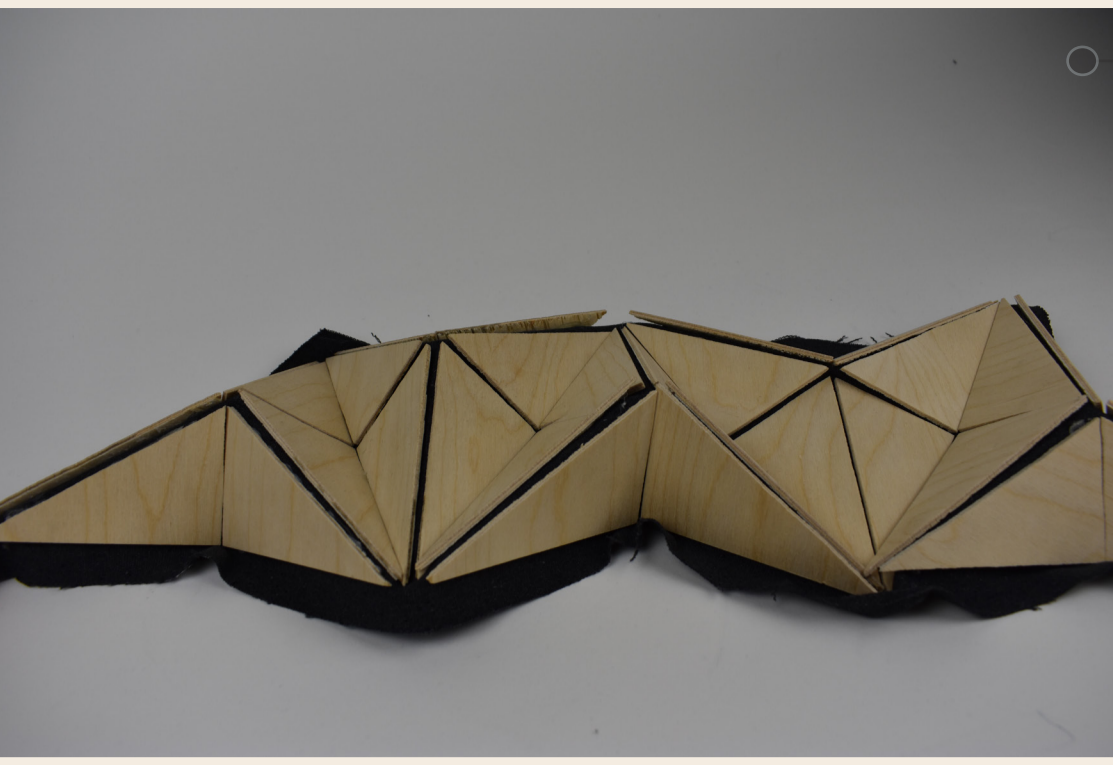
Unfortunately, our boards and drawings were considered hard to read. Since architecture is all about communication through drawings, we should have presented our material in a slightly different way. Our three-dimensional model could have been shown to facilitate further understanding on how the area is connected. Moreover, we could have developed our drawings and pictures to clarify them. The big rendering over the roof and seating area could have shown the connection with the open lawn area by choosing another view. The section could have shown more details such as the elevators from the parking to the entrance building.

The acoustics was naturally a very central part of the project. We decided that we wanted to work with the adjustable triangular panels in an early state and saw a lot potential in that kind of roof structure. Not only was it visually beautiful but also acoustically interesting. What if we could change the acoustical condition depending on performance and what if we could combine the panels with loudspeakers. The acoustician helped us with these questions and we saw that our ideas were possible. This kind of interdisciplinary collaboration was very instructive and I understood the importance of communication and understanding between the different disciplines. It was enlightening to work with someone who had another aim with the project and pleasant that we could work together.

However, I wished that we had developed the acoustical ideas further by investigating angles and conditions to really understand the potential from calculated values. Instead our calculations were very simplified. Nevertheless, we received good critique on our figures of the acoustics. They highlighted the possibilities and showed the potential of blending electro acoustics with room acoustics in a good way.

METHOD AND PROCESS

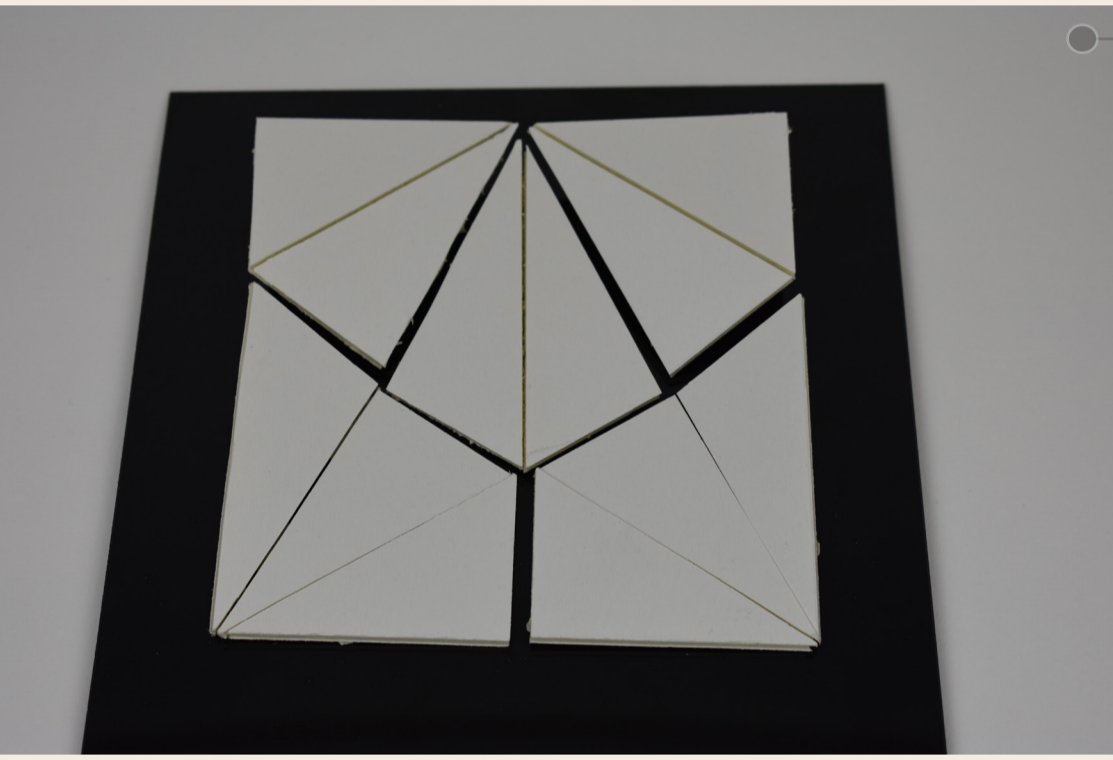
1. The model on our first idea of roof structure and acoustical concept. The model was very helpful in terms of understanding the flexibility of the structure.



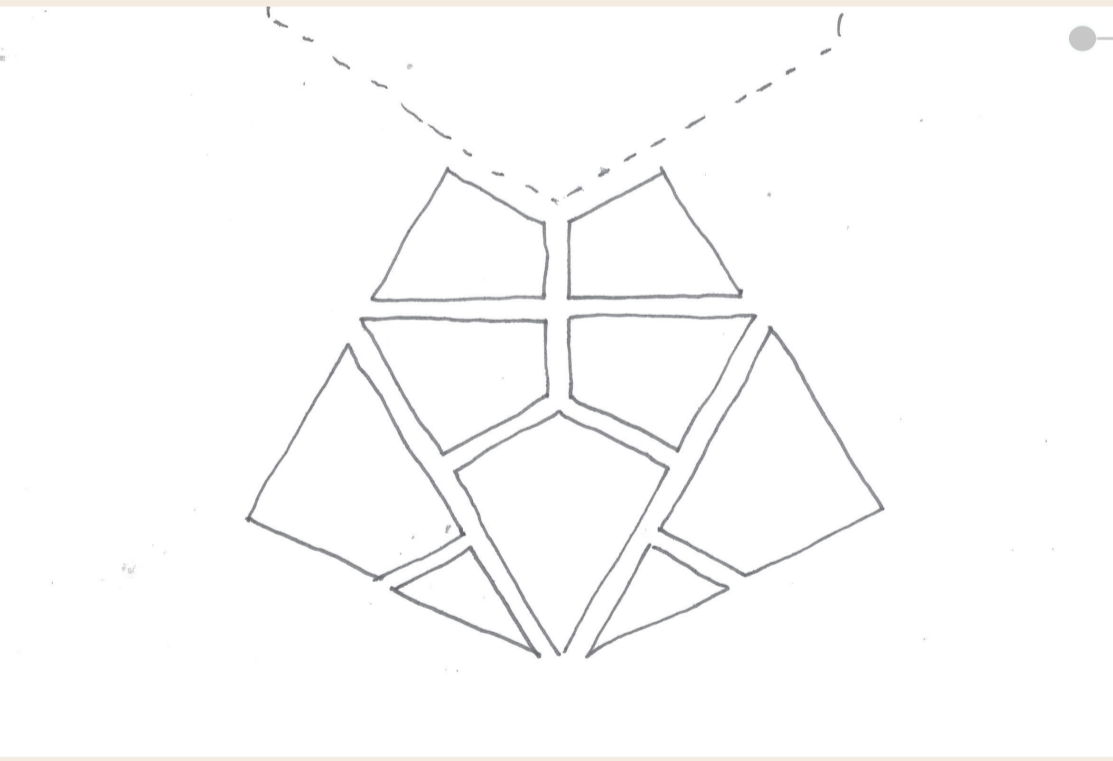
2. We experimented different applications on the triangular pattern and the model. This picture shows a potential stage appearance. I personally appreciated when the roof structure started from the floor and continued to the ceiling, an idea that we decided to keep throughout the entire project.



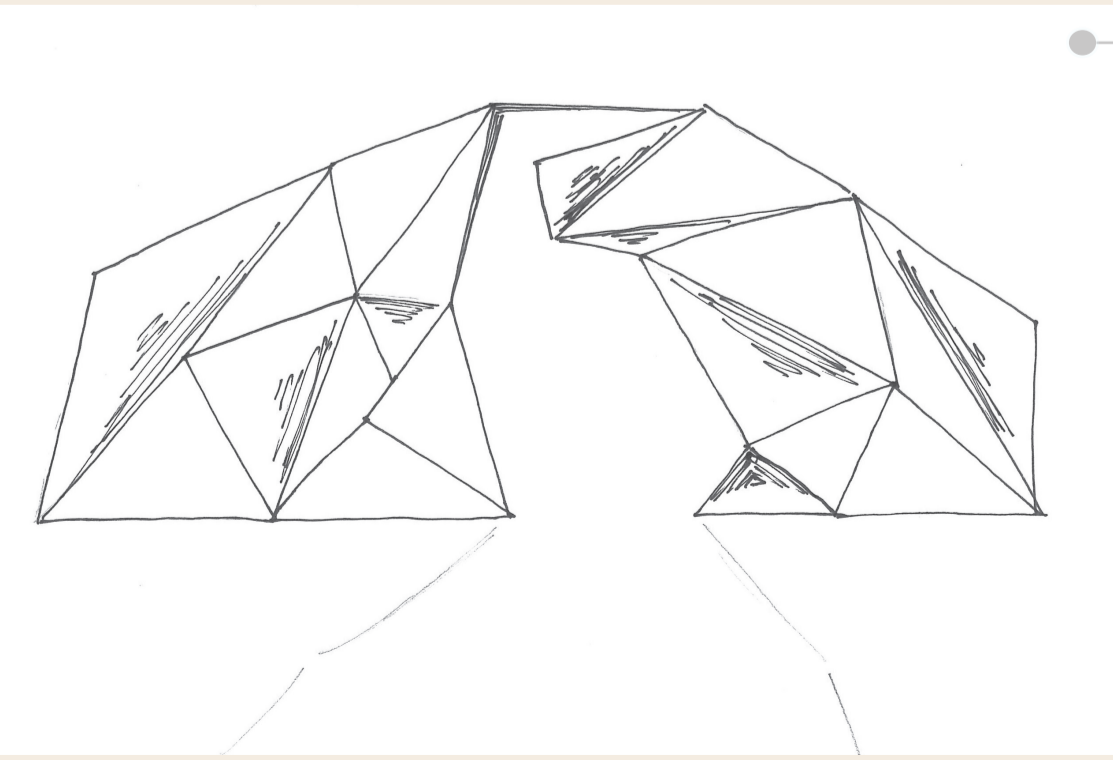
3. The pattern was initially used to form the open lawn area. It created clear zones but also problematic corners.



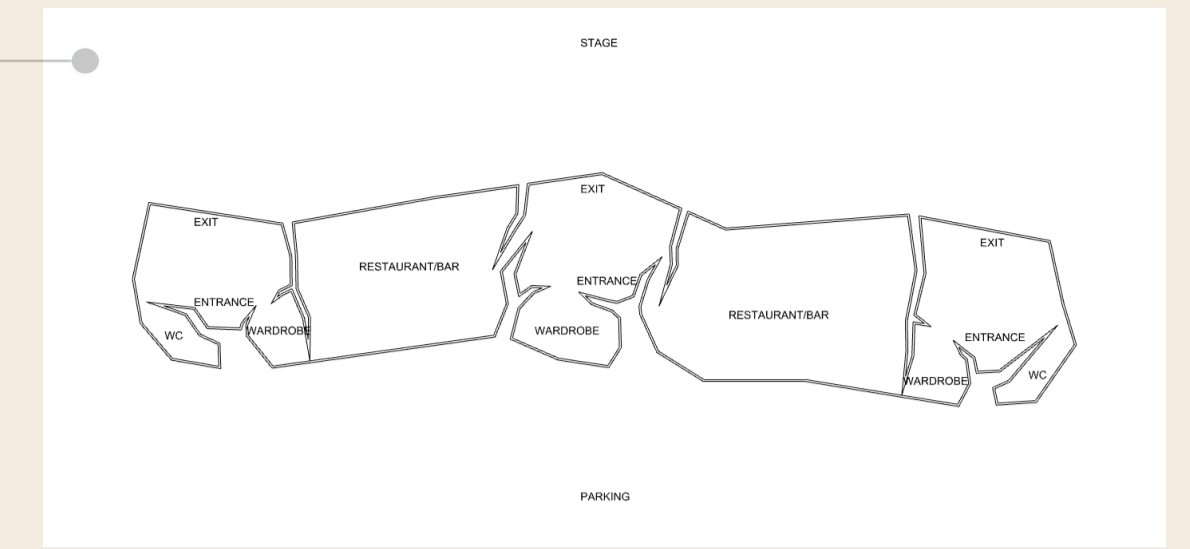
4. The same triangular pattern from the model was used to create a backstage plan. However, the problematic corners resulted in new proposals on plans.



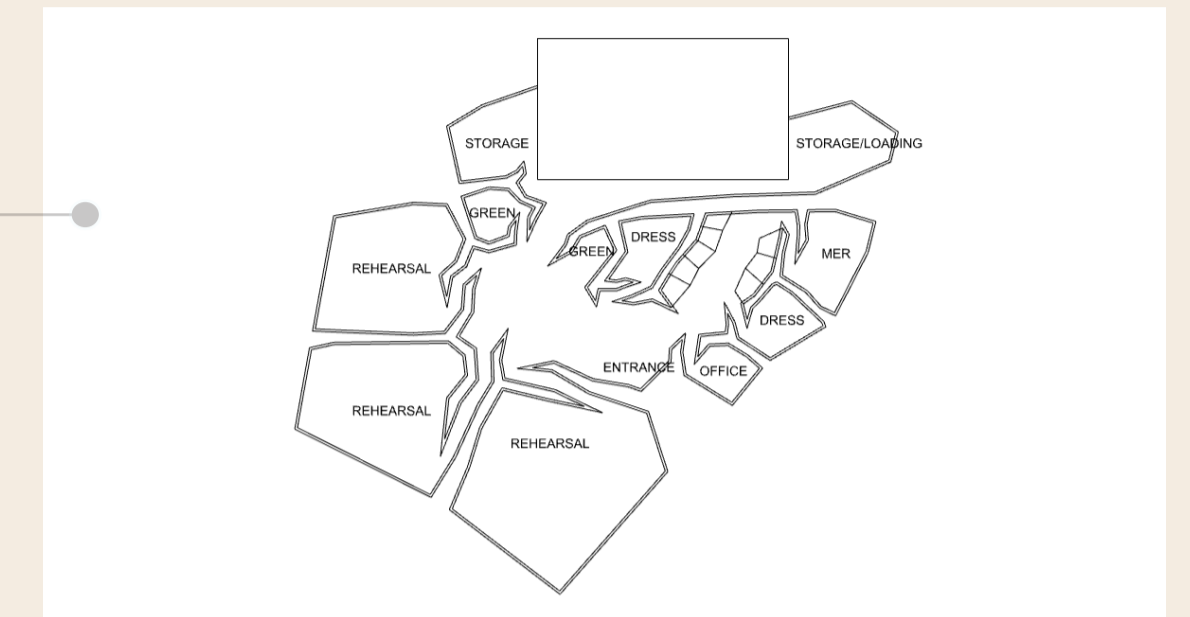
5. The idea on an abstract cave created by triangles was born. We made a quick sketch on how we imagined a facade and an entrance.



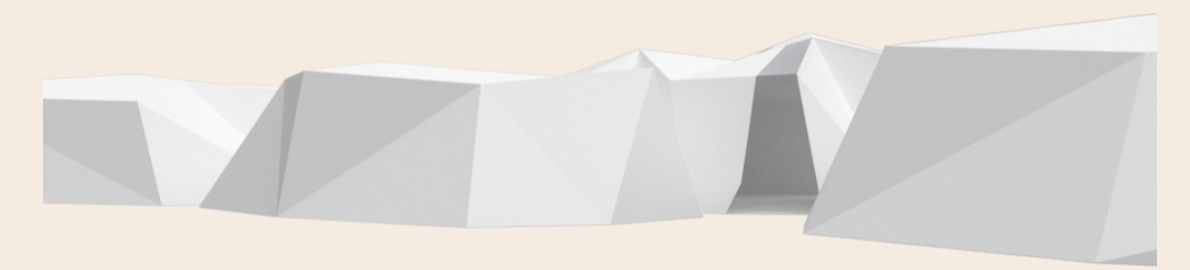
6. When we developed our acoustical roof, we established that the cracks between the triangles would be of major importance. By changing the angle of the triangles, we could increase or decrease the area of the space between them. By using an absorbent material in that space we could change the acoustical conditions. Since the cracks were very important for the acoustics, we started to experiment with cracks in other ways too, resulting in using cracks to form rooms in our buildings. This was a very important decision as the cracks came to be a vital connection for our project in large.



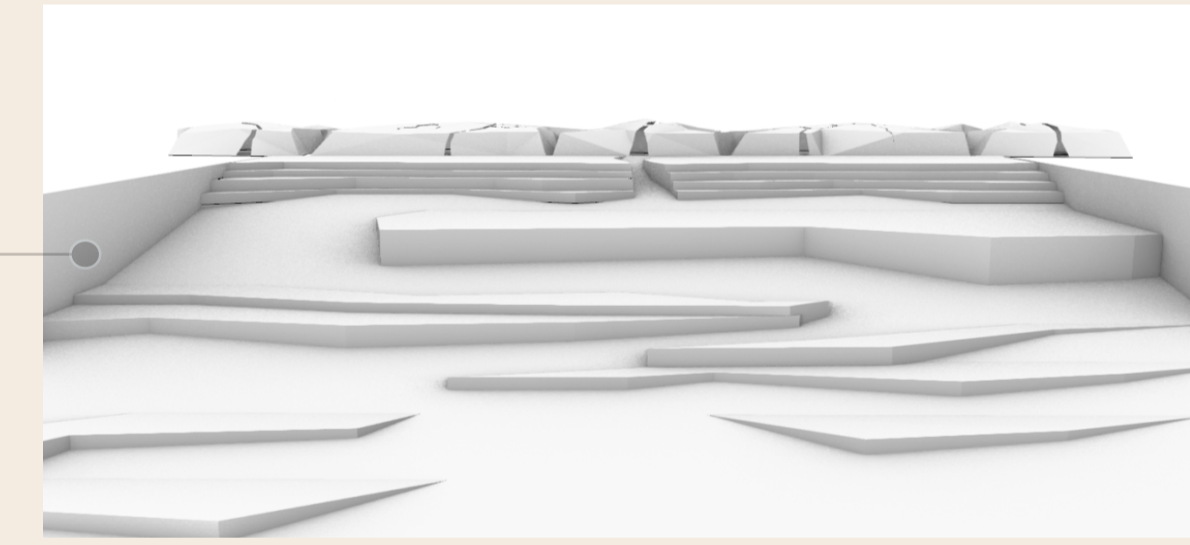
7. We used the same method when we created the backstage plan. One important decision was to overlap the cracks, forming long corridors that together with a very absorbent material eliminated the need for an ordinary door. More detailed calculations must be done to establish the possibility of this solution. Nevertheless, I am very fond of the idea.



8. After finishing the plans we created 3D models to visualize the exterior expression.



9. The open lawn landscape was designed to collaborate with the cave like buildings instead of using triangles as we initially did.



10. From the beginning we planned to use parking houses as acoustical barriers around the area. In the end however, we used the parking to create difference in altitude since the location itself was rather flat. We considered that the staff, using the backstage building, required daylight and therefore we chose not to build underground. Instead we created a small mountain on the site which connects to the abstract cave concept.

