

THE TRIANGULAR CAVE

Linnéa Gabrielsson Elin Israelsson Jing Zheng The following project was the final bachelor project during my studies at Architecture and Engineering. The assignment was to create an open roof theatre that could host different types of performances. One big focus point was the consideration of the acoustics, as this project was a collaboration with the master programme sound and vibration. The project was done in a group of three. 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 cavelike 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. PLAN 1:3000



- 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
- 10 Decesing sooms
- 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.











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 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. Notice, 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.

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 CORRIDOR

THE REHEARSAL

To create a more cave like experience, the rehearsal rooms are doorless, and so 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 low 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.

The landscape behind the roof is the place for the standing audience. Here you can find plenty of things to do, you can have a picknick, take a seat at the bleachers or use the restaurants outdoor seating area and enjoy a cold drink as you listen to your favourite music. You exit the parking by taking the elevator to the very top of the hill. Here, you are greeted with the entrance building. This is a huge and abstract building with facades dressed in triangles. The concept of the in-between spaces and the cracks are clearly reflected in both the plan and the unique windows.



TRANCE







THE PROCESS & CRUCIAL DECISIONS

The concept of the triangles was something that we stuck with from the start. We also had an idea of a grand wood structure very early in the process. The thing that took the longest time was to explore how to iterate the triangles in different ways. The roof was the easiest part, we found the idea of a flexible roof very interesting and intriguing. The plan was something that we struggled with; we tried several options to integrate the triangles to a plan. At the same time, we wanted it to be a logical solution, that did not compromise the experience. The solution was to go back and consider how we do experience triangles, when we got that revelation, we started to apply the triangles to a smaller scale. That is when we started to work more on the interior of the buildings. The idea of the landscape was also present from start but was constantly developed throughout the process.

REFLECTION

The overall finish of the project is something that me and Elin are very happy and proud of. We feel like we created an interesting and unique project. We wanted to challenge ourselves and go out of our comfort zone by working with a freeform concept and irregular shapes. That challenged us in both our sketch process and our computational modelling, which was mostly done with grasshopper. I am very happy that we stuck with our original triangular concept and applied it to many different levels. The things that I would have liked to further explore is the path from the parking to the main centre. At the critique, we were told that our presentation was hard to understand. We understand this and are going to learn from this critique in later projects.

The teamwork between me and Elin worked very well. We had some miscommunications with our acoustician. Although, the result of the acoustics worked out fine. We thought that the concept of working with corridors and no doors was very interesting, and the adjustable roof was very fun and challenging to work with. In a further process, we would have liked to explore how we could use the adjustable tiles to create good acoustics without electro acoustic amplification.