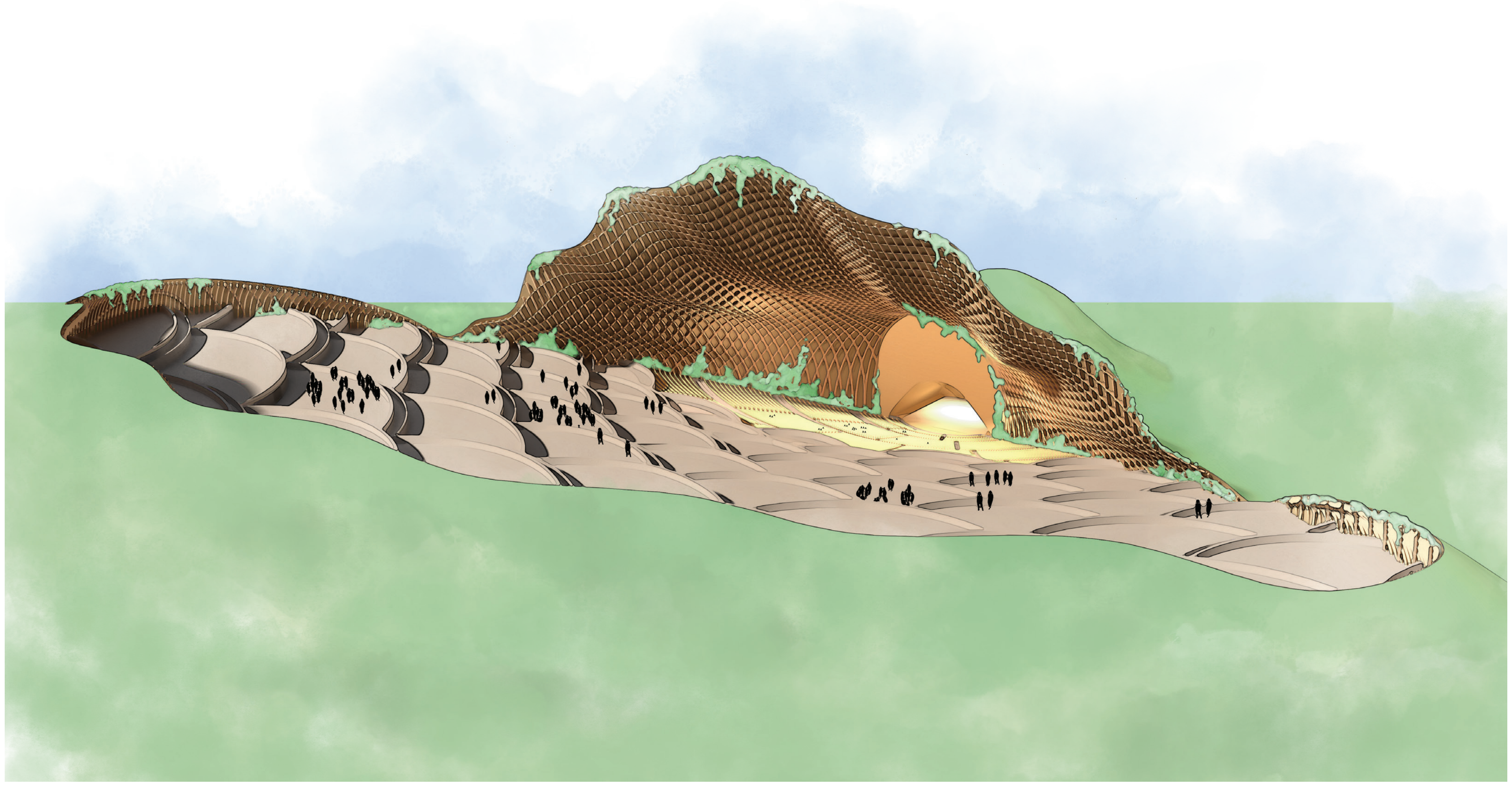


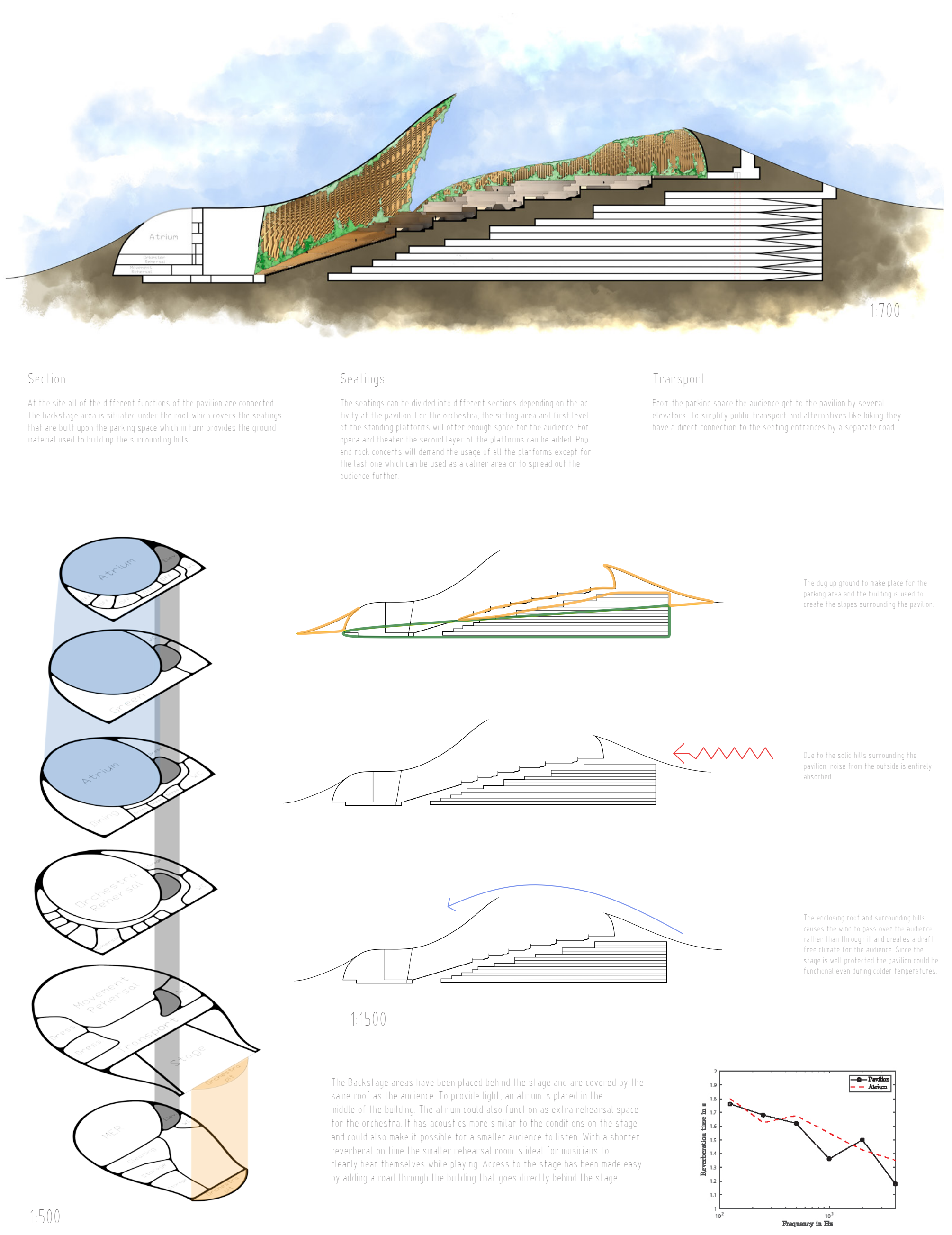
Sound of nature

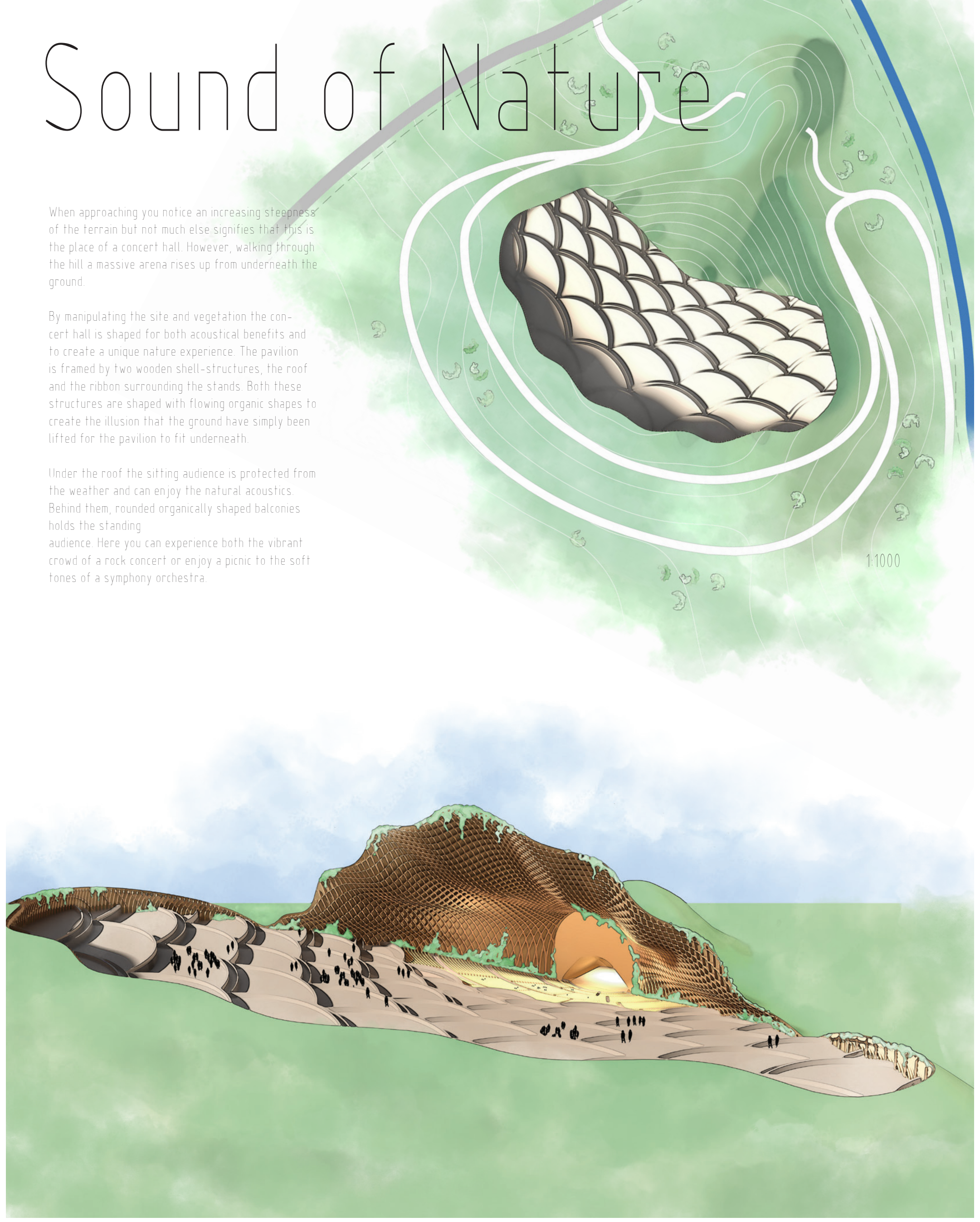
- A collaboration of architecture and acoustics

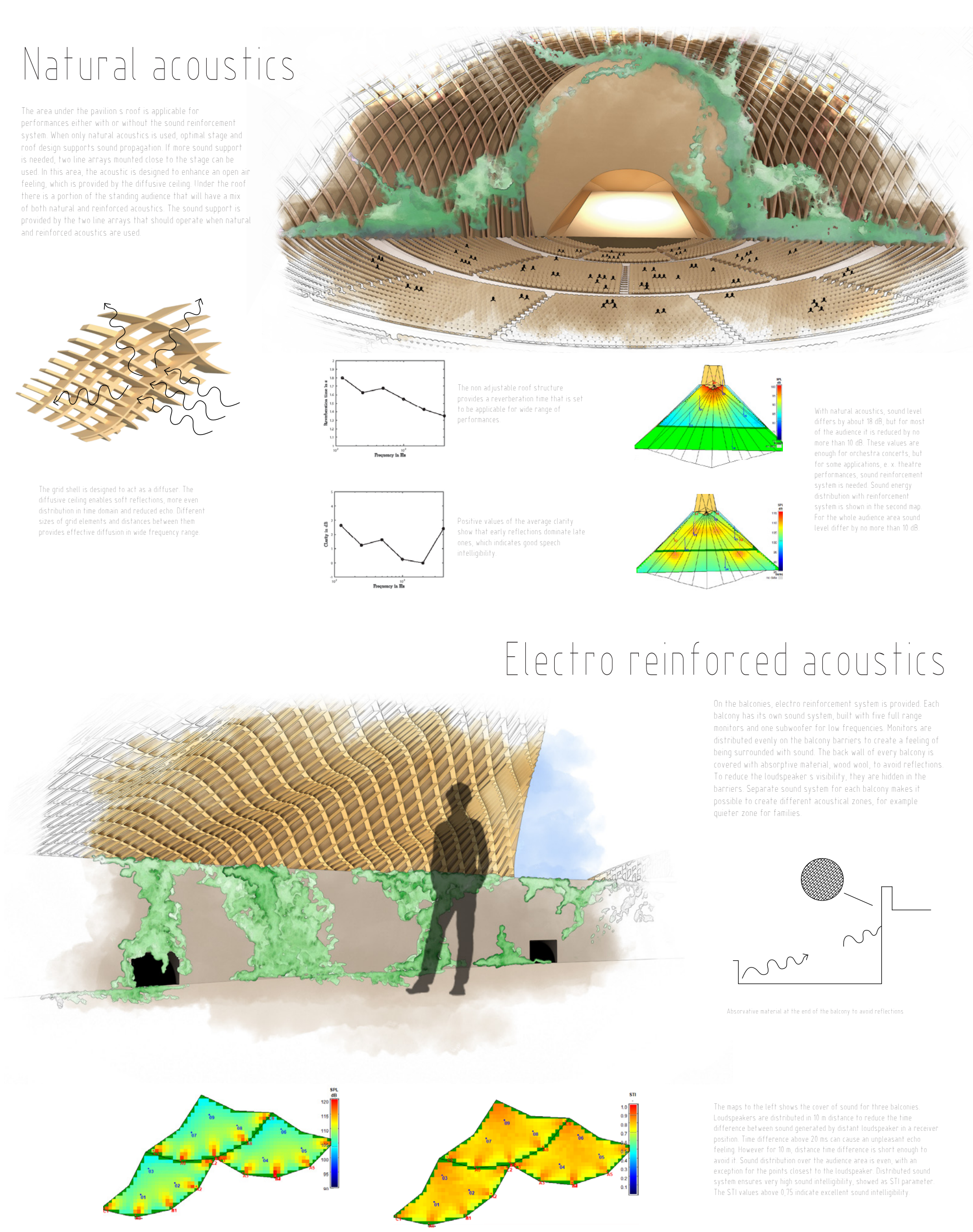
Course ACEX15 Bachelor's thesis in Architecture and engineering
Extent 6 hp
Period HT 2019
Team Hanna Eriksson, Aleksandra Sadowska
Examiner Morten Lund, Peter Christensson

Task To create a music pavilion, with both covered and lawn seating, for a city orchestra to use during summer.

Focus The red thread throughout this project was to unite great acoustics with an architecture that would bring the visitor closer to nature. By manipulating the ground, we strived to create an experience where it would feel like nature had provided the pavilion for the listener. While using organic shapes and static structures we wanted to bring a sense of calmness and obviousness to the pavilion. A sense that we believe also can be found in nature.







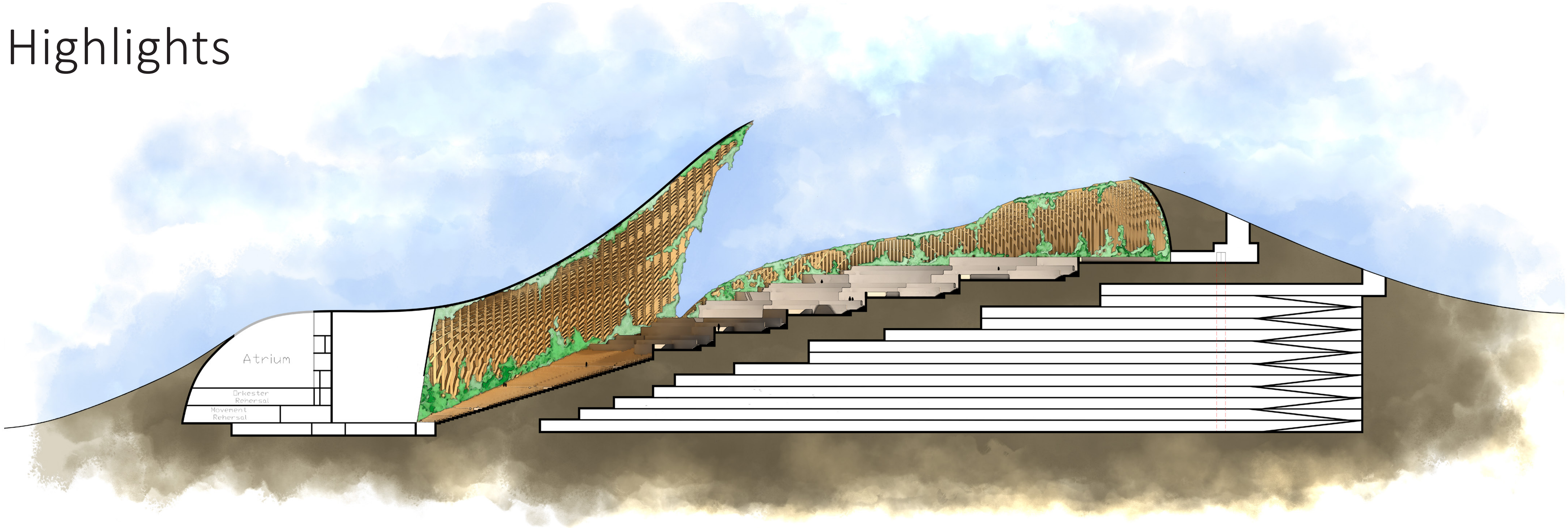
The competition

Every year the Acoustical society of America holds a student design competition to provide an opportunity for students within building disciplines to express their knowledge of architectural acoustics. The demands and program of this competition (the 2020 Newman award fund student design competition) served as the basis for our bachelor's thesis. During the project, we had a collaboration with the acoustics department at Chalmers to deepen the understanding of the acoustics at the pavilion.

The program of the competition demanded an open-air pavilion where part of the audience should be covered by a roof and be dependent on natural acoustics. Apart from orchestra performances, the pavilion also had to hold events such as opera, theatre and pop/rock concerts which all demanded different acoustical demands as well as audience space. The backstage area had to provide rehearsal spaces that would be acoustically sensitive and the competition site was surrounded by several different noise sources.

Our goal during the project was to fulfill these demands as well as offering a great architectural experience. The material of the final project was mounted on three posters, which are shown above.

Highlights



Section

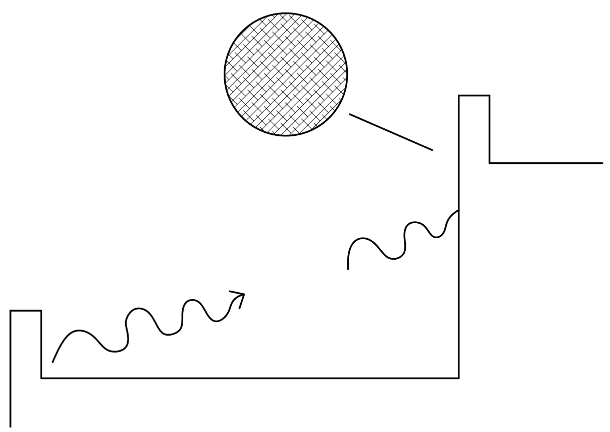
At the site all of the different functions of the pavilion are connected. The backstage area is situated under the roof which covers the seatings that are built upon the parking space which in turn provides the ground material used to build up the surrounding hills.

Seatings

The seatings can be divided into different sections depending on the activity at the pavilion. For the orchestra, the sitting area and first level of the standing platforms will offer enough space for the audience. For opera and theater the second layer of the platforms can be added. Pop and rock concerts will demand the usage of all the platforms except for the last one which can be used as a calmer area or to spread out the audience further.

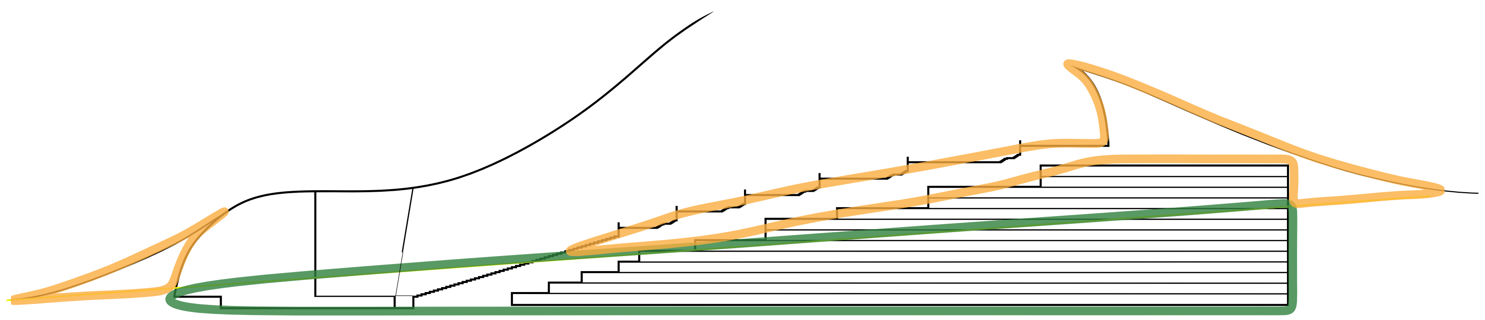
Transport

From the parking space the audience get to the pavilion by several elevators. To simplify public transport and alternatives like biking they have a direct connection to the seating entrances by a separate road.



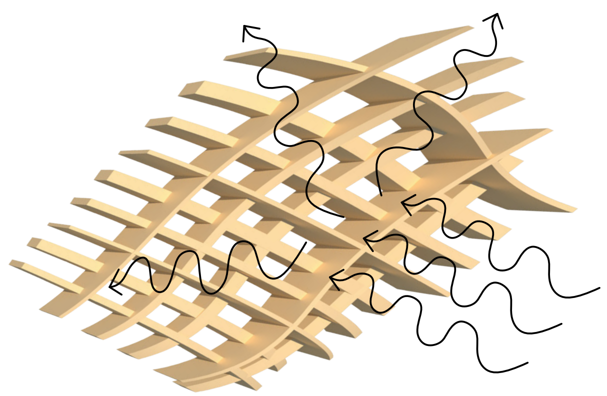
Absorption

Absorvative material is placed at the end of the balcony to avoid reflections.



Ground placement

The dug up ground to make place for the parking area and the building is used to create the slopes surrounding the pavilion.

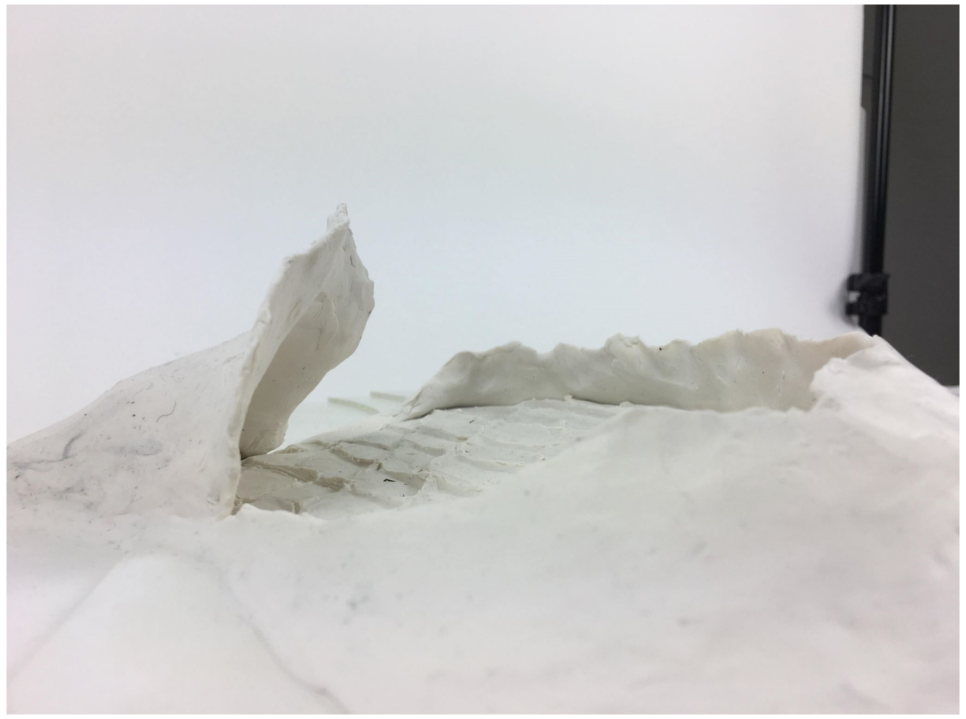


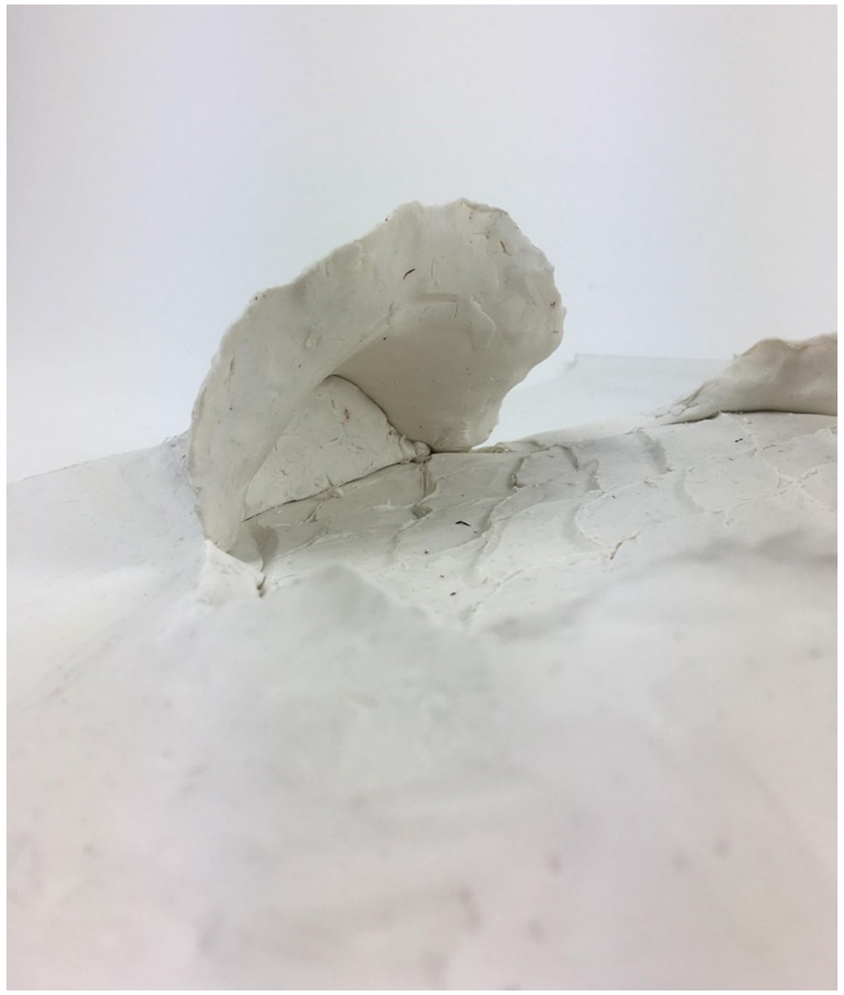
Diffusion

The grid shell is designed to act as a diffuser. The diffusive ceiling enables soft reflections, more even distribution in time domain and reduced echo. Different sizes of grid elements and distances between them provides effective diffusion in wide frequency range.

Design process

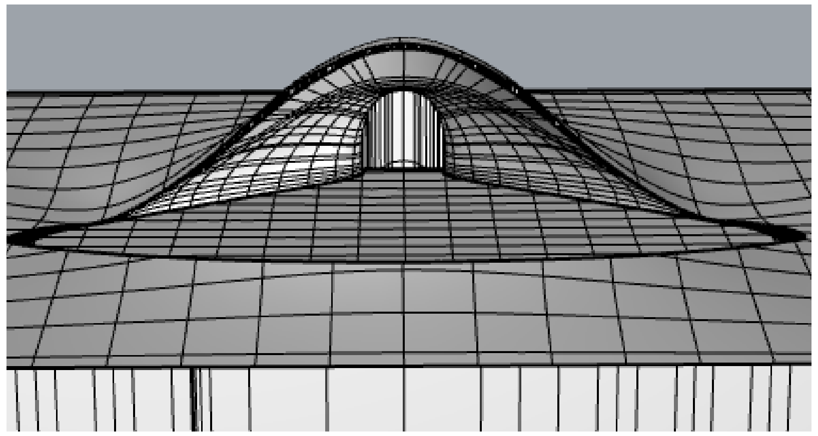
By continued meetings with the acoustician and consultations with teachers the project was developed. From the basic geometry tweaks to improve acoustics were made. We also developed the architecture by adding materials and considering logistics.





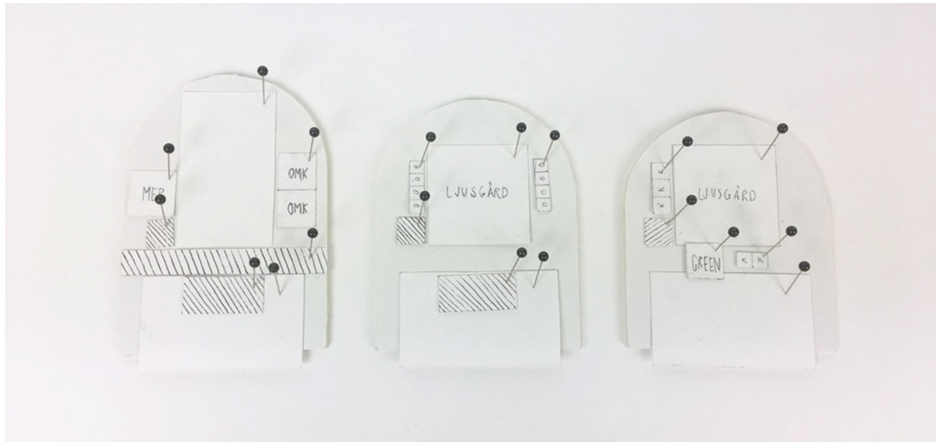
Clay model

During the very first iterations of the project we decided to use a clay model to develop an unrestricted geometry. Having a simple theory in mind, with a sound spreading “cone” meeting a sound catching “ribbon”, an organic, flowing shape was developed. While the details of the shape changed, the base geometry was something we held on to during the continuation of the project.



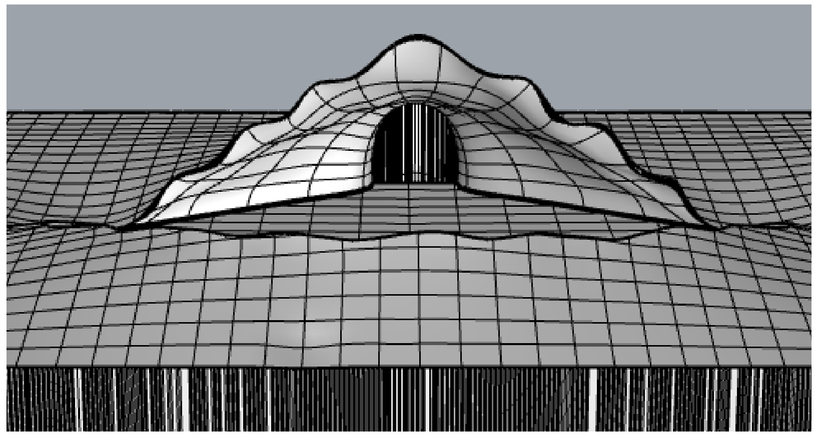
Different developements of the roof

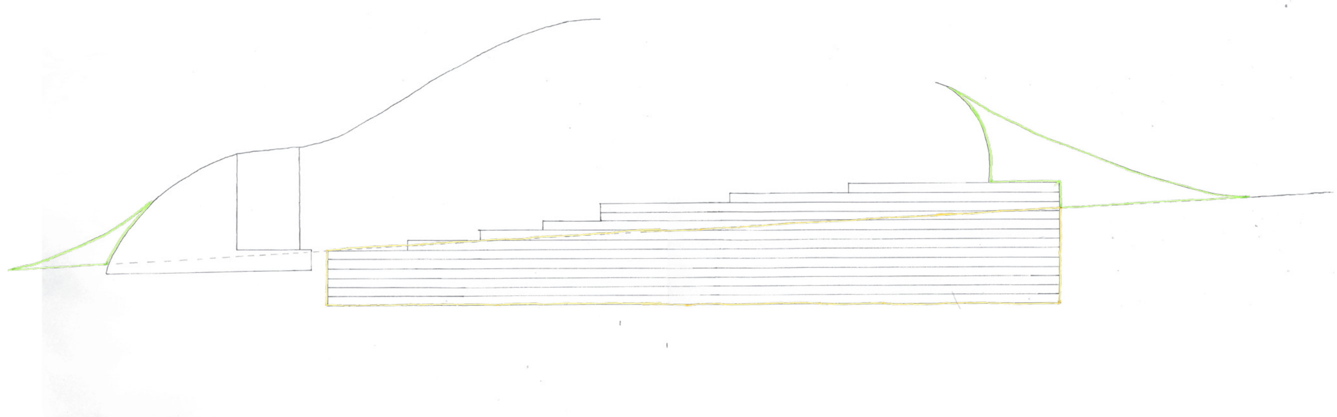
To prepare for the acoustical part of the project a number of different roof constructions were explored. During this process, we set for the more intricate curves of the roof as well as the curve of the ribbon.



Indoor areas

For the backstage areas, it was an important part to keep them easily accessible in one space. We also wanted the rooms to comfortably be used with enough space and access to daylight. The atrium in the building would help achieve the daylight and also improve the atmosphere.



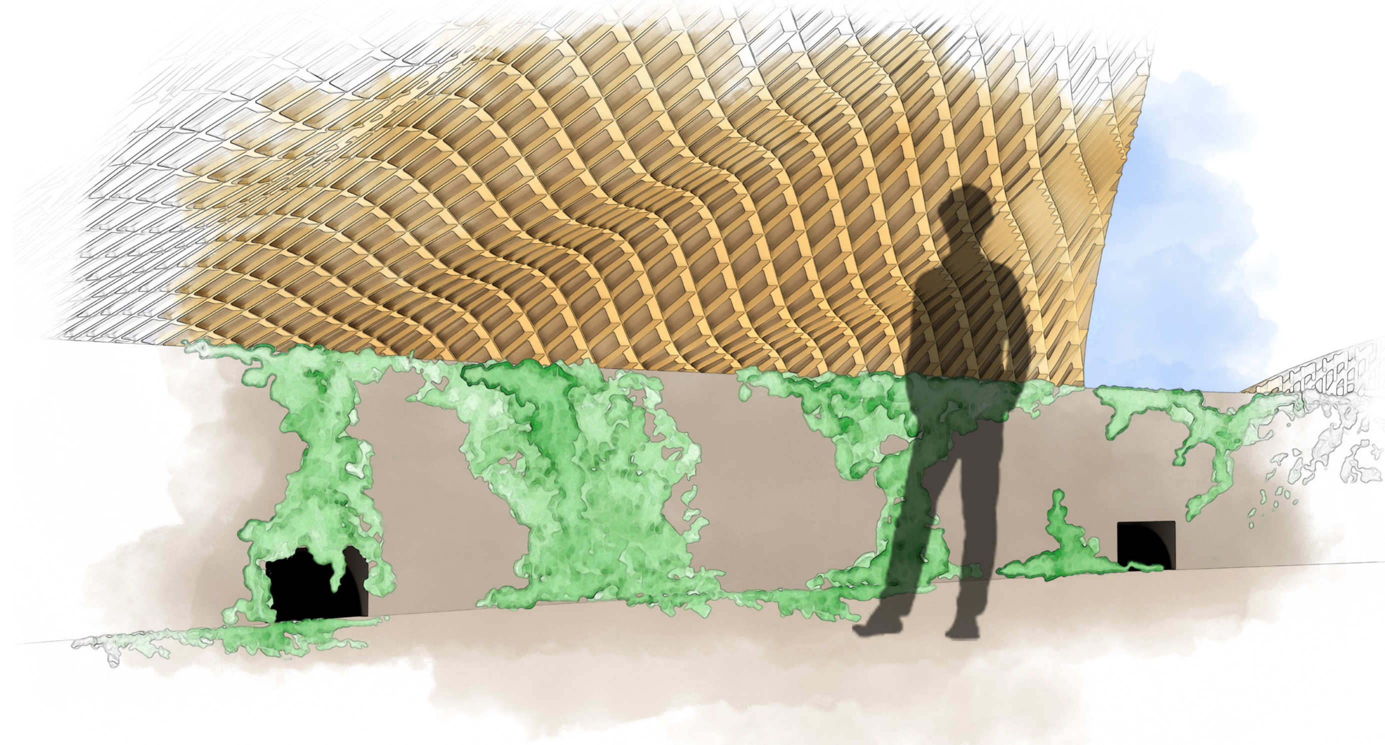


Parking space and treatment of the ground

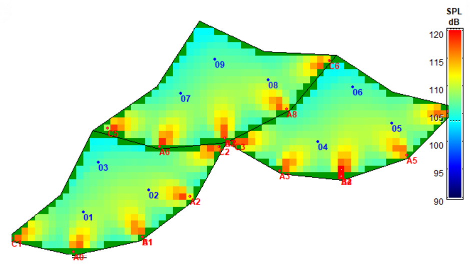
In the competition program a large parking space was required. Our solution was to put the parking area underground which resulted in a large amount of leftover soil. To avoid wasting the soil it was then used to build up the hills surrounding the pavilion and function as protection from the noise.

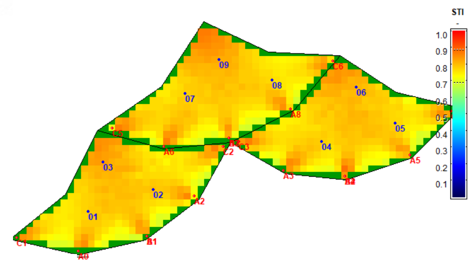
Acoustics

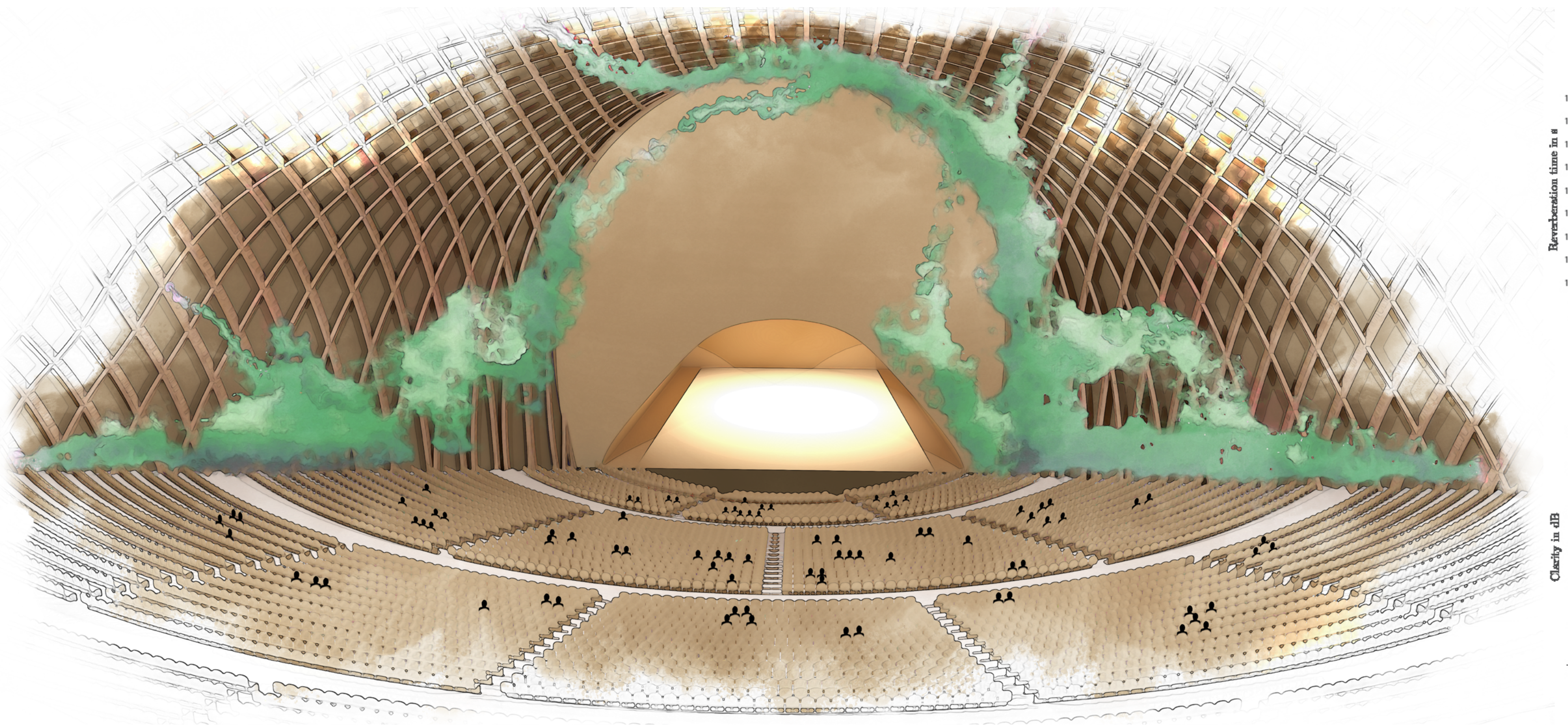
Throughout the course we had a collaboration with a master’s degree student from the acoustician discipline. By continual meetings we kept an ongoing discussion of how the pavilion could be shaped to provide the acoustics set in our goals. In our case the design of the roof became prime focus. To improve the acoustics, the roof was lowered and set to cover a larger part of the seating area. The grid shell, that we chose for its design purposes, was also developed to be used as a diffuser. Other parts of interest were the stage opening, where walls were angled to improve the ability for the sound to spread, as well as the discreet loudspeaker system for the electro-acoustic reinforcement at the balconies.

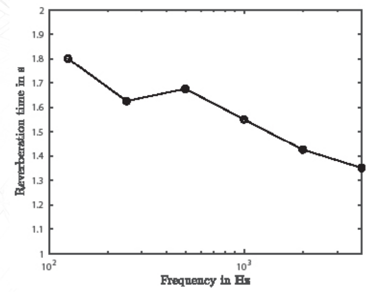


The maps to the left shows the cover of sound for three balconies. Loudspeakers are distributed in 10 m distance to reduce the time difference between sound generated by distant loudspeaker in a receiver position. Time difference above 20 ms can cause an unpleasant echo feeling. However for 10 m, distance time difference is short enough to avoid it. Sound distribution over the audience area is even, with an exception for the points closest to the loudspeaker. Distributed sound system ensures very high sound intelligibility, showed as STI parameter. The STI values above 0,75 indicate excellent sound intelligibility.

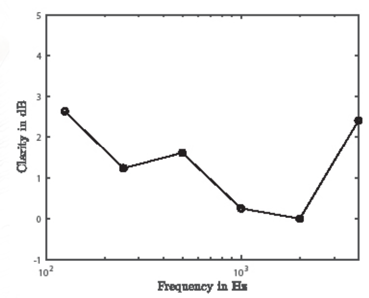




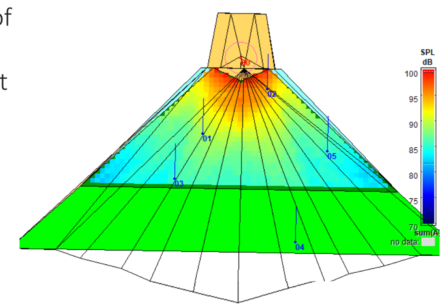


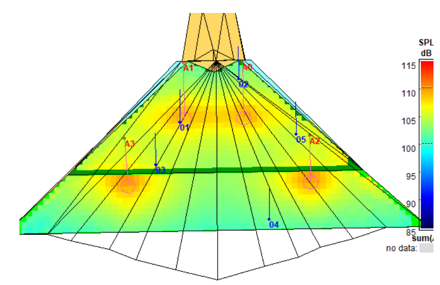


The non adjustable roof structure provides a reverberation time that is set to be applicable for wide range of performances.



Positive values of the average clarity show that early reflections dominate late ones, which indicates good speech intelligibility.





With natural acoustics, sound level differs by about 18 dB, but for most of the audience it is reduced by no more than 10 dB. These values are enough for orchestra concerts, but for some applications, e. x. theatre performances, sound reinforce-ment system is needed. Sound energy distribution with reinforcement system is shown in the second map. For the whole audience area sound level differ by no more than 10 dB.

Sound of nature

Reflection

We were very content with the result and felt like we reached the goals we had set for the project. Despite the static structure good acoustics for all the events at the pavilion was achieved. The main focus during the project was to achieve enough sound strength at the acoustical part of the audience. However, an improvement of the acoustic experience could be made at the balconies where the area closest to the loudspeaker could become too loud for comfort. For example, the distance between the listener and the loudspeaker could be increased by moving them further into the wall.

The design was interesting but was focused on the visual effects. To realize the project, it would be necessary to further analyze the physics of the building. Likely the roof would have to be lowered and decreased in size. The balconies would also be an interesting part to continue developing. At their current state, they contrast the other parts of the design with their geometrical shape, in a continued design progress it would be interesting to try and create more organic shapes. During our final critique, there was a mention of rice fields that would be a fun image to investigate.