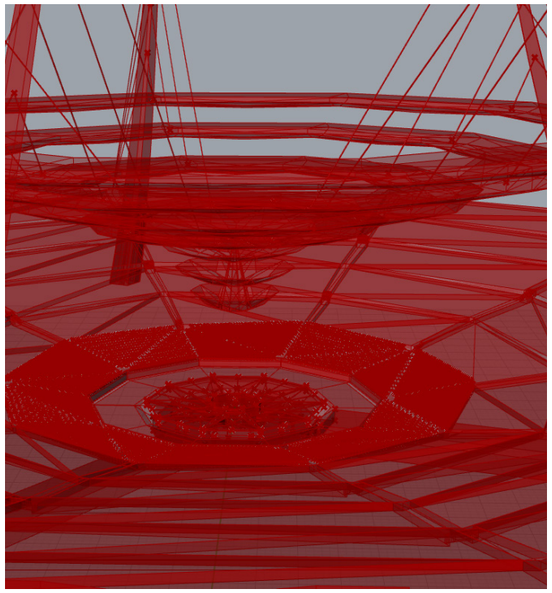
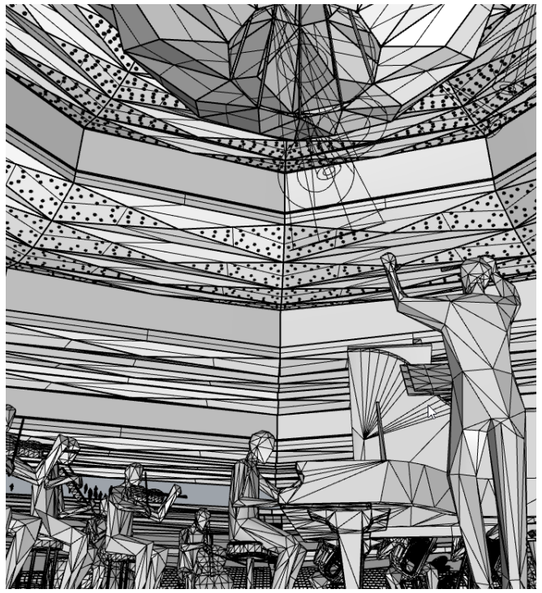
ACEX15 - Fall 2020
Bachelor in Architecture & Engineering
ACOUSTIC PAVILLION & STUDENT COMPETITION

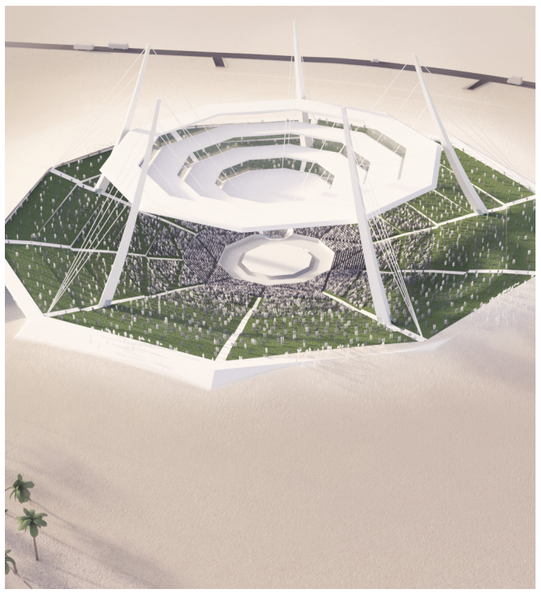
Teacher & examinator: Morten Lund

Project description:
Architecture & engineering has a bachelor project as opposed to a thesis at the end of the third year. The project combines acoustics with architecture and engineering as it follows the ASA student competition format.

The ASA student desgin competition is arranged by The Acoustical Society of America and is a yearly competition for students that promote the collaboration between architects and engineers in the field of acoustics. (http://www.newmanfund.org/).


Parametric modelling


Rendering preperations


Renderings & plansch preperations

Student Design Competition 2020

PRESENTED BY:
TECHNICAL COMMITTEE ON ARCHITECTURAL ACOUSTICS,
ROBERT BRADFORD NEWMAN STUDENT AWARD FUND

SPONSORED BY:
THE WENGER FOUNDATION

Brief competition narrative for 2020

An outdoors music pavillion with various functions, will serve performances ranging from orchestra, opera and ballet to large rock and jazz performances, during a summer season.

For the bigger performances like rock & jazz, audiences of up to 25,000 are expected, whilst the other performances expect between 7,0000 to 10,000 patrons.

The circumstance beg for a venue where acoustics are variable and design solutions that are flexible and innovative.

Early February

To prepare us for the competition, our class had a two weeks course in acoustics.

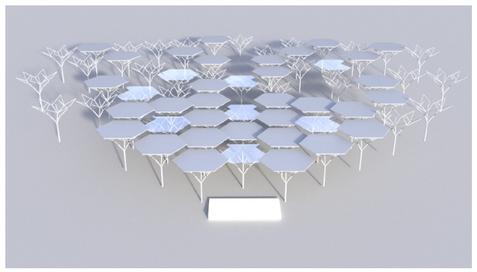
We also visited a few different sites, to give us a scope and feel of the competition site.

The project is done in pairs of three, normally two AT - students and one acoustician from Chalmers Sound & Vibration engineering department.

Me and two other AT - students teamed up as a group of three AT - students as we where comfortable we could manage with very little help from the acoustics department

February 18th

During our early design phase we decided to try our hands on a concept where structural trees carry roof panels with integrated acoustical properties. It didn't take long untill we would find the idé flat and dull.

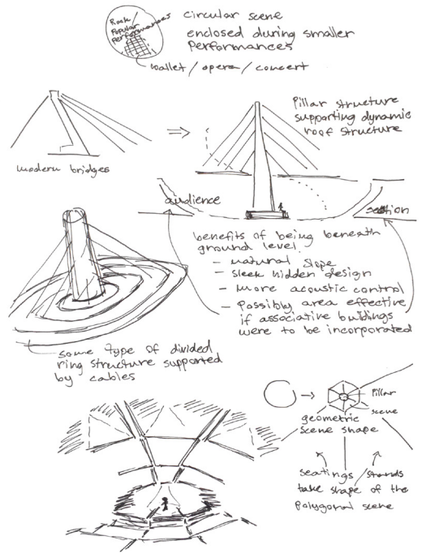


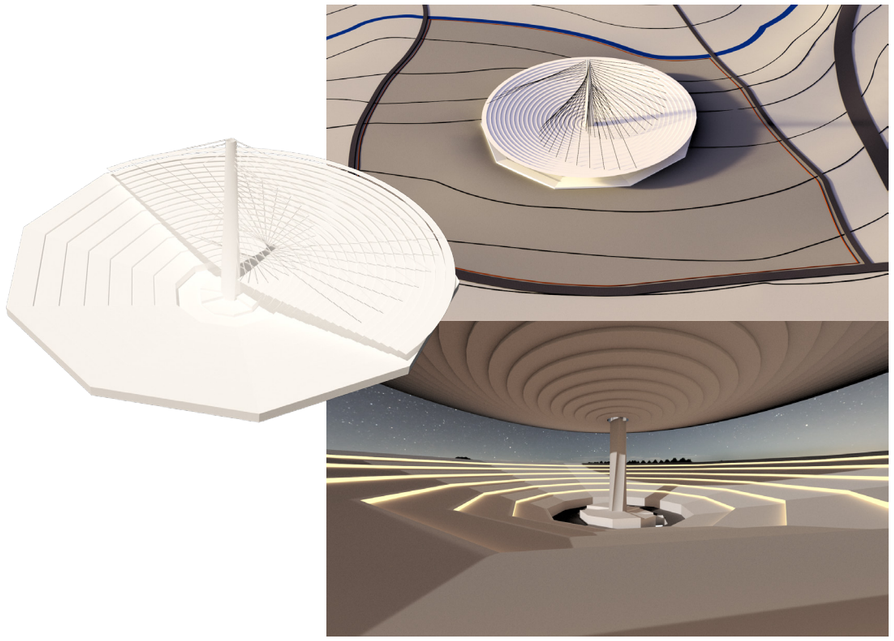
All of us three where eager to do a more complicated structure, something challanging from an engineering perspective. Inspired by sleek modern bridge structures and the challanges and benefits of a circular stage would spark our new motivation as we started over again.

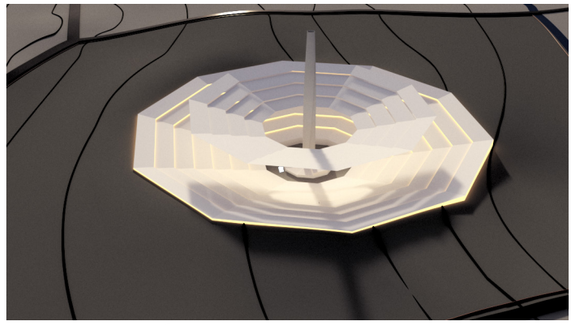
The result would be a pillar carrying a circular roof divided into ring segments that could be lowered and heightened to adjust acoustical variables. Three cables would attach to each ring as they would slightly rotate from one ring to another as to mimic some kind of motion.

The decagon stage shape would reflect itself onto the seating arrangements, and would integrate electro acoustical equipment.

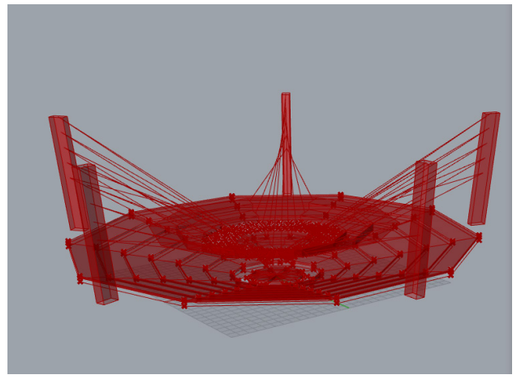
March 13th



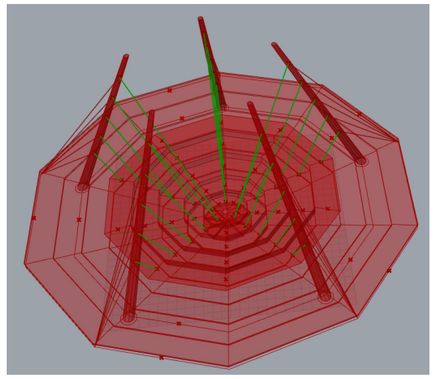




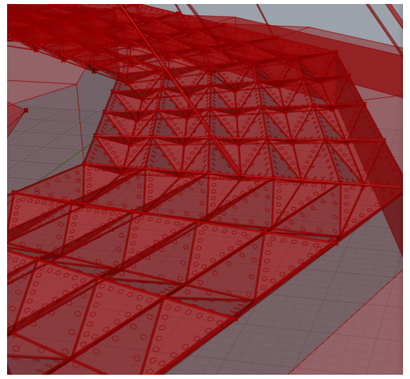
The concept of the circular rings was soon changed to a decagon-like ring structure that would match the stage and arena during a closed setting.



Soon after we agreed on splitting the pillar into five smaller ones. This is the concept that we eventually went with and expanded upon.



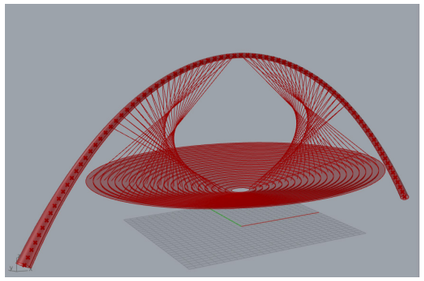
New pillar design and position.

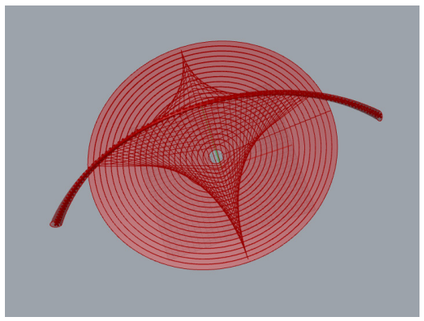


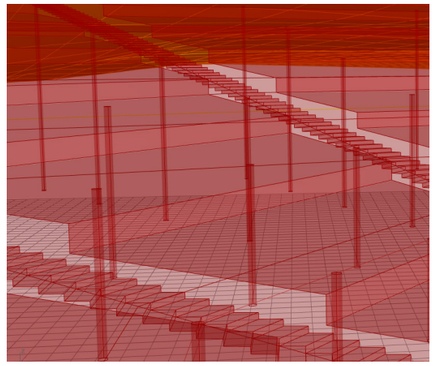
Kinetic ceiling design with helmholtz resonators.

Mid to late March

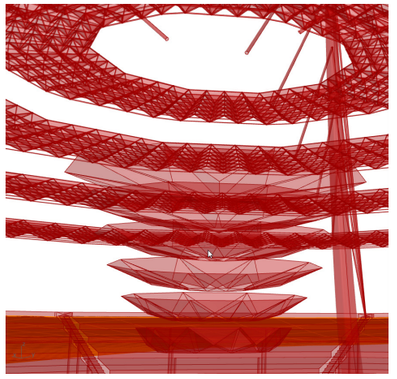
The flaws of having a pillar in the middle of the stage eventually led us to working on ideas where the roof could be carried through other means. One of our ideas was to have a bow structure in compression spanning over the arena. Because we thought that it would be ineffective structurally, we decided against it.



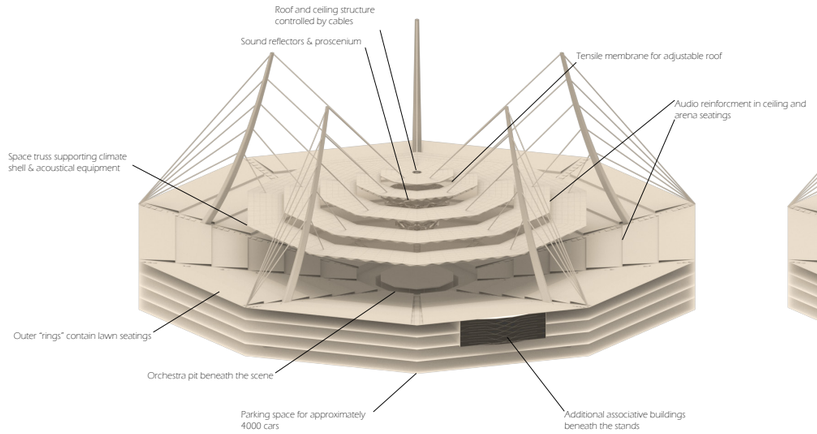


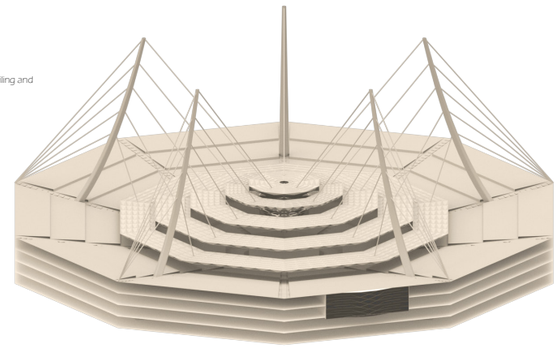


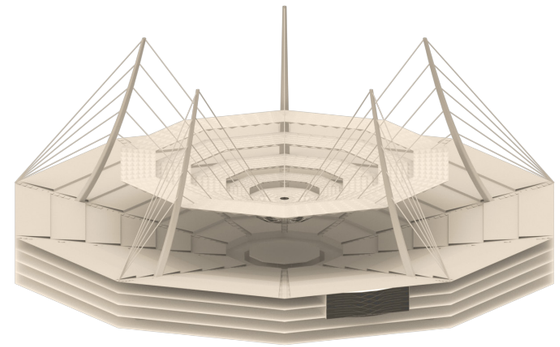
Seating arrangements and pillars for the garage beneath.



Reflector structure to distribute and control some of the early sound reflections.







For our "Mid criticism session" we presented some renderings and explanations of our acoustical prototypes, mainly being the roof, ceiling, sound reflector and the seating arrangements.

Orchestra - Opera - Ballet

Natural acoustics

Closed - Semi-closed setting

During the smaller performances ranging from 5,000-10,000 audience members, the roof structure comes down to increase the reverberation time and allow for better controllable natural acoustics

Rock - Pop

Natural acoustics & sound reinforcment systems

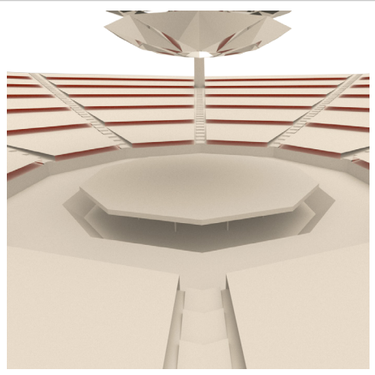
Open setting

During the larger "popular" performances for up to 25,000 audience members, the roof structure opens up and the acoustics are then combined between natural and reinforced

April 4th

Integrated prototypes
Stands and seatings

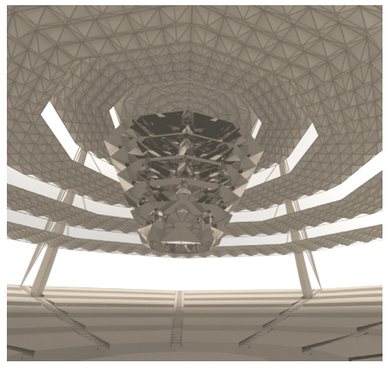
For larger audiences the arena is equipped with equally distributed electro acoustic sound reinforcment, in the form of speakers integrated to the stands.
The speakers will provide equal sound strength to the audience during pop & rock performances.



Integrated prototypes
Early sounds reflector

The early sound reflector is combined with the proscenium to distribute the early reflections and to supply the stage with lighting and different needs depending on the performance.

The reflectors consists of triangulated decagons with openings that decrease in size as the decagons increase in size further up. This design lets sound reflections pass through the crown and to distribute evenly across the arena.



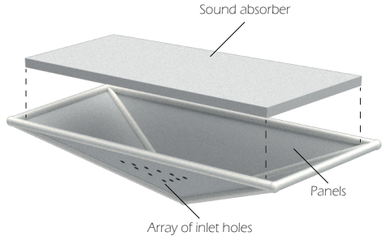
Integrated prototypes
Ceiling

The volume enclosed by the four panels is the cavity of the resonator, with one of the panels being perforated with an array of inlet holes that can be open or closed.

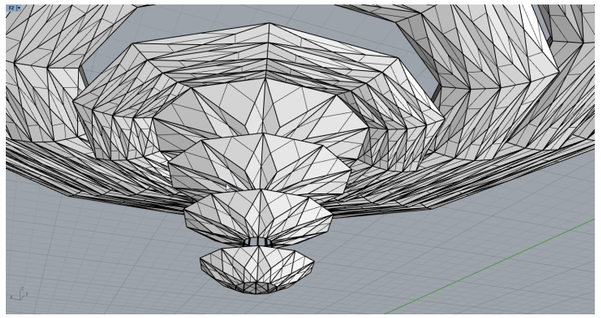
This prototype can thereby act as an absorbing element, or a pure reflective one. This variability is needed in order to adjust acoustic parameters, such as reverberation time, for the different performances.

The absorption coefficient of a Helmholtz resonator, without an absorber in the cavity, has a high peak at the tuning frequency, but is very low in other frequencies. A way to flatten this curve, and thereby make the effective frequency range broader, is to add an absorber in the cavity as illustrated to the right. This leads to a resonator that is less effective in absorption at its peak, but more effective in a larger frequency interval.

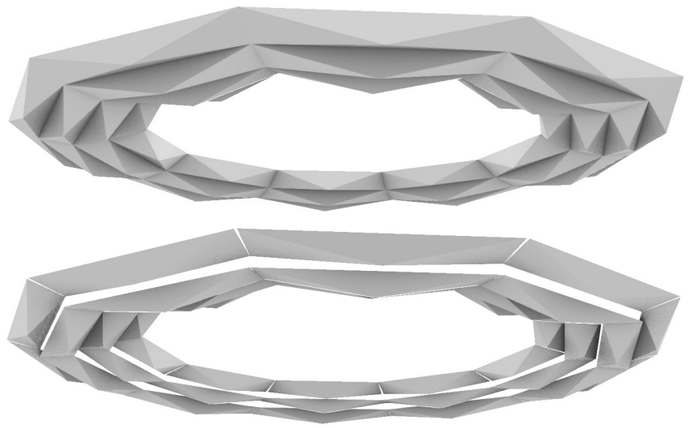
The structure that carries the flexible ceiling elements is a triangulated space truss, meaning that the structure forms pyramids. These contribute with a number of possible opportunities for different parallel uses, which in this case is their use as a base for Helmholtz resonators and lighting devices.



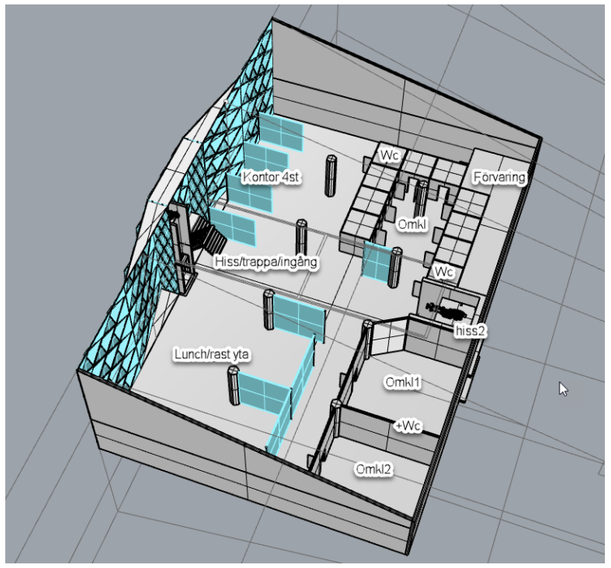
In order to fully utilize the ceiling structure, some of the pyramids can be used for integrating lighting equipment



During the last month before our in- class competition (Each university is only alloweed to send three groups to compete), we focused a lot on details.



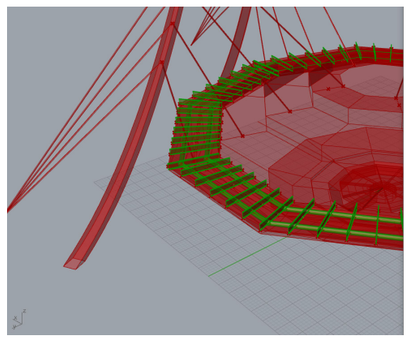
We desired to further increase the ceilings impact on the acoustics and so we decided on a ceiling structure that would reveal absorbing material when lower reverberation times would be needed.

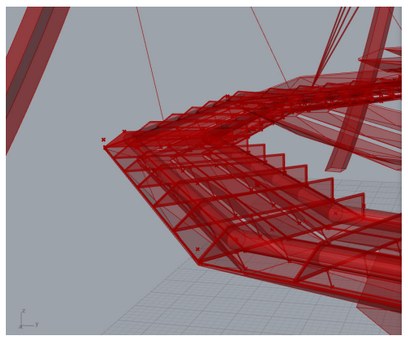


The supporting facility was also very important as it would answer to the remaining program demands. It was designed continuously during the last few weeks.

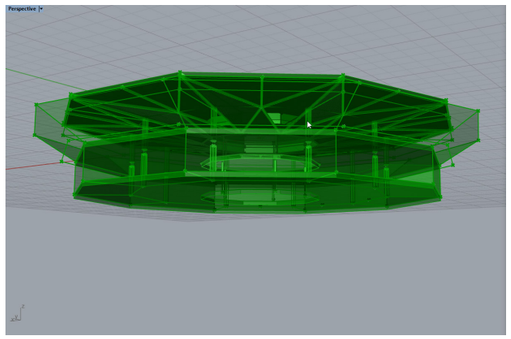
Mid April to May

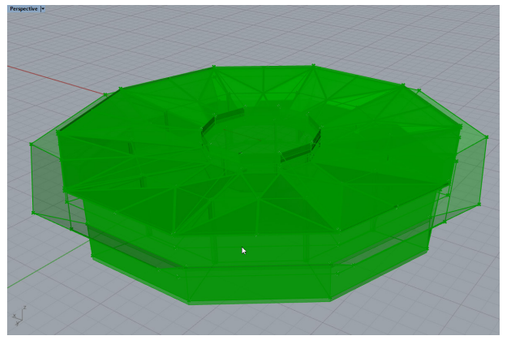
The structural support system was redesigned to fit the new ceiling design from the previous space truss supporting the pyramid like ceiling.

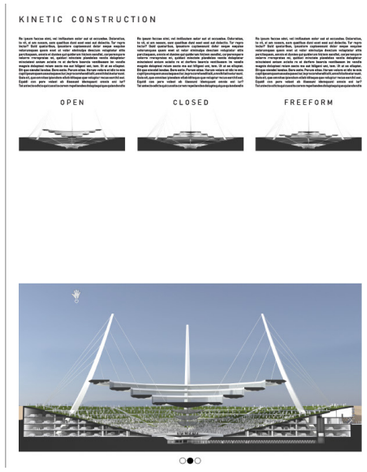


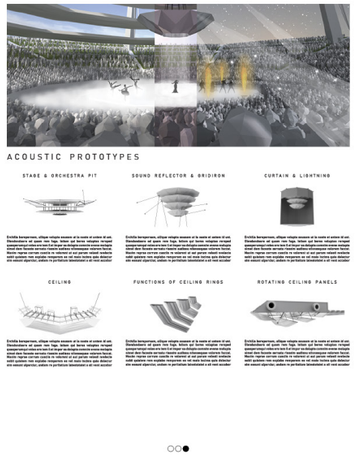


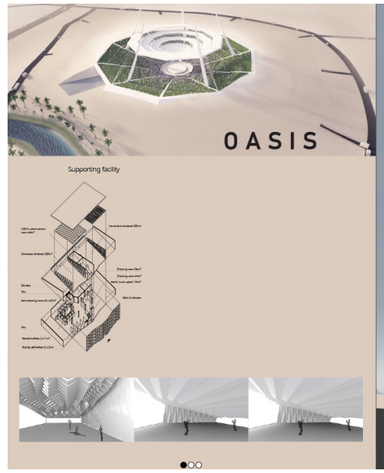
The stage was important, which together with the reflector structure would answer to many of the program demands.

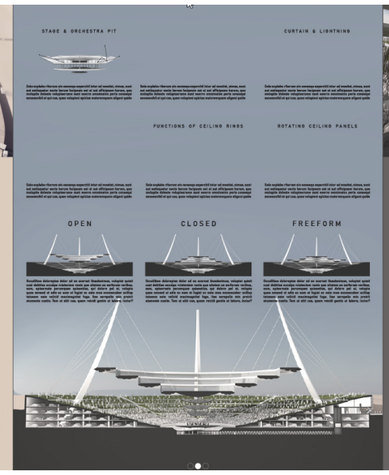


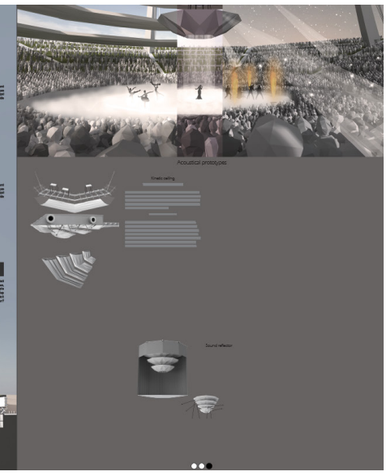






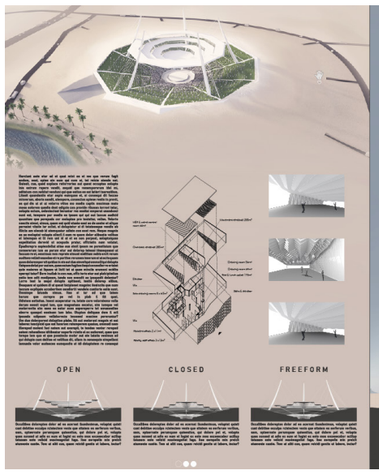


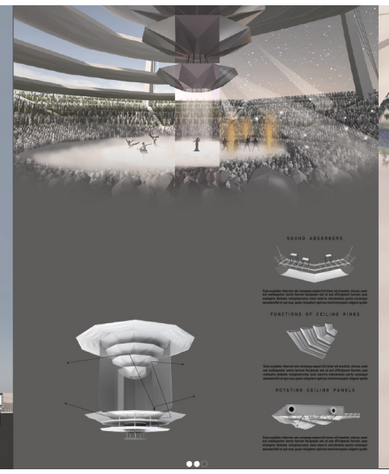


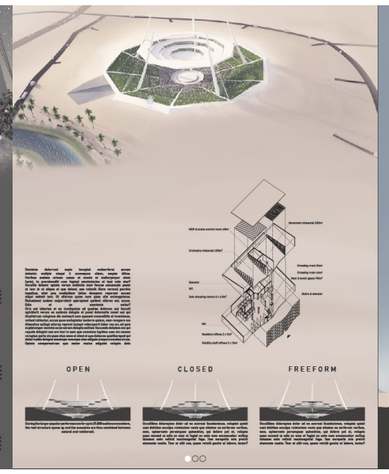


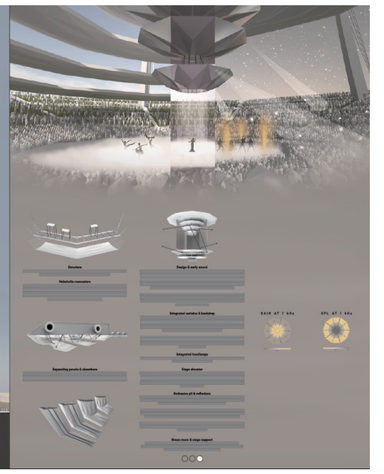
Preparing competition posters

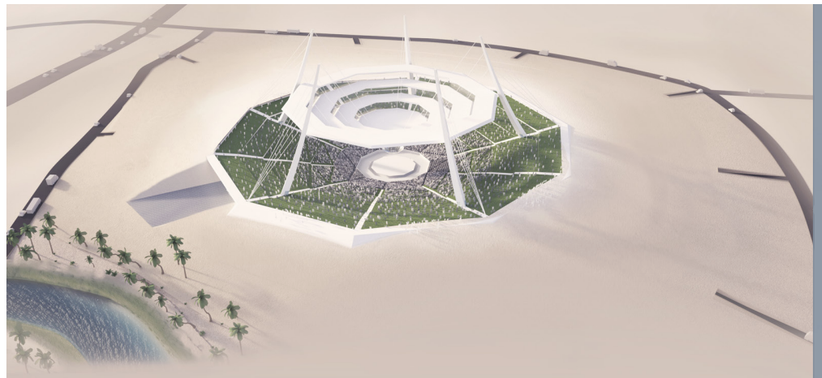
Early May











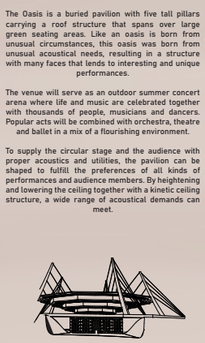
OASIS

IN A DESERT LANDSCAPE
NEAR A LAKE WITH FLOURISHING GREENERY,
AN OASIS IS BORN

The Oasis is a buried pavilion with five tall pillars carrying a roof structure that spans over large green seating areas. Like an oasis is born from unusual circumstances, this oasis was born from unusual acoustical needs, resulting in a structure with many faces that lends to interesting and unique performances.

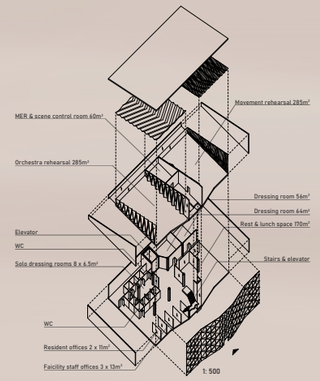
The venue will serve as an outdoor summer concert arena where life and music are celebrated together with thousands of people, musicians and dancers. Popular acts will be combined with orchestra, theatre and ballet in a mix of a flourishing environment.

To supply the circular stage and the audience with proper acoustics and utilities, the pavilion can be shaped to fulfill the preferences of all kinds of performances and audience members. By heightening and lowering the ceiling together with a kinetic ceiling structure, a wide range of acoustical demands can meet.



SUPPORT FACILITY FACADE

A glassed facade connected to an outdoor area for facility staff and associatives. The glassed facade with the high ceiling allows for a bright floor plan with interesting light plays.



SUPPORTING FACILITY

The supporting facility is located beneath the north-eastern stand and constitutes only a slight portion of what would otherwise be parking space, which is only limited by terrain. The facility houses the needs of the performers and the facility staff, as shown opposite. The facility is connected to the stage through a long tunnel beneath the parking space accessed through an elevator.

MER & STAGE CONTROL ROOM

Between the two rehearsal rooms, a room is fitted that can control stage variables like headlamps, curtains and backdrop. This room is spacious and could serve multiple facility technicians and the equipment required to control the stage.

MOVEMENT REHEARSAL ROOM

The movement rehearsal has a reflective ceiling in a stripe like fashion that that resumes its shape on the walls where they act as retractable mirror stripes that offer the opportunity of variable acoustics and room types. When the stripes are flat, they cover absorbers attached to the walls, and when extended they vary the shape and acoustics of the room.

ORCHESTRA REHEARSAL ROOM

On the second floor the facility houses a rehearsal room equipped with reflective ceiling panels joined together with absorbing wall panels that cooperate to ensure a desirable distribution of sound and clarity at the same time.

NATURAL ACOUSTICS & SOUND REINFORCEMENT

Rock, Pop & Jazz

During the larger popular performances for up to 25.000 audience members, the roof structure opens up and the acoustics are then combined between natural and reinforced.

NATURAL ACOUSTICS

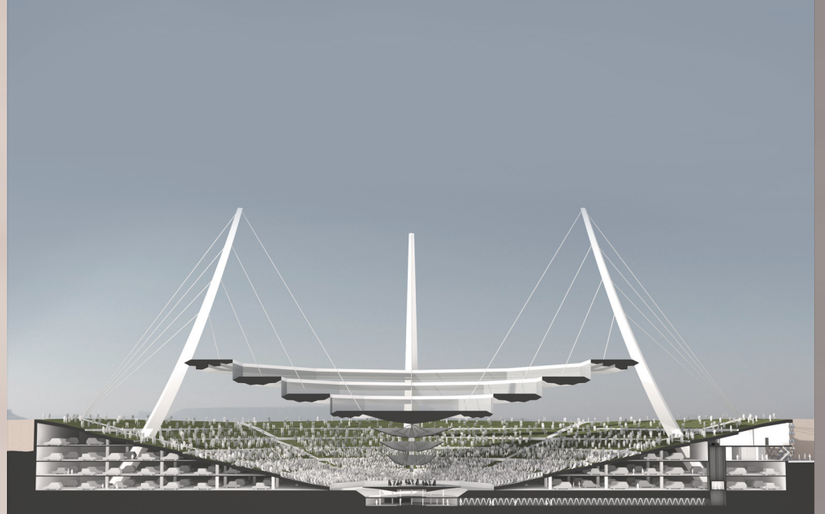
Orchestra, Opera, Ballet & Theatre

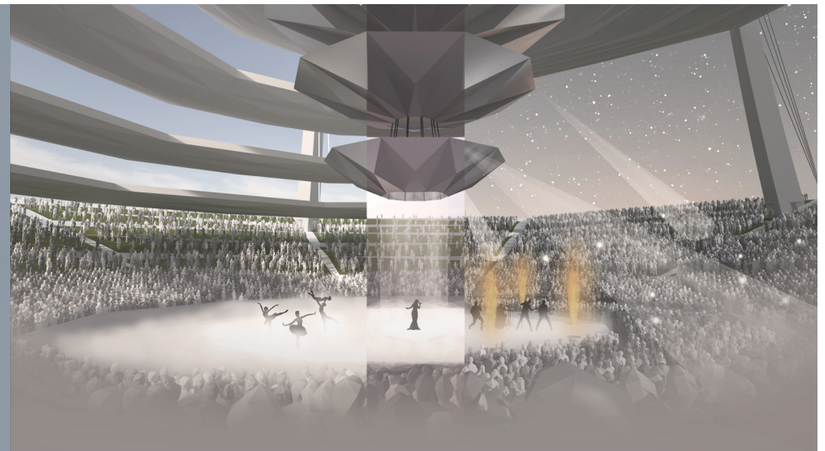
During the smaller performances ranging from 5.000 to 10.000 audience members, the roof structure comes down to increase the reverberation time and allow for better controllable natural acoustics.

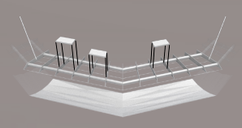
IMPROVISED ACOUSTICS

Special performances

During special occasions and performances that does not conform to conventional acoustics, the flexibility of the arena allows for a wide range of acoustic properties and different spatial experiences.





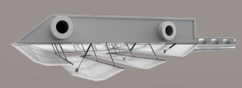


CEILING DESIGN

The ceiling elements hang in cables and are each supported by a structure consisting of two main beams running tangentially along the element, and secondary perpendicular beams with sound absorbers in between.

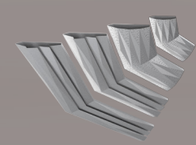
SEPARATING PANELS & ABSORBERS

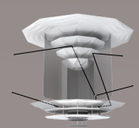
The ceiling consists of four decagonal rings each with a wider radius than the previous. These "rings" are divided into four segments of panels able to slightly open up, revealing absorbing material between the segments, allowing for adjustable acoustics.



HELMHOLTZ RESONATORS

To control the acoustics through a wide spectrum of frequencies, we have integrated Helmholtz resonators to the two inner rings of panels. These resonators have the purpose of absorbing low frequency sound waves during performances when the ceiling would be closed, allowing for a good baseline high reverberation time that can be further lowered by either separating the panels or raising the ceiling structure.





REFLECTOR DESIGN & EARLY SOUND

The sound reflector continues the geometric shape of the ceiling rings and ties them together with a diamond shaped structure that extends down towards the stage. The reflector panels make up four separate reflector structures that gradually opens as they reduce in size. The purpose of the openings increasing in size is to allow for some of the sounds to be evenly distributed to the reflector structure where they are reflected to the listeners, allowing for more controlled early sounds.

The distance between the reflector structures and the stage dictates the time for the sounds to travel to the listeners ear, thus we have decided to allow for adjustable distances between the reflectors structures themselves and the stage to allow for more adjustable acoustics.

INTEGRATED CURTAIN & BACKDROP

The outer ring of the lowest hanging reflector structure allows curtains to enclose the stage lift for a transition of the stage. For some larger transitions, or even a scene change, a curtain can be lowered from the outside ring of the highest reflector structure to enclose the whole stage.

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INTEGRATED LIGHTING

Within the reflector structure headlamps are concealed and allows for dynamic scenery with discrete equipment.

STAGE ELEVATOR

The elevator consists of three decagonal platforms acting as a large multifunctional lift, allowing for travel between the three levels; ground, pit and stage. The purpose of the lift having three platforms is to allow for travel between the ground level and stage level in one motion whilst always maintaining one platform at the ground level when not in motion.

ORCHESTRA PIT & REFLECTORS

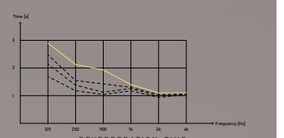
The orchestra pit sits right underneath the stage and is a spacious decagonal area with carefully planned structural support as to not obstruct the view for the sitting orchestra, and to allow for a seemingly hovering stage.

Because the stage takes the shape of a reflector structure, it has a natural slope to its underside which aids the sounds coming from the orchestra to escape the orchestra pit by bouncing off the roof of the stage and the sloped area enclosing the pit.

The orchestra pit has the function to be closed during performances that usually have a crowd closer to the actual stage, like concerts, otherwise it grants a hovering effect to the stage, if desirable.

GREEN ROOM & STAGE SUPPORT

On the ground floor right beneath the orchestra pit, sits the green room with supporting stage rooms such as the mechanical equipment room (MER), additional dressing rooms and space for stage logistics.



REVERBERATION TIME

The reverberation time for the closed setting with closed panels ranges from 1.2 seconds at 4 kHz to 2.8 seconds at 125 Hz and are displayed in the graph with a yellow line. The flexibility of the roof can adjust the values if preferred by heightening or lowering the ceiling and by opening or closing the panels. The reverberation times that can be achieved are displayed with the dotted lines.

SPL CLOSED SETTING

The sound pressure level for the closed setting at 1 kHz is evenly distributed inside the setting with a value of 80 dB while it quickly decreases outside of the setting.

GAIN CLOSED SETTING

The gain for the closed setting at 1 kHz is evenly distributed inside the setting with a value of 5 dB while it quickly decreases outside of the setting.

SPL OPEN SETTING

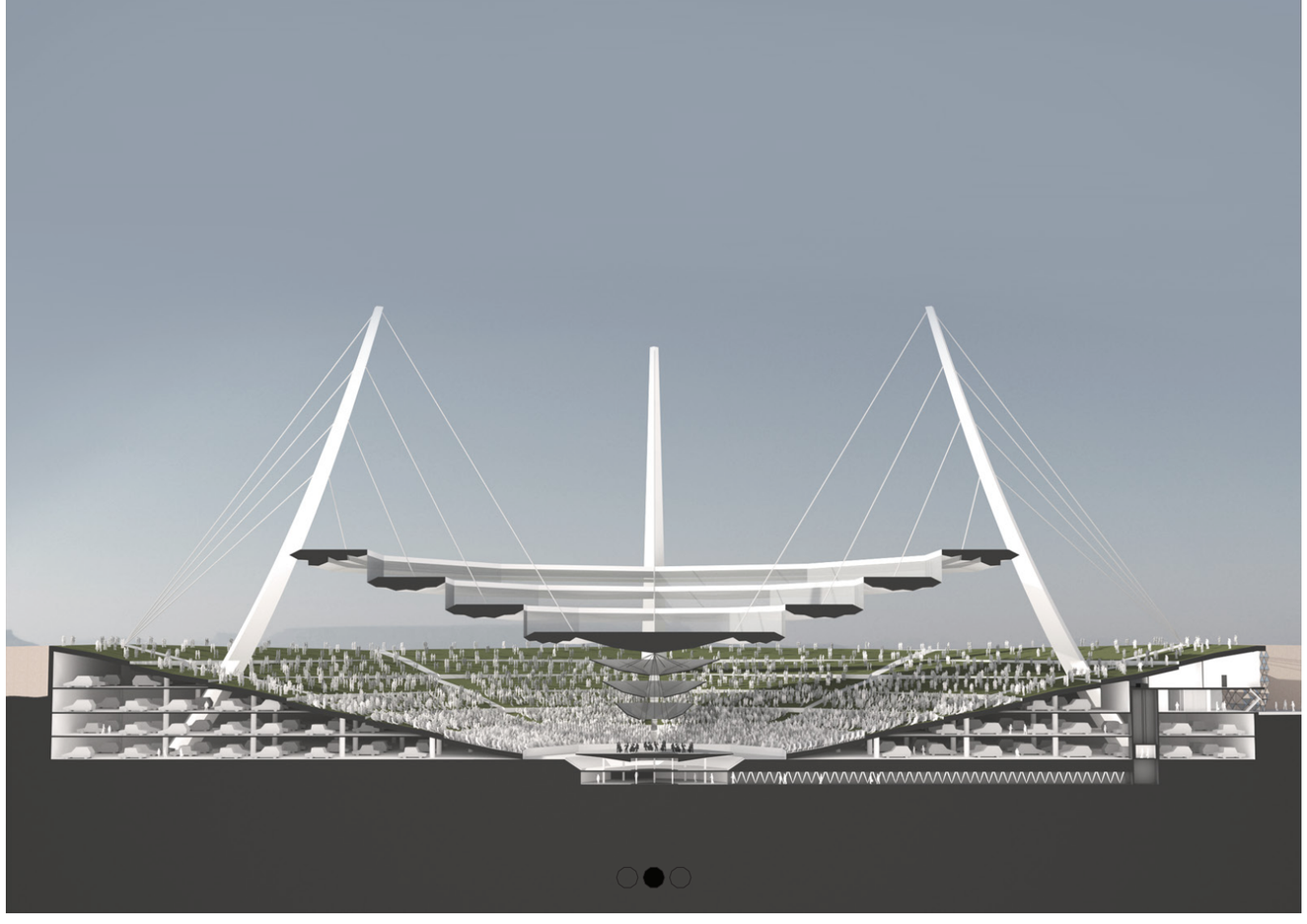
The sound pressure level for the open setting at 1 kHz is evenly distributed around the setting with an average value of 75 dB. The natural acoustics are reinforced with electro acoustics to compensate for the loss of sound pressure with an open roof.

GAIN OPEN SETTING

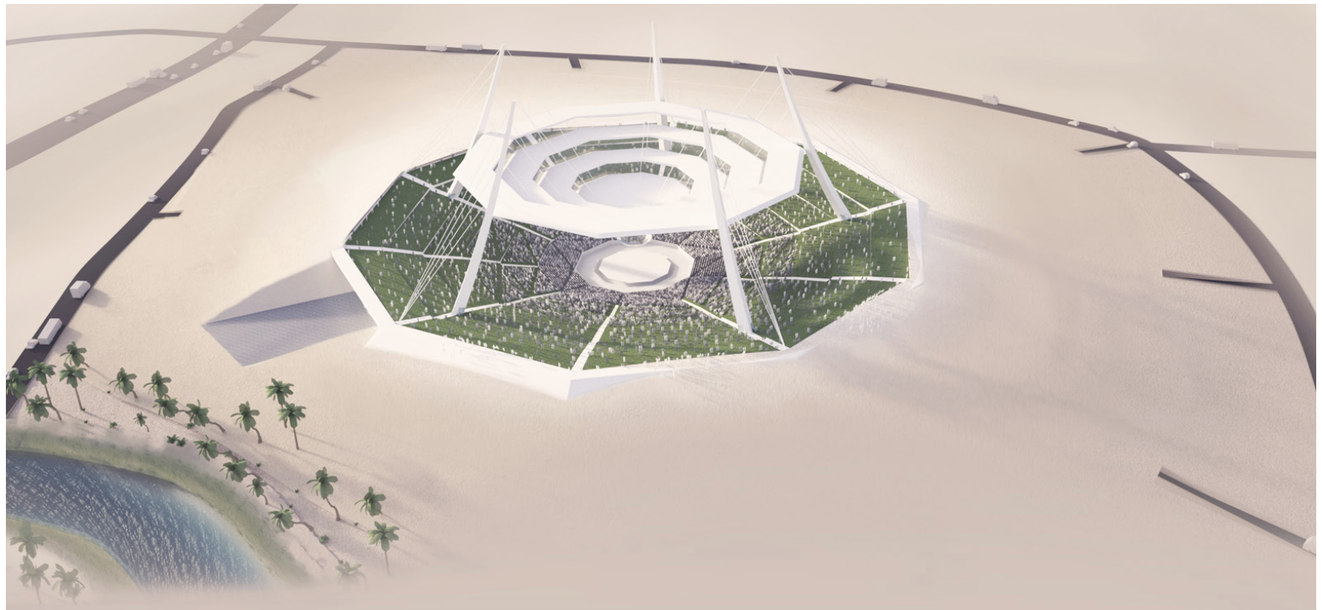
The gain for the open setting at 1 kHz is evenly distributed around the setting with an average value of 2 dB.

OASIS

IN A DESERT LANDSCAPE
NEAR A LAKE WITH FLOURISHING GREENERY,
AN OASIS IS BORN



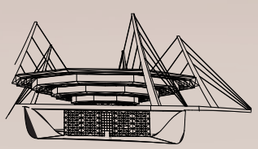
Plansch 1 – Introduction
A brief introductory text explaining the concept with a section demonstrating the venue in action.



The Oasis is a buried pavilion with five tall pillars carrying a roof structure that spans over large green seating areas. Like an oasis is born from unusual circumstances, this oasis was born from unusual acoustical needs, resulting in a structure with many faces that lends to interesting and unique performances.

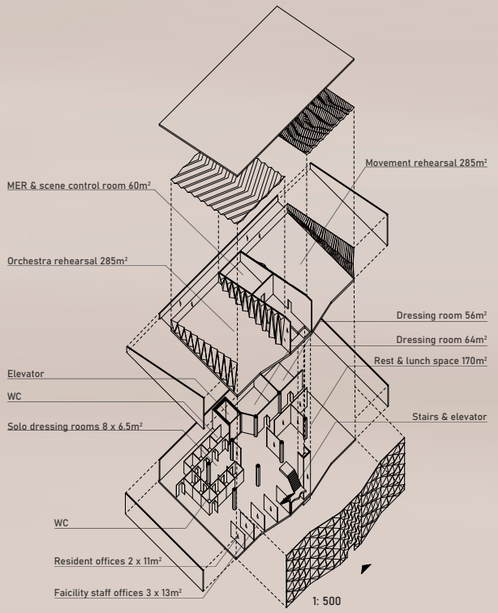
The venue will serve as an outdoor summer concert arena where life and music are celebrated together with thousands of people, musicians and dancers. Popular acts will be combined with orchestra, theatre and ballet in a mix of a flourishing environment.

To supply the circular stage and the audience with proper acoustics and utilities, the pavilion can be shaped to fulfill the preferences of all kinds of performances and audience members. By heightening and lowering the ceiling together with a kinetic ceiling structure, a wide range of acoustical demands can meet.



SUPPORT FACILITY FACADE

A glassed facade connected to an outdoor area for facility staff and associatives. The glassed facade with the high ceiling allows for a bright floor plan with interesting light plays.

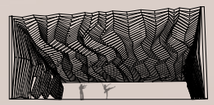


SUPPORTING FACILITY

The supporting facility is located beneath the north-eastern stand and constitutes only a slight portion of what would otherwise be parking space, which is only limited by terrain. The facility houses the needs of the performers and the facility staff, as shown opposite. The facility is connected to the stage through a long tunnel beneath the parking space accessed through an elevator.

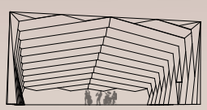
MER & STAGE CONTROL ROOM

Between the two rehearsal rooms, a room is fitted that can control stage variables like headlamps, curtains and backdrop. This room is spacious and could serve multiple facility technicians and the equipment required to control the stage.



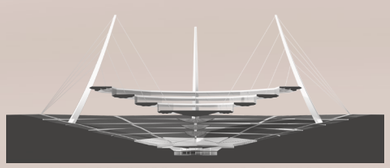
MOVEMENT REHEARSAL ROOM

The movement rehearsal has a reflective ceiling in a stripe like fashion that that resumes its shape on the walls where they act as retractable mirror stripes that offer the opportunity of variable acoustics and room types. When the stripes are flat, they cover absorbers attached to the walls, and when extended they vary the shape and acoustics of the room.



ORCHESTRA REHEARSAL ROOM

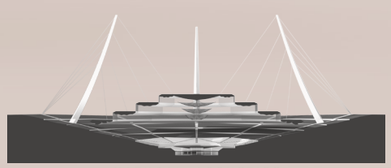
On the second floor the facility houses a rehearsal room equipped with reflective ceiling panels joined together with absorbing wall panels that cooperate to ensure a desirable distribution of sound and clarity at the same time.



NATURAL ACOUSTICS & SOUND REINFORCEMENT

Rock, Pop & Jazz

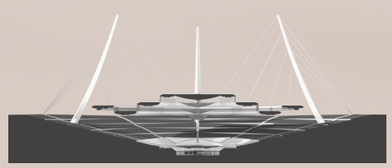
During the larger popular performances for up to 25.000 audience members, the roof structure opens up and the acoustics are then combined between natural and reinforced.



NATURAL ACOUSTICS

Orchestra, Opera, Ballet & Theatre

During the smaller performances ranging from 5.000 to 10.000 audience members, the roof structure comes down to increase the reverberation time and allow for better controllable natural acoustics.



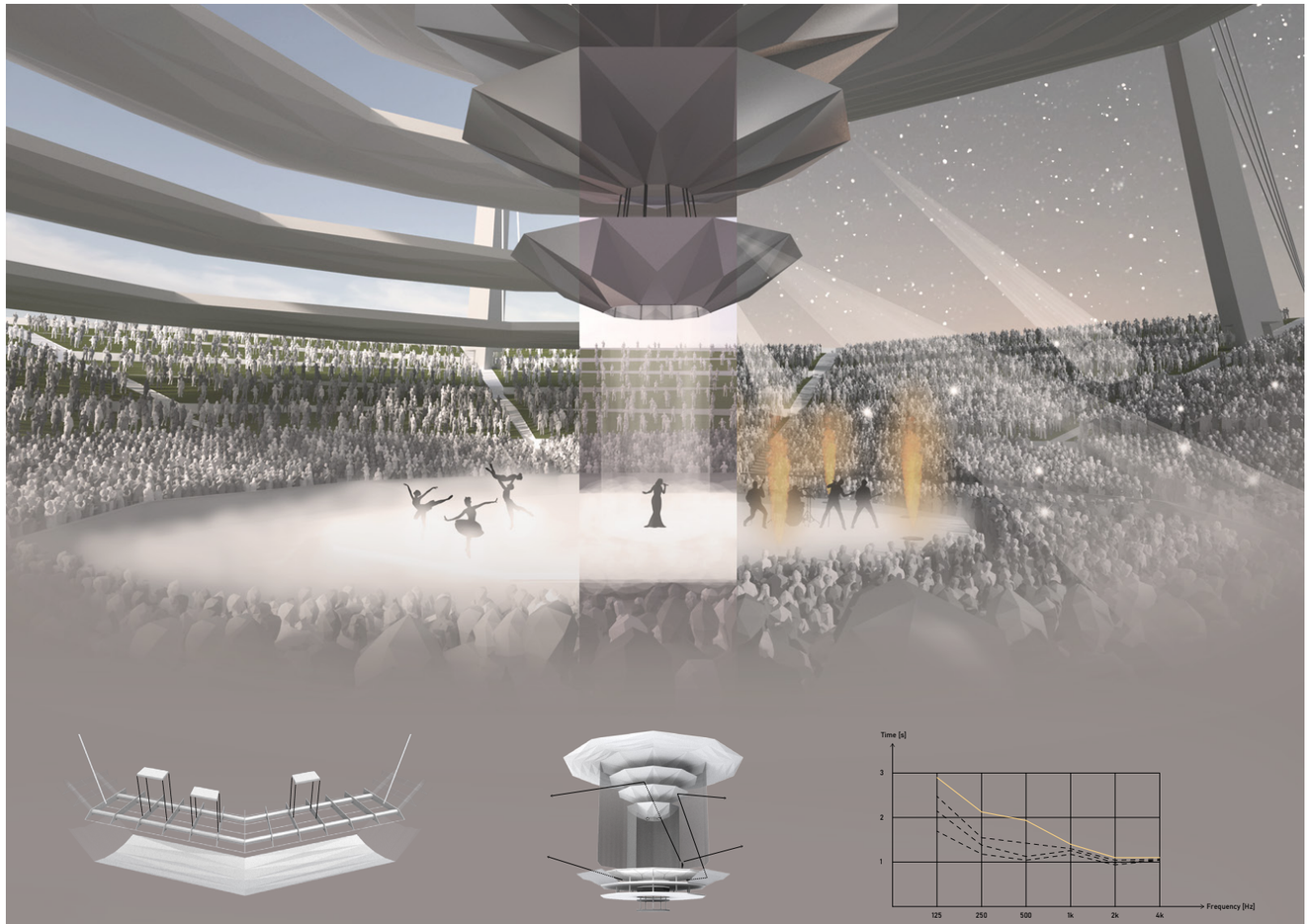
IMPROVISED ACOUSTICS

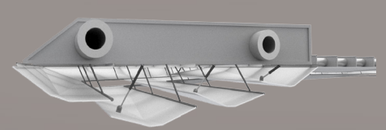
Special performances

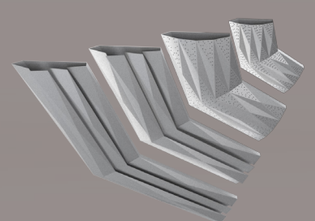
During special occasions and performances that does not conform to conventional acoustics, the flexibility of the arena allows for a wide range of acoustic properties and different spatial experiences.

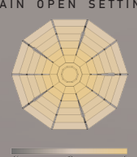
Plansch 2 – Overview & facilities

A bird's perspective of the site and some acoustical properties of the situation combined with a breakdown of the supporting facility which include all the demands of the program. At the bottom we find the general acoustical principles of the concept.









Plansch 3 – Acoustical prototypes & properties
An explanation of the acoustical prototypes, as well as answers concerning initial problems of a circular stage. Acoustical values from CATT simulations and some simple explanations.

CEILING DESIGN

The ceiling elements hang in cables and are each supported by a structure consisting of two main beams running tangentially along the element, and secondary perpendicular beams with sound absorbers in between.

SEPARATING PANELS & ABSORBERS

The ceiling consists of four decagonal rings each with a wider radius than the previous. These "rings" are divided into four segments of panels able to slightly open up, revealing absorbing material between the segments, allowing for adjustable acoustics.

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GAIN CLOSED SETTING

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SPL OPEN SETTING

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