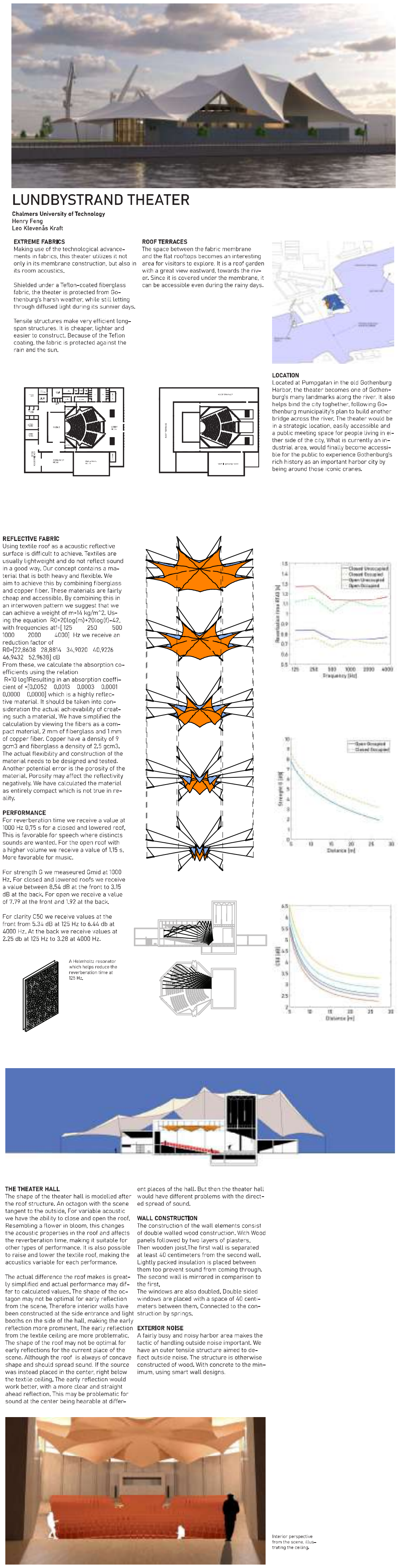
LUNDBYSTRAND THEATER
MEMBRANE ACOUSTICS

Chalmers University of Technology
Architecture and Engineering
ACEX15 Bachelor's Thesis
SPRING 2025W
Leo Klevenås Kraft
With Henry Feng

The Bachelor's Program in Architecture and Engineering is a collaborative study between architecture and acoustics. Each year, students participate in the International student competition organized by the Acoustical Society of America.

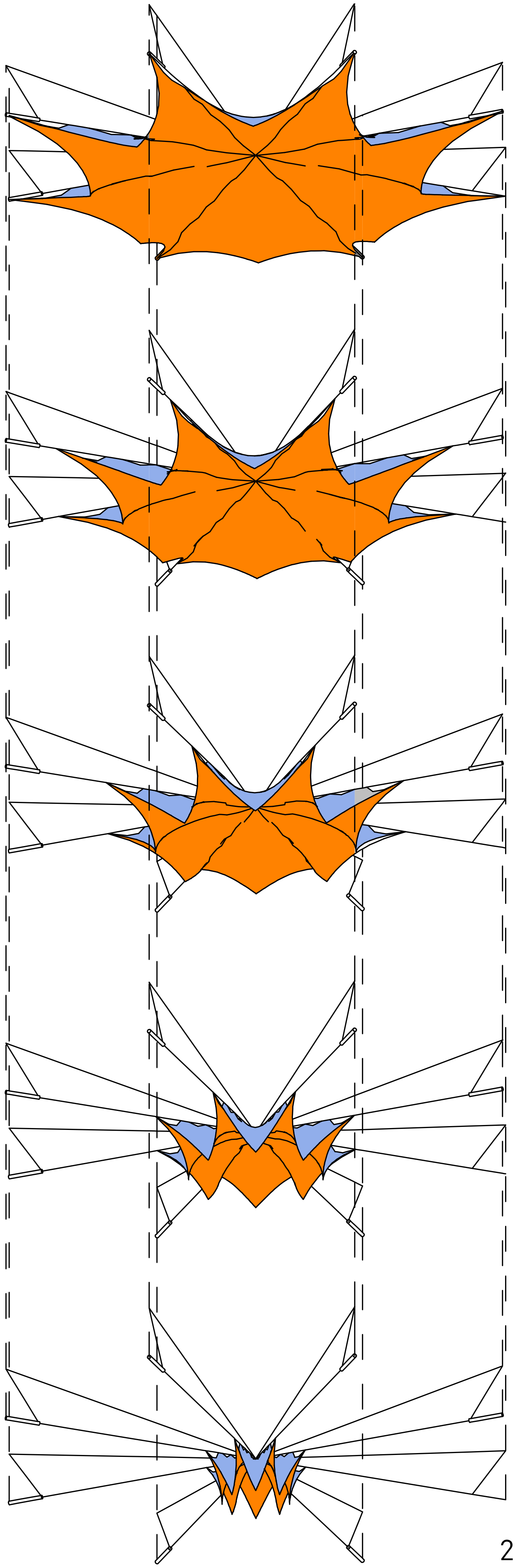
In this year's challenge, the object was to design a campus theater with good acoustical and conceptual properties. The project aims to prepare us for professional life through collaboration and an artistic approach to iterative design. Including several stages and a project that gradually develops.

Our project explores the potential of using textiles in acoustic applications. By being both reflective and adaptable. Making the acoustic experience adjusted to the specific needs, while also changing the visual impression with a foldable, reflective and textile roof. The design is inspired by musical instruments such as the drum. Symbolising the collaboration between sound and structure.



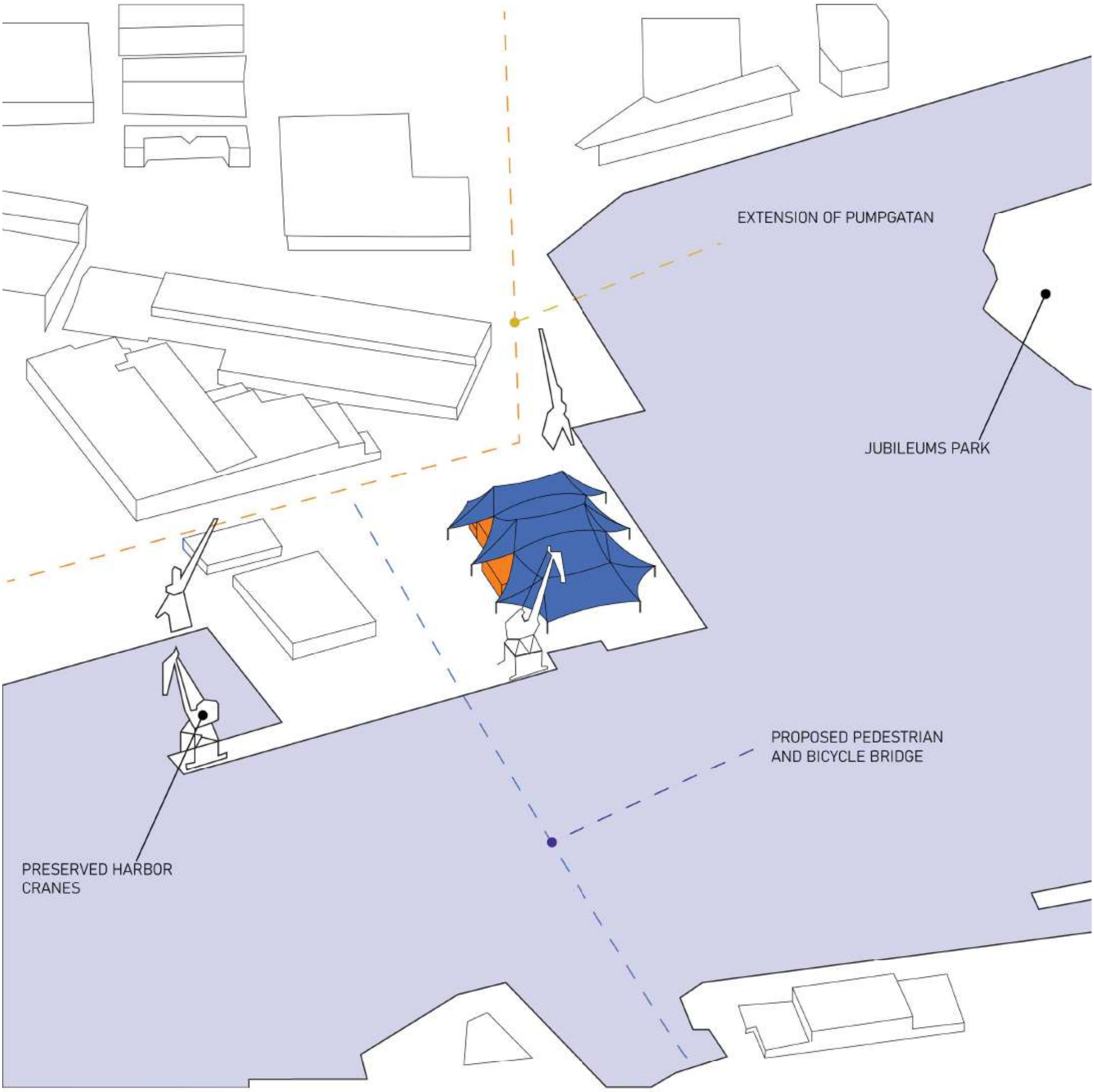
REFLECIVE FABRIC

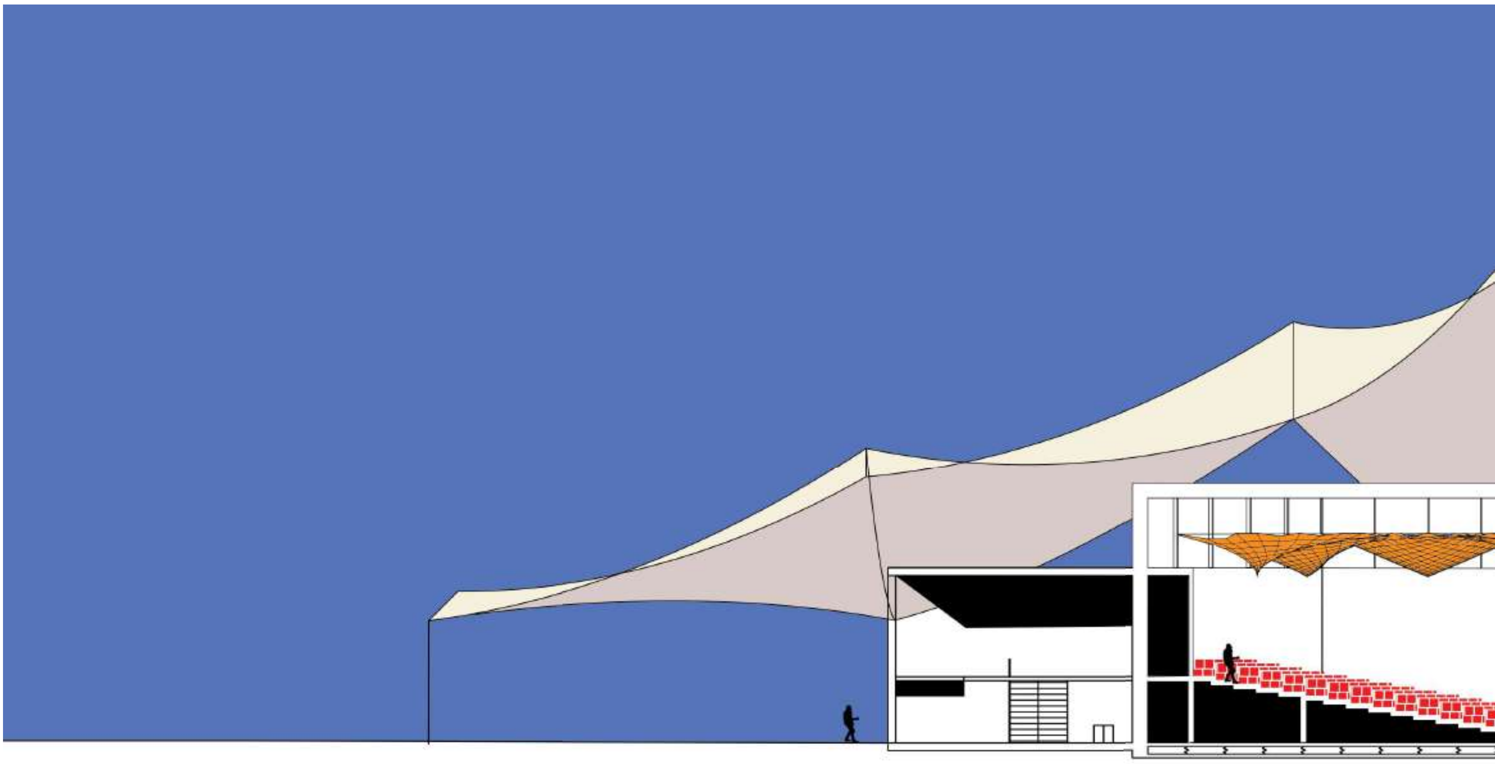
Using textile roof as a acoustic reflective surface is difficult to achieve. Textiles are usually lightweight and do not reflect sound in a good way. Our concept contains a material that is both heavy and flexible. We aim to achieve this by combining fiberglass and copper fiber. These materials are fairly cheap and accessible. By combining this in an interwoven pattern we suggest that we can achieve a weight of m=14 kg/m^2. Using the equation R0=20log(m)+20log(f)-42. with frequencies atf=[125 250 500 1000 2000 4000] Hz we receive an reduction factor of R0=[22.8608 28.8814 34.9020 40.9226 46.9432 52.9638] dB
From these, we calculate the absorption coefficients using the relation
R=10 log1Resulting in an absorption coefficient of =[0.0052 0.0013 0.0003 0.0001 0.0000 0.0000] which is a highly reflective material. It should be taken into consideration the actual achievability of creating such a material. We have simplified the calculation by viewing the fibers as a compact material. 2 mm of fiberglass and 1 mm of copper fiber. Copper have a density of 9 gcm3 and fiberglass a density of 2.5 gcm3. The actual flexibility and construction of the material needs to be designed and tested. Another potential error is the porosity of the material. Porosity may affect the reflectivity negatively. We have calculated the material as entirely compact which is not true in reality.



LOCATION

Located at Pumpgatan in the old Gothenburg Harbor, our theater aims to connect the city over the river. The municipality of Gothenburg has decided to construct a pedestrian bridge next to our location. Connecting the island Hisingen to the mainland. The theater would be strategically located beside busy walking traffic. At the connection from central Gothenburg to the education Hub Lindholmen. Making the theater a natural stop for commuting, eligible for survival and thriving. Also be a part of the city's landmarks bringing attention to Gothenburg's rich tradition of theater.


EXTENSION OF PUMPGATAN
JUBILEUMS PARK
PROPOSED PEDESTRIAN
AND BICYCLE BRIDGE
PRESERVED HARBOR
CRANES



THE THEATER HALL

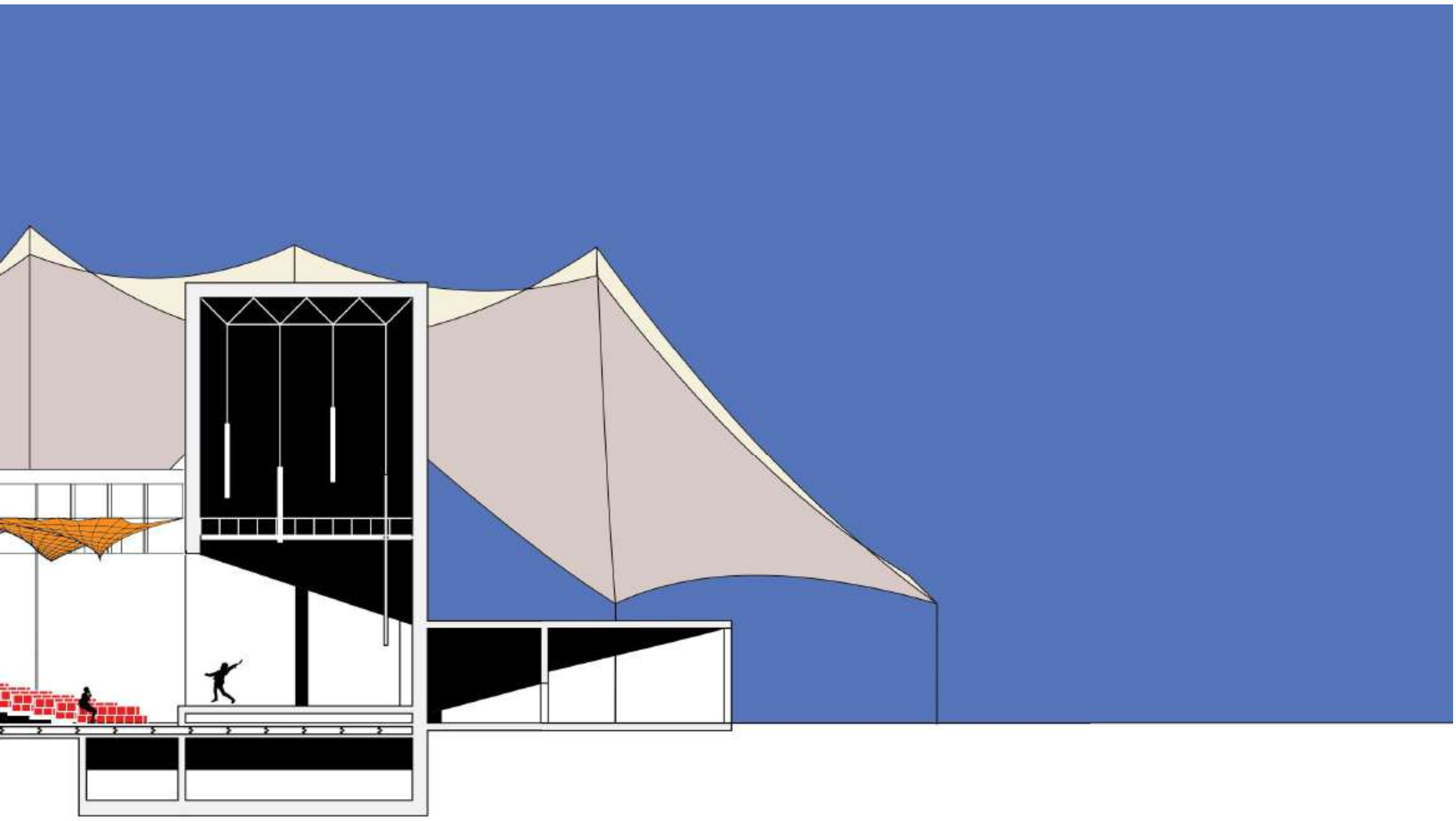
The shape of the theater hall is modelled after the roof structure. An octagon with the scene tangent to the outside. For variable acoustic we have the ability to close and open the roof. Resembling a flower in bloom This changes the acoustic properties in the roof and affects the reverberation time. Making it suitable for other types of performance. We also have the ability to heighten and lower the textile roof. Making the acoustics variable for each performance. The actual difference the roof makes is greatly simplified and actual performance may differ to calculated values. The shape of the octagon may not be optimal for early reflection from the scene. Therefore we have constructed the side entrance and light booths on the side of the hall. Making the early reflection more prominent. The early reflection from the textile roof are more problematic. The shape of the roof may not be optimal for early reflections for the current place of the scene. Although the roof is always of concave shape and should spread sound. If the source was instead placed in the center, right below the textile roof. The early reflection would work better, with a more clear and straight ahead reflection. This may be problematic for sound at the center being hearable at different places of the hall. But then the theater hall would have different problems with the directed spread of sound.

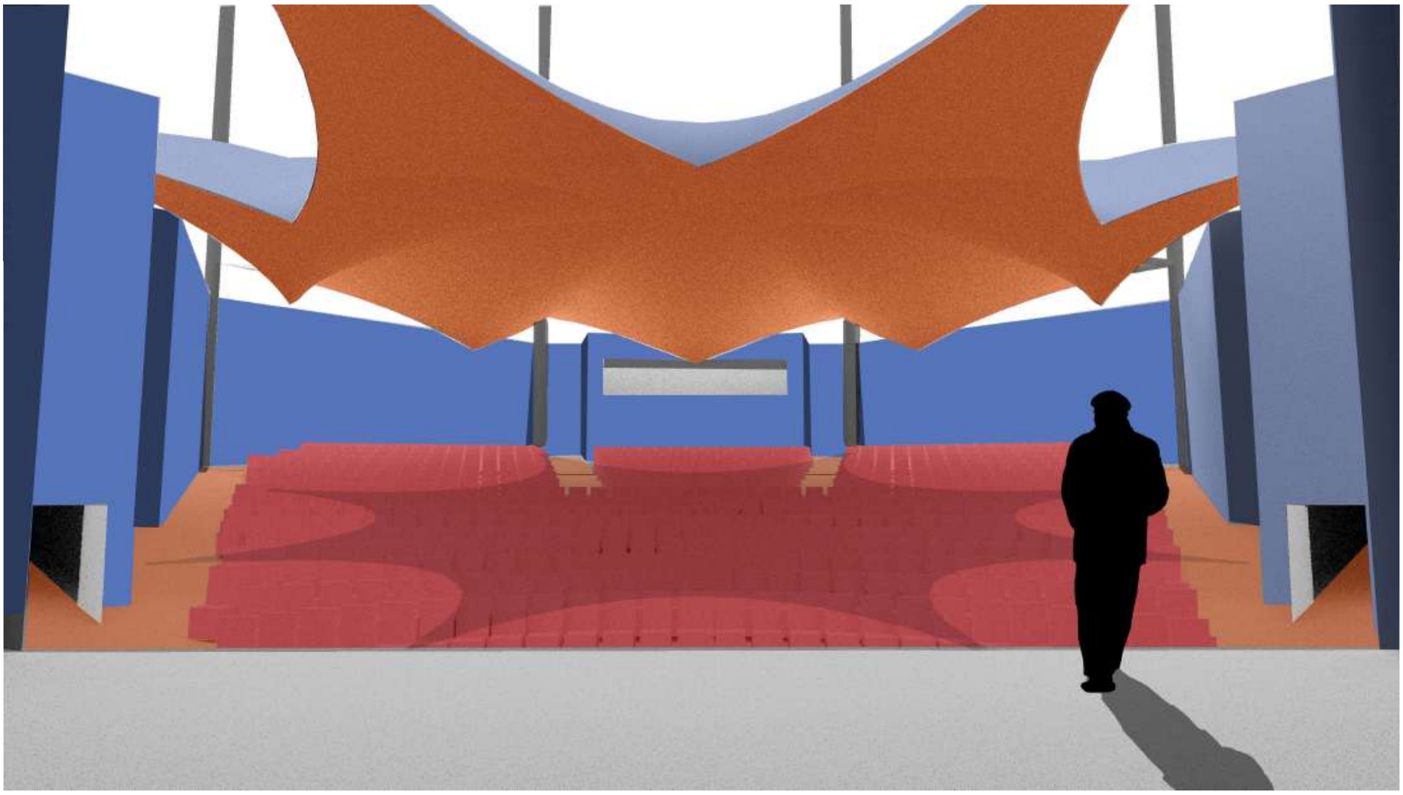
WALL CONSTRUCTION

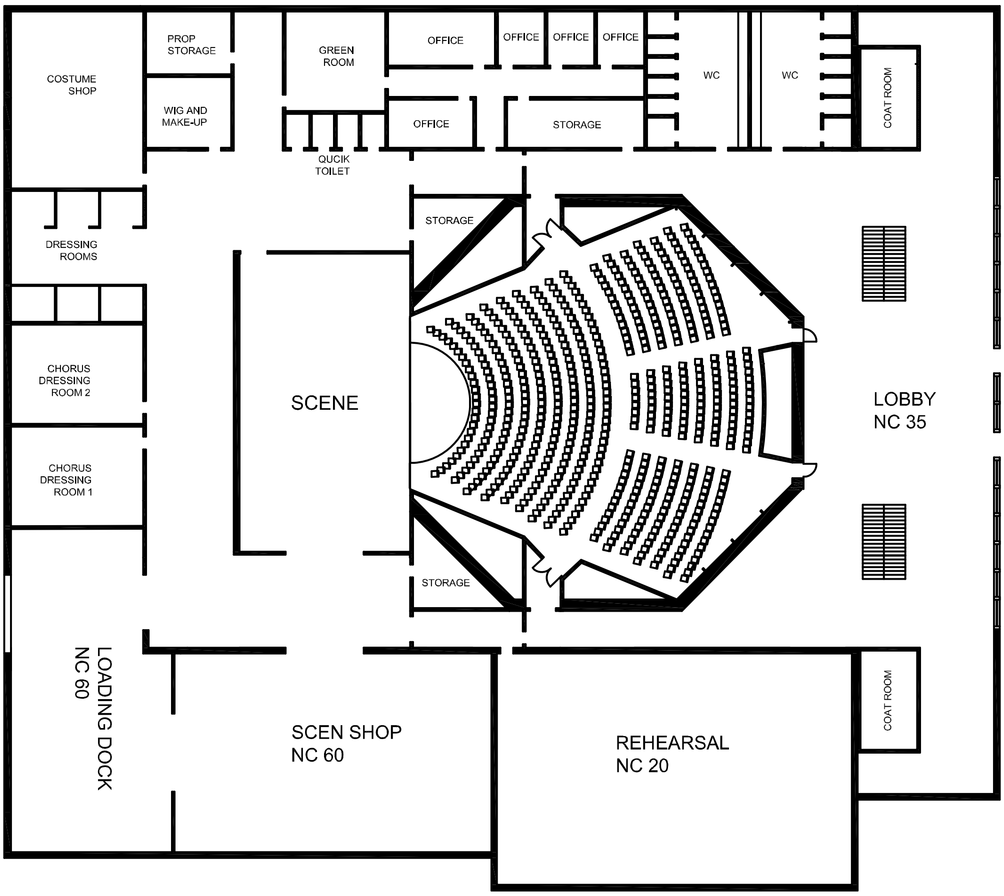
The construction of the wall elements consist of double walled wood construction. With Wood panels followed by two layers of plasters. Then wooden joist.The first wall is separated at least 40 centimeters from the second wall. Lightly packed insulation is placed between them too prevent sound from coming through. The second wall is mirrored in comparison to the first. The windows are also doubled. Double sided windows are placed with a space of 40 centimeters between them. Connected to the construction by springs.

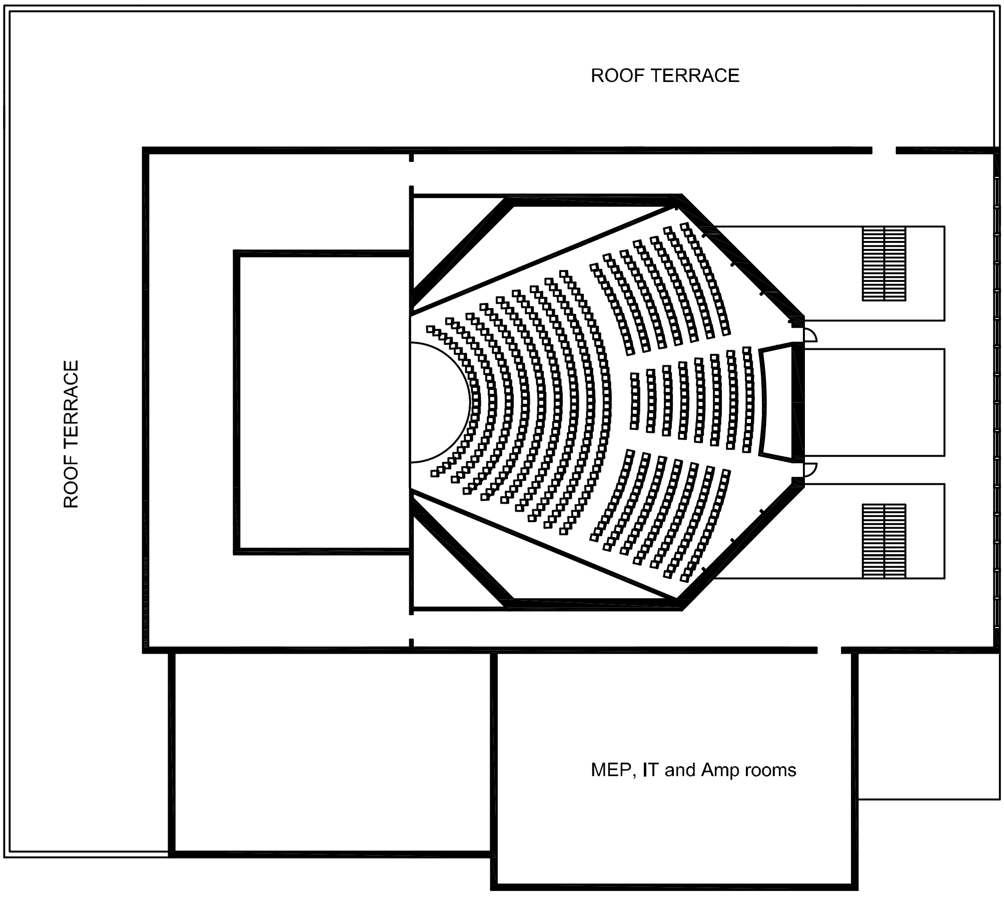
EXTERIOR NOISE

A fairly busy and noisy harbor area makes the tactic of handling outside noise important. We have an outer tensile structure aimed to deflect outside noise. The structure is otherwise constructed of wood. With concrete to the minimum, using smart wall designs.






PROP STORAGE
GREEN ROOM
OFFICE
OFFICE
OFFICE
OFFICE
WC
WC
COAT ROOM
COSTUME SHOP
WIG AND MAKE-UP
OFFICE
STORAGE
QUCIK TOILET
STORAGE
DRESSING ROOMS
CHORUS DRESSING ROOM 2
SCENE
LOBBY NC 35
CHORUS DRESSING ROOM 1
STORAGE
LOADING DOCK NC 60
SCEN SHOP NC 60
REHEARSAL NC 20
COAT ROOM

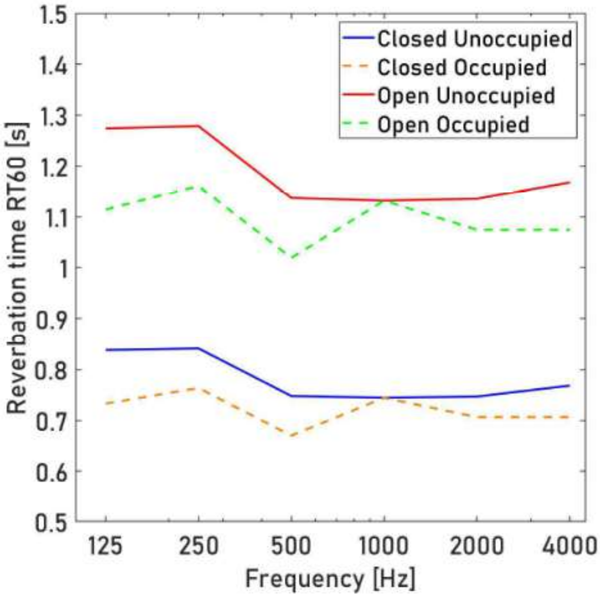

ROOF TERRACE
ROOF TERRACE
MEP, IT and Amp rooms

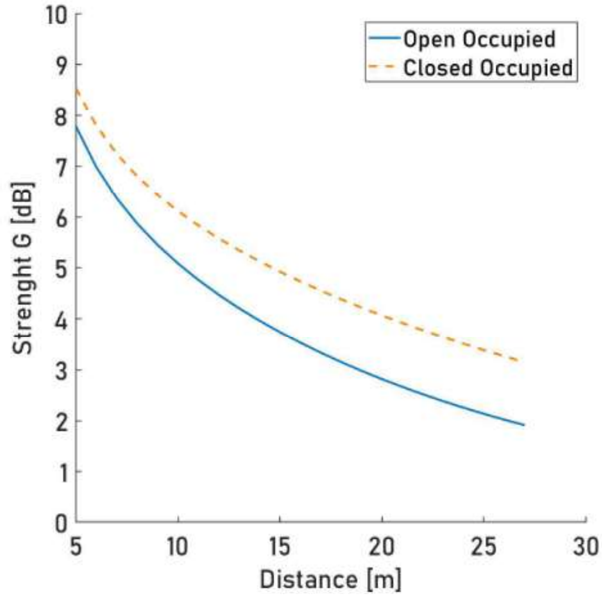
PERFORMANCE

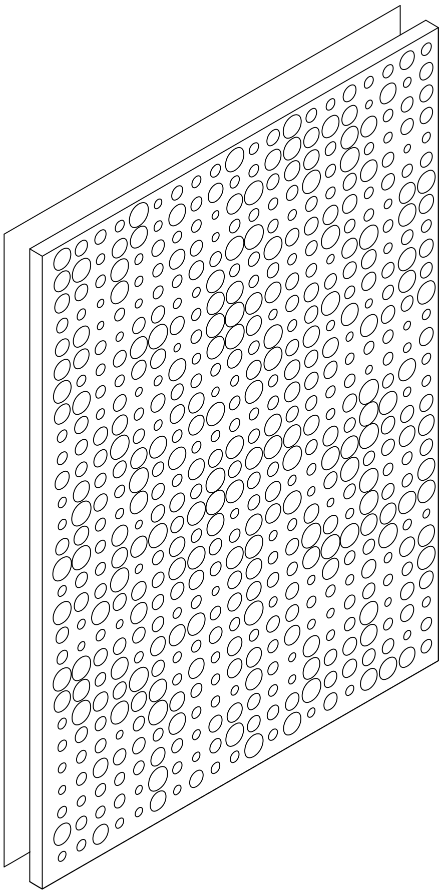
For reverberation time we receive a value at 1000 Hz 0.75 s for a closed and lowered roof. This is favorable for speech where distincts sounds are wanted. For the open roof with a higher volume we receive a value of 1.15 s. More favorable for music.

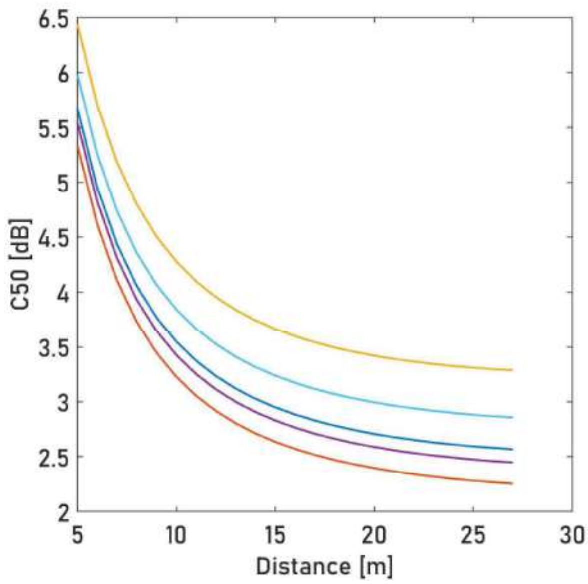
For strength G we measeured Gmid at 1000 Hz. For closed and lowered roofs we receive a value between 8.54 dB at the front to 3.15 dB at the back. For open we receive a value of 7.79 at the front and 1.92 at the back.

For clarity C50 we receive values at the front from 5.34 dB at 125 Hz to 6.44 db at 4000 Hz. At the back we receive values at 2.25 db at 125 Hz to 3.28 at 4000 Hz.

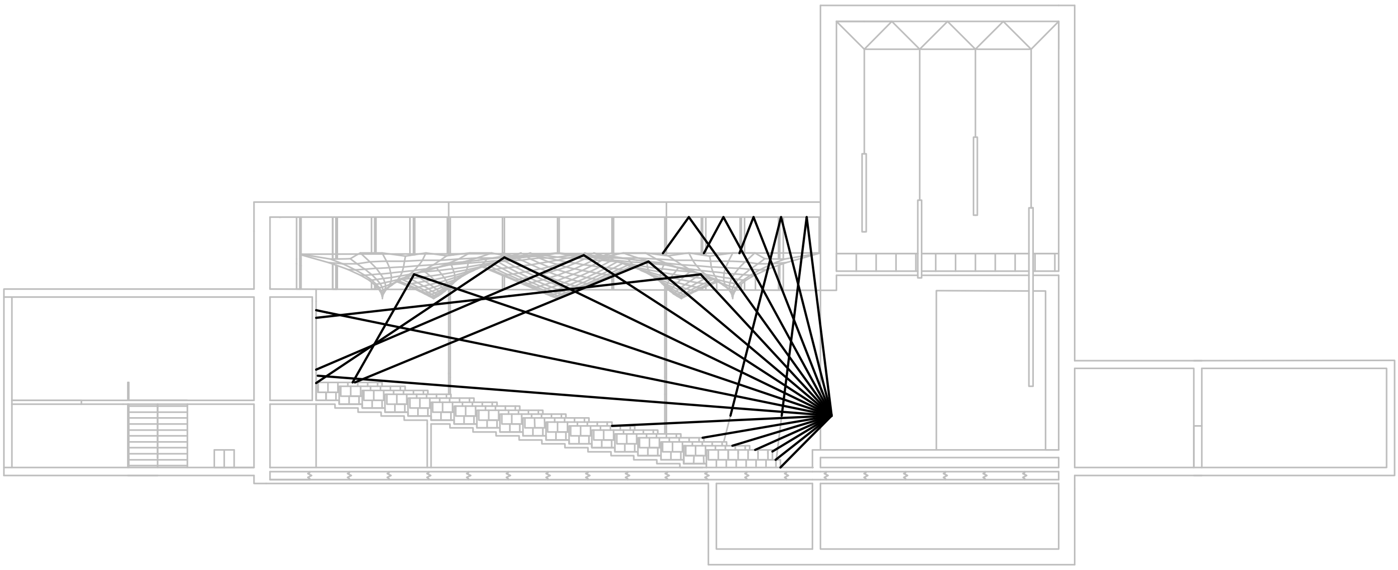


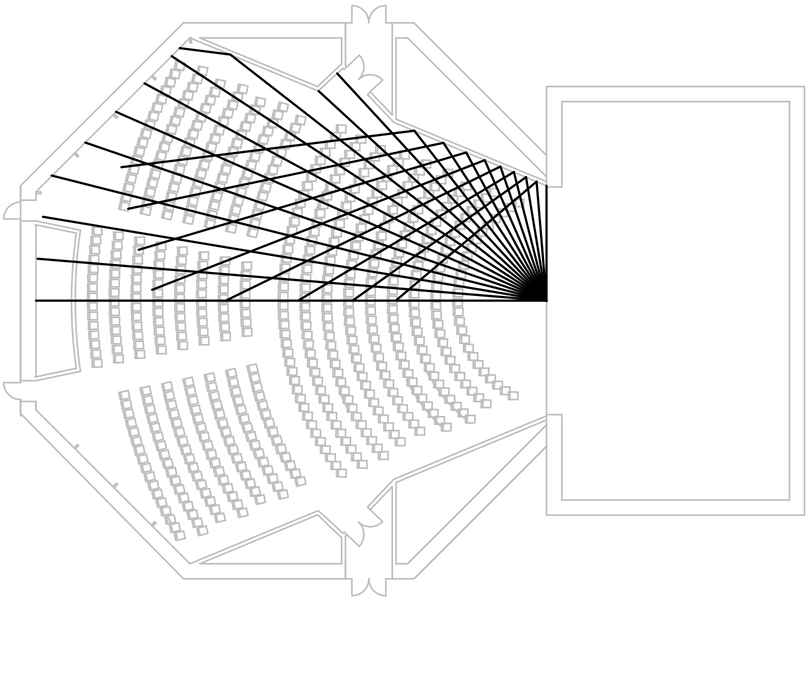






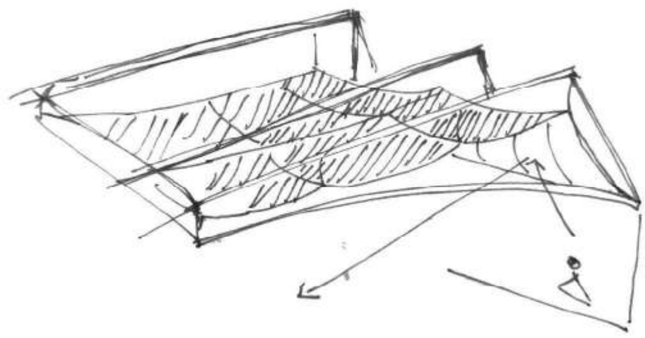
The Helmholtz resonator reduces the reverberation time at 125 Hz by x amount.



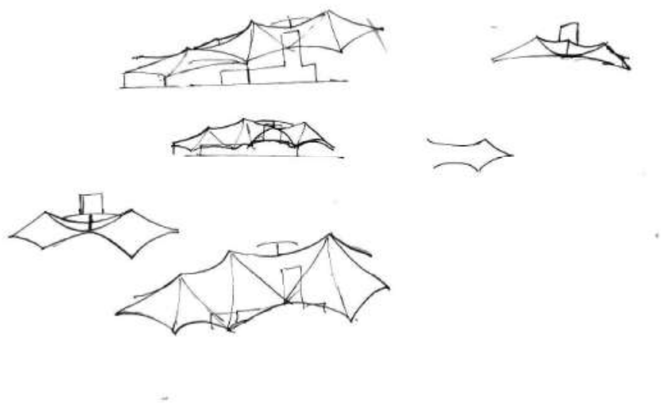


REFLECTION

Design Process
The process was a bumpy road with many conceptual and structural challenges. We took a bold approach in the competition by using textile. A material not typically suited for acoustics and attempted to modify its properties to meet specific needs. A clear example of this was our early idea of using textile under tension to both absorb and reflect sound. It was a concept with pure intentions, but not feasible in reality. We used drumskin leather as a metaphor for the roof structure. After discussions with acoustic professionals, the idea was discarded. However, the structure and design inspired us to develop our foldable roof, “the flower.”

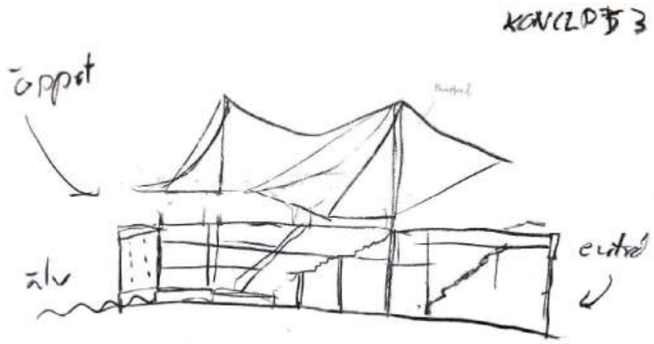


Architectural Qualities
The theater is both a functional and expressive building. Connecting Gothenburg and highlighting the importance of theater. Which in itself is an architectural quality. The most notable feature is the foldable roof, which combines structural innovation with strong visual qualities. Aimed to enhance the overall experience.

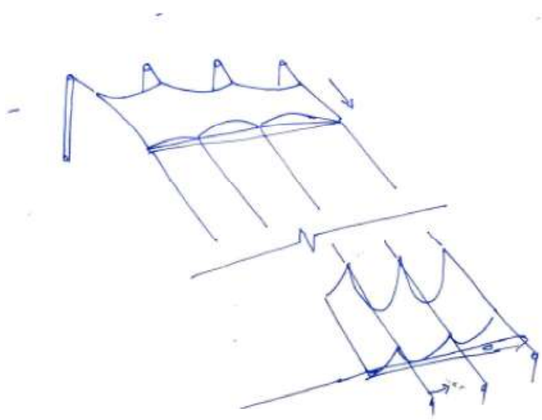


Sustainable Strategies
We initially struggled with our similarity to the circus. Looking back, this was not a bad comparison. A circus represents a humble and socially sustainable model. Able to reach remote areas and bring entertainment to everyday people. Our concept included the idea of being able to disassemble and move the entire theater. With lightweight materials like textile and wood this seemed achievable. But the lack of time made it impossible. Textile is a lightweight material that minimizes environmental effect and has many possibilities in architecture.

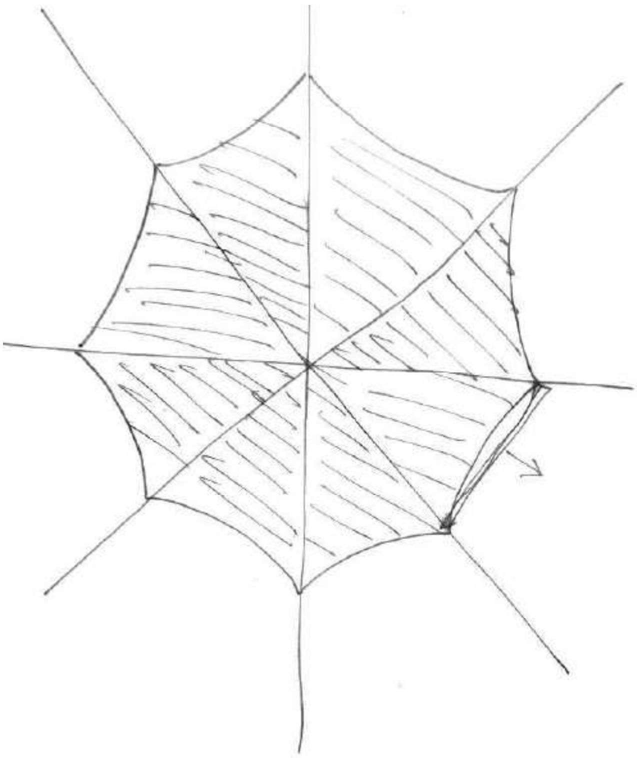
Integration of Technical Disciplines
The collaboration between sound and structure was the most obvious integration. The project involved input from many fields. Indoor climate was discussed in this course. We thought about noise pollution from ventilation systems and how we would construct walls for soundproofing. Light and color were also part of the project. Taking inspiration from our field trip to the art museum. Using colors from the Gothenburg Colorist collective in our project.



Interdisciplinary Collaboration
Collaboration was a major challenge during the course. It tested our abilities as team members. Being humble and open is essential for creating a good environment. The stress of deadlines and ambitions made collaboration difficult. Making clear intentions from the start and maintaining a respectful relation is essential for future projects.



Issues of Leadership
Leadership earlier in the process would have been helpful. In a real world scenario, with more people involved the project would feel less personal. Clearly defined roles and responsibilities would have led to a more balanced workload and an overall better project.



Artistic Methodologies, Iterations
Parametric design played a significant role in the project. Bringing conceptual sketches with complex geometries into reality. Although we shouldn't overemphasize its importance. The true strength of the project lies in its core ideas and the conceptual foundation. Sketching and the iterative process was the most important part. Developing concepts and filtering out the good from the bad. Iteration gave us time to explore various solutions. Resulting in a more creative project.

Afterthoughts on Three Years of Study, Future Practice
During three years of Architecture and Engineering studies I have learned many things. Among others hard work, dedication, and the competitive environment of architecture. I have developed a deeper understanding of architecture and gained confidence in my abilities. Working through difficult challenges with my classmates has brought us closer together and emphasized the importance of collaboration. Laying a solid foundation for future studies in structural engineering and a work-life with many friendly AT-colleagues.