FRAME
EXPLORATIVE OPERA

COURSE: Bachelor's Thesis - ACEX15
SUPERVISORS: Peter Christensson, Wolfgang Kropp & Morten Lund
IN COLLABORATION WITH: Johan Blomsterberg & Matthew Polidano

In the bachelor's project, groups consisting of two Architecture and Engineering students, with assistance from a master's student specializing in Sound and Vibrations, were tasked with creating a competition proposal for an architecture and acoustics competition organized by the Acoustical Society of America and the Robert Bradford Newman Fund.

This year's challenge was to design an opera house for a university with a very strong music and vocal program, accommodating 1,200 guests. A significant challenge of the competition was that the concert hall had to be situated in a dense urban environment, where the site was surrounded by roads with emergency vehicles operating on all sides. Additionally, the competition assigned acoustic values for noise levels at the facade, focusing on how to manage noise problems both in the construction and inside the building. The program required that the concert hall be adaptable for various types of opera, as well as for speeches and other events, thus necessitating more flexible acoustic qualities.

POSTERS

MODULARITY

The proposal emphasizes modularity, reusability, and interaction. Building frames serve as the structural system for the adjustable Auditorium roof and sun/noise-reducing draperies. Inside, similar frames support acoustic prototypes in the Audiotorium and Rehearsal Hall, as well as the playful stair in the Lobby leading to the Auditorium balconies.

Modularity extends to surface materials, with 25 mm plywood and cork used in acoustic prototypes for both reflecting and absorbent surfaces, allowing for versatile applications.

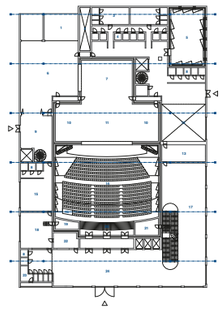
REUSEABILITY

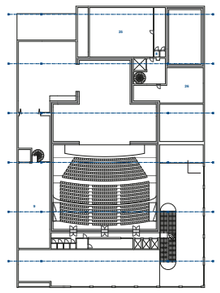
Different parts of the building incorporate reused elements for sustainability. The Auditorium roof utilizes overdimensioned, outdated cableway wires as the structural support, enabling adjustability. Reused sails from sailboats cover the roof, connecting the building's appearance to its imagined location in Köln, Germany, near the Rhine River and the Cologne University of Music and Dance.

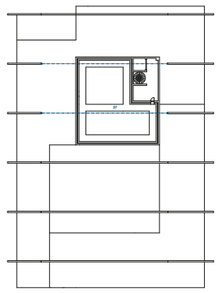
Additionally, absorbent panels feature milled cork sourced from recycled bottle caps, providing a relatively flat surface while promoting sustainability.

INTERACTION

The interaction aspect facilitates flexibility in the building's acoustics for students and performers. The adjustable roof in the Auditorium alters volume, affecting reverberation times. Its undulating surfaces redirect reflections. This principle extends to the side proscenium towers and side wall frame-panels, which can rotate on two axes to redirect reflections in both height and depth.





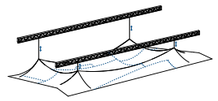


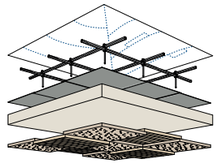
NOISE CRITERIA 15 30 40

1. Loading Dock
2. Vertical Shaft
3. Chorus Dressing Room
4. Solo Dressing Room
5. Rehearsal Hall
6. Scene Shop
7. Back Scene
8. Restroom
9. Storage
10. Side Scene
11. Proscenium
12. Green Room
13. Kitchen/Bar
14. Opera Hall
15. Office
16. Audio Mix Position
17. Study Area
18. Cloakroom
19. Follow Spot Booth
20. Integrated Lift
21. Control Room
22. Box Office
23. Janitor Closet
24. Lobby
25. MER
26. MEPFIT
27. Stage Tower Service Path

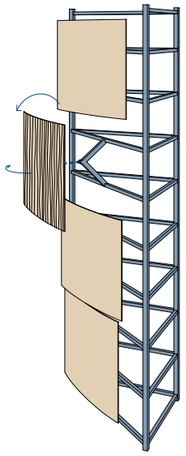
MOVABLE ROOF

In addition to reused sails and wires, the roof is also constructed using flat plates in lead, plywood, cork and a pre-stressed, and therefore expandable, layer of foam insulation. The lead plates is used to gain weight in the construction to better reflect sounds within the Auditorium, and reduce noise from exterior sources. Plywood and cork panels works as the interior surface aimed to reflect, absorb and diffuse the sound. All the plates are overlapped and fastened in one point, allowing the structure to be closed as the roof changes position. Due to the pre-stressed foam insulation, the structure also keeps airtight independent of the roof's position.





ACOUSTIC PROTOTYPES

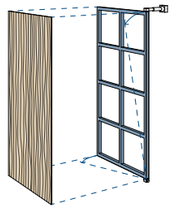


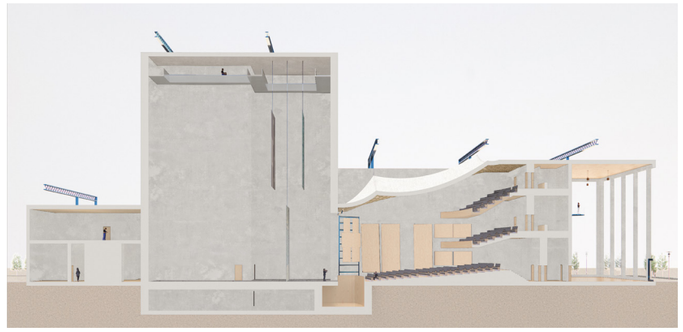
AUDITORIUM

The main hall's parallel walls can lead to unwanted reflections and echoes. To address this, rotating reflector panels are installed on the side walls. These panels can be closed during audience seating to widen aisles and then rotated for performances. They can also angle downwards to direct sound toward the audience. Reflectors in the corners of the stage redirect sound towards the audience, enhancing acoustics.

REHEARSAL HALL

The rehearsal hall do not include seating area, requiring additional absorptive material to match the acoustic properties of the main hall. Walls feature rotating panels to disperse parallel wall reflections and redirect sound downward to balance the high ceiling. Absorbers between rotating elements target both low and high frequencies. Thick double walls and small double-glazed windows minimize outside noise, ensuring a quiet rehearsal environment.

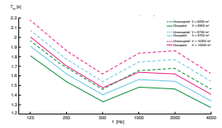




ACOUSTICAL PERFORMANCE

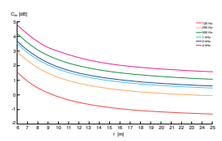
REVERBARATION TIME

A checkerboard pattern of plywood and cork on the ceiling balances reflection and absorption properties, achieving a desirable reverberation time throughout the room. Seats feature soft material on both top and bottom to minimize differences in reverberation time between occupied and unoccupied states. Additional absorbing material targets specific frequency bands, 1 kHz and 2 kHz, to reduce frequency-dependent reverberation time. Adjusting ceiling height can vary reverberation time by approximately 0.1 second for every 500 m³ volume change.



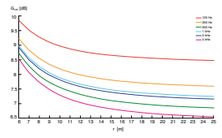
CLARITY

The clarity remains high when close to the stage but decreases as distance increases, reaching values between 0 dB and -2 dB for various frequency bands. The variation in clarity among frequency bands is not significant.



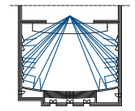
STRENGTH

Past 10 meters from the stage, there is minimal change in strength, providing consistent audience experiences. Across frequency bands, strength remains consistent except for 100 Hz. Boosting bass frequencies aids perception, as they are perceived quieter than higher frequencies.

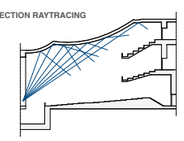


SOUND REFLECTIONS

PLAN RAYTRACING



SECTION RAYTRACING



THE HALL'S REFLECTIONS

Due to only having two balconies, the ceiling's height allows to be positioned relativley low. The reflections from the roof can therefore be credited in greater occurence. On account of this, the Audiotorium has a larger width than depth allowing for a bigger audiance in orchestra area where the sound is usually better. With having a smaller depth, the largest distance from proscenium to back row does not exceed 25 meters which aims to obtain even sound throughout the Audiotorium.

Lisa Reinhardt

PROCESS

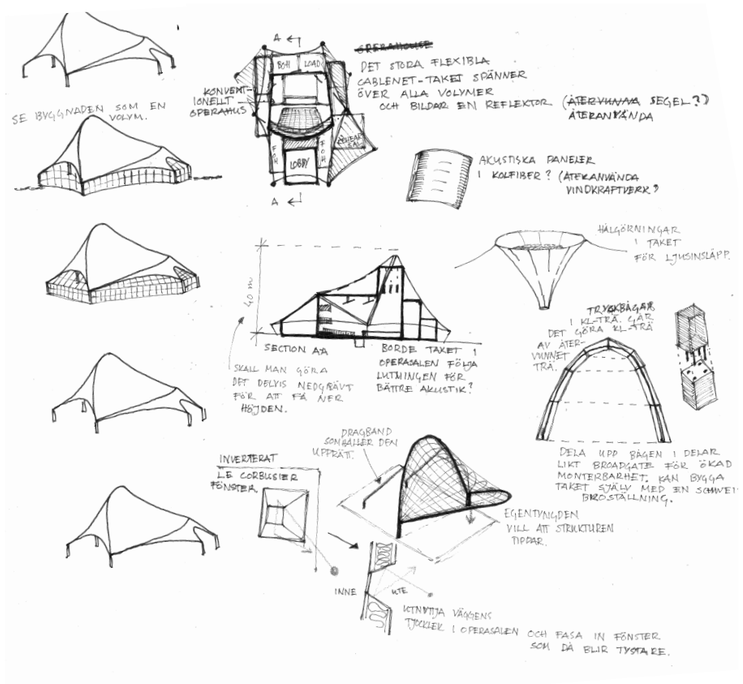
During the design process, we conducted five iterations.

In the first iteration, we explored various acoustic environments, measuring and documenting key parameters such as reverberation time, clarity, strength, and noise levels. This data was essential for designing the auditorium and understanding the achieved acoustic environment.

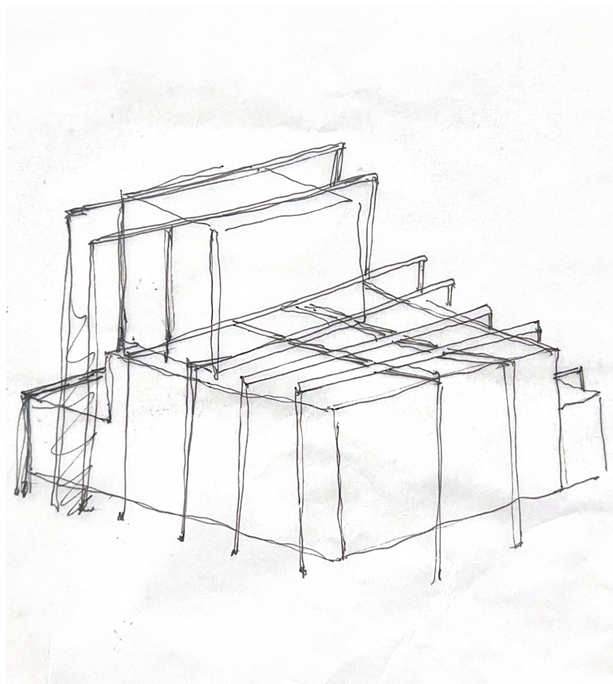
The second iteration involved a conceptual design phase. Johan and I was teamed up with Matthew, a Master's student in Technical Acoustics at Chalmers. Together, we explored different building volumes and conducted early ray tracing of reflections to find a volume that balanced both acoustic and architectural needs.

In the third iteration, we fabricated spatial acoustic prototypes that would serve as key elements in the proposed auditorium.

The fourth and final iteration involved assembling the complete project design, integrating all the components into a cohesive and complex proposal.



EARLY SKETCHES



PLANS

NOISE CRITERIA

15 ■ 30 ■ 40 ■

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2. Vertical Shaft
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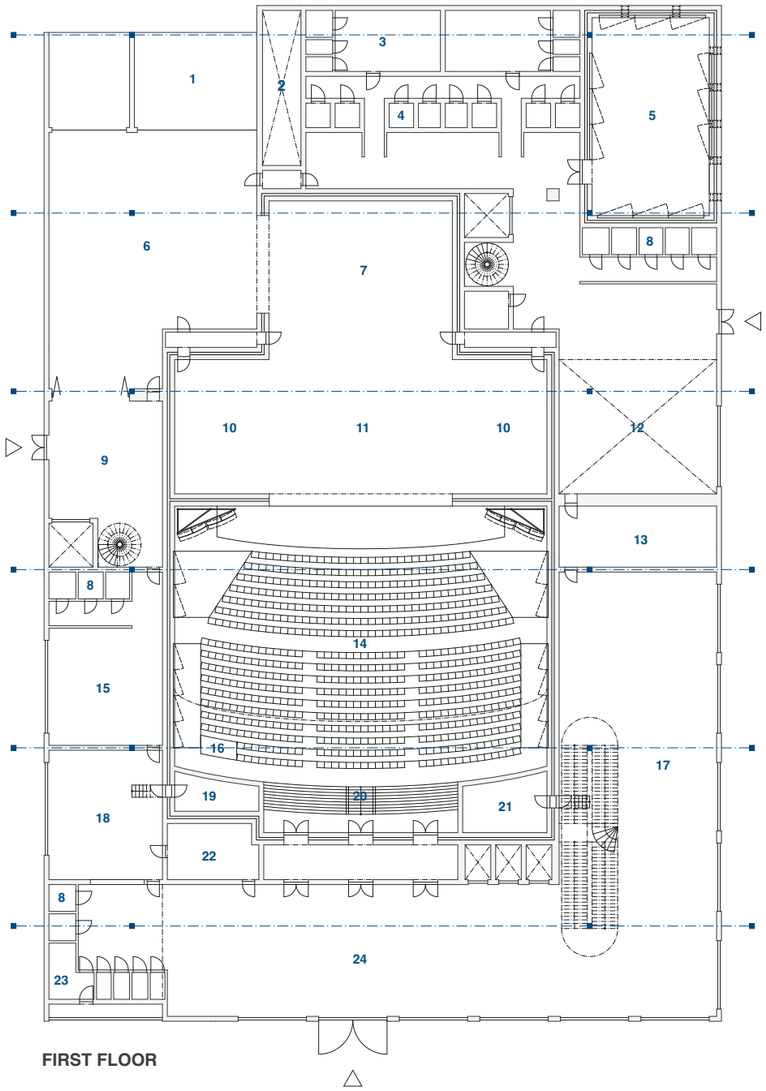
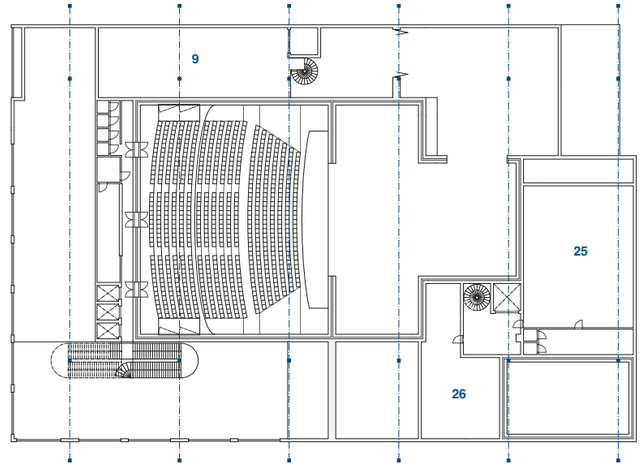
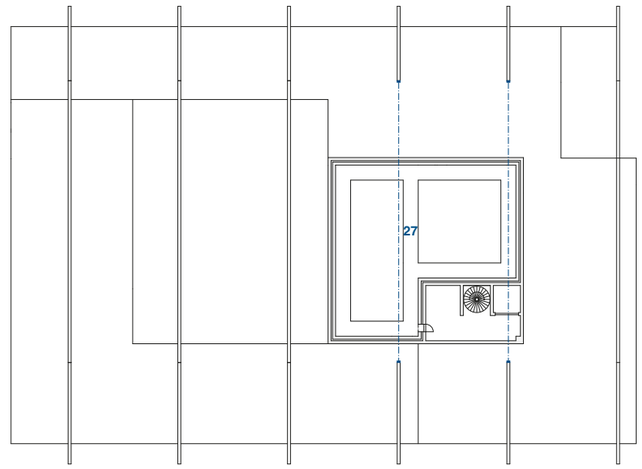


FIRST FLOOR



SECOND FLOOR



THIRD FLOOR

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MAIN FOCUSES

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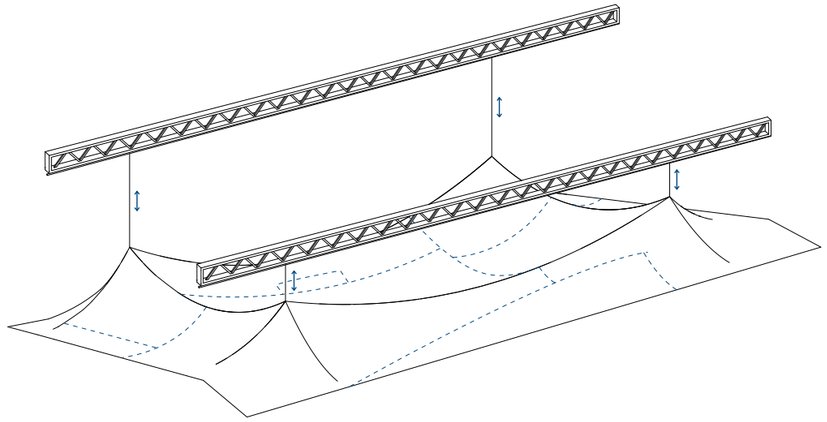

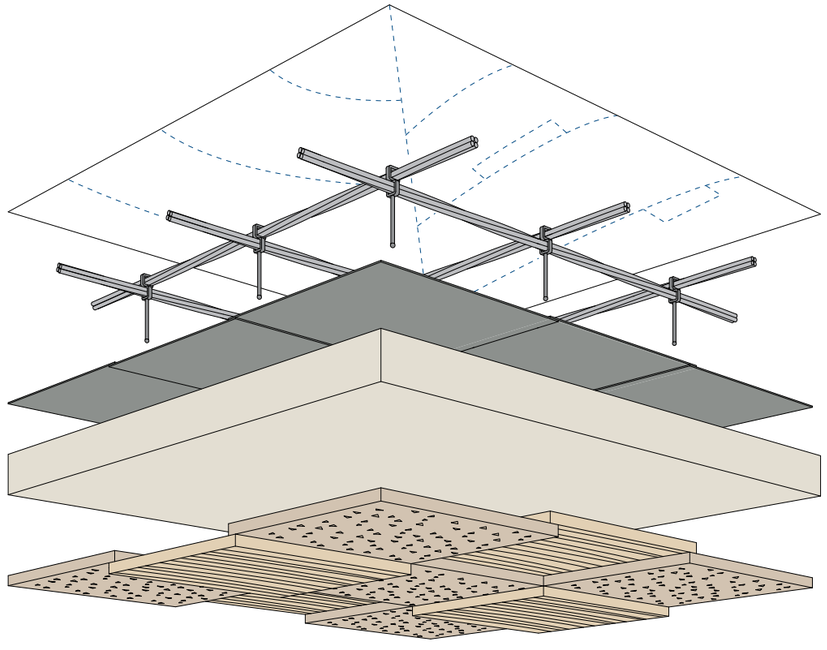

ROOF CONSTRUCTION

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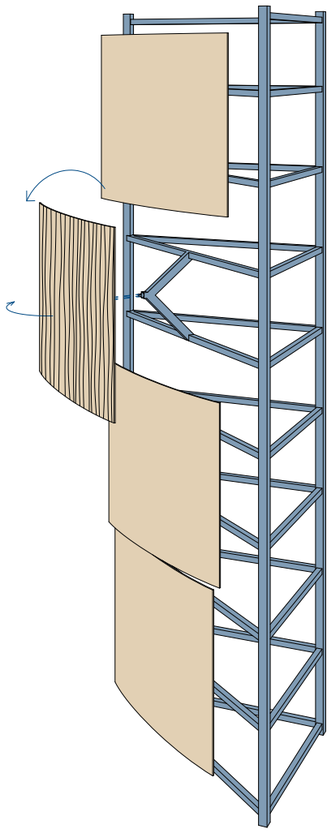
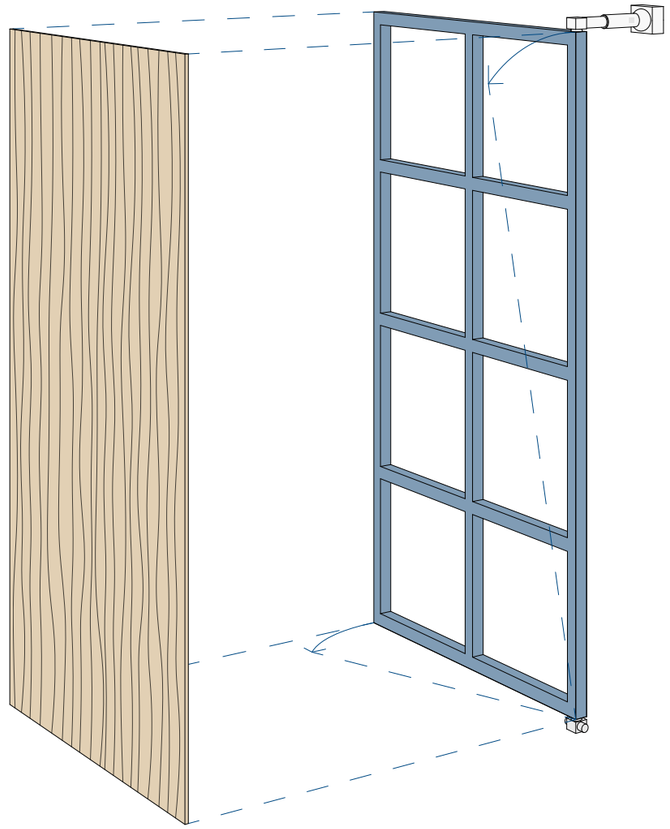


SIDE STAGE REFLECTORS



WALL REFLECTORS

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AUDITORIUM

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ACOUSTICAL PERFORMANCE

A checkerboard pattern of plywood and cork on the ceiling balances reflection and absorption properties, achieving a desirable reverberation time throughout the room. Seats feature soft material on both top and bottom to minimize differences in reverberation time between occupied and unoccupied states. Additional absorbing material targets specific frequency bands, 1 kHz and 2 kHz, to reduce frequency-dependent reverberation time. Adjusting ceiling height can vary reverberation time by approximately 0.1 second for every 500 m³ volume change.

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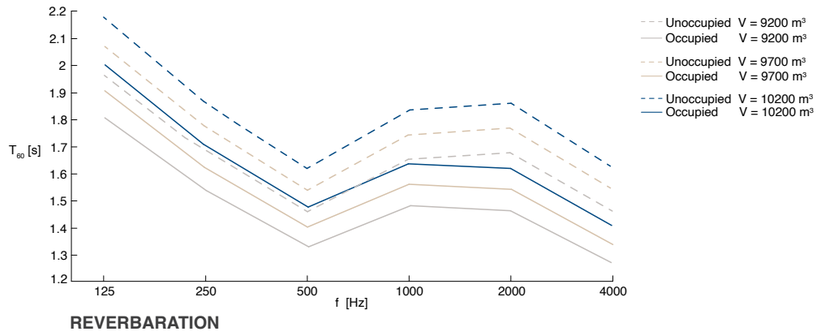
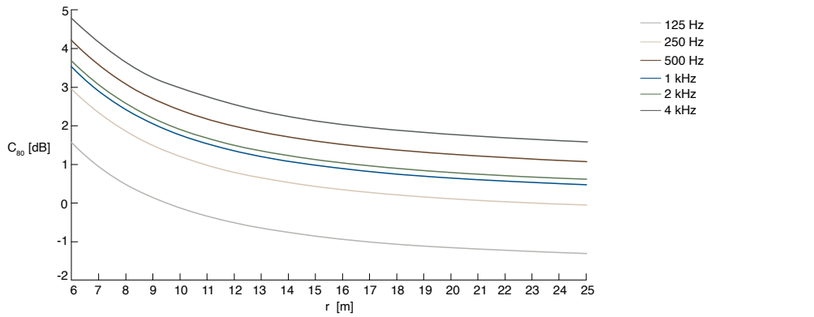
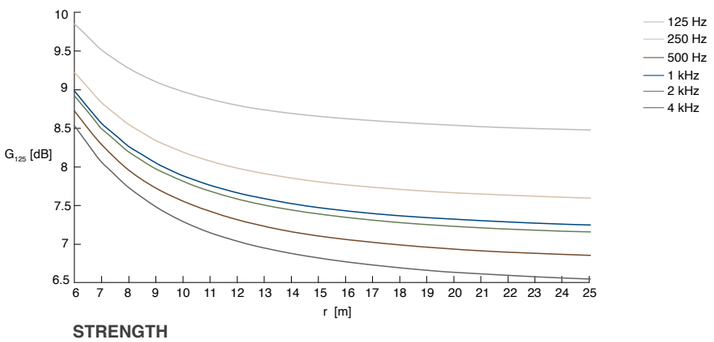


REVERBARATION



CLARITY



STRENGTH

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REFLECTION

When designing the opera house, the plans proved crucial for our comprehensive understanding of the eventual outcome. Initially, we gravitated towards an organic architectural form for the exterior, favoring arches over frames. However, this posed challenges in accommodating functional spaces that could also ensure optimal acoustics.

A pivotal moment in the project occurred when we opted to encase the building with frames, thereby establishing the structure for the movable roof. This decision facilitated a smoother progression in plan design, where the layout strictly followed the function in order to maintain the modularity.

The opportunity to work with other disciplines was an interesting and educational experience. The project served as a good example of the importance of collaborating with people who possess expertise that one may lack oneself.

I am pleased with the resulting building that we accomplished. I believe that we adhered to our initial main focuses: modularity, reusability, and interaction. Given more time, I would have loved to delve deeper into certain aspects of the opera house. During our critique, we received a comment suggesting that the sails used as sun drapes could also function as projector screens. Exploring this idea and its potential impact on the building's expression would have been intriguing.