FRAME OPERA

An explorative opera space for students and performers

Bachelor thesis, Architecture and Engineering
Chalmers University of Technology
Johan Blomsterberg
Collaborated with: Lisa Reinhardt and Matthew Polidano
2024

INTRODUCTION & WORKFLOW

The objective of the project was to discover the interplay between architectural design and building acosutics by designing an Opera House for a school. It was a part of the Acoustical Society of America's annual design competition.

Our personal aim for the project was to design an Opera House with three main focuses. Modularity, reuasbility and interaction.

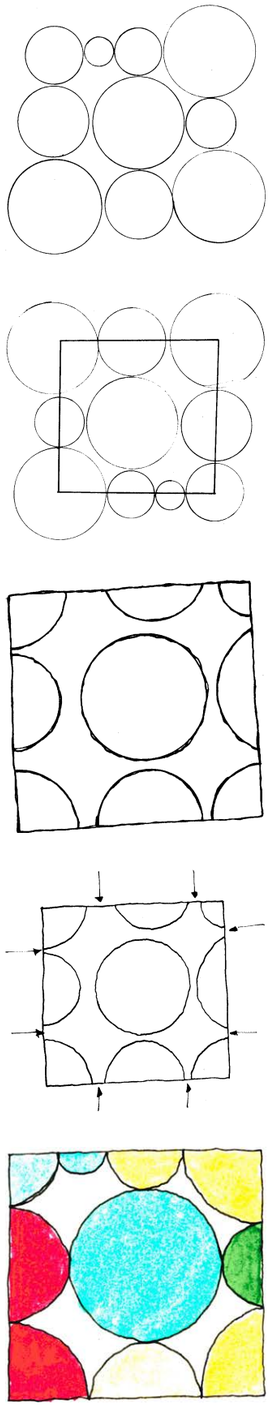
When designing the project, we carried out five iterations. The first iteration included experiencing different acoustic environments while measuring and documenting goal values for parameters such as reverbaration time, clarity, strength and noise levels. This data would later be used when designing the audiotorium and to ensure comprehension of what acoustic environment we had achieved.

The second iteration consisted of a conceptual design phase where me and Lisa got teamed up with Matthew, a Master's student in Technical Acoustics at Chalmers. We explored different building volumes and carried out early raytracing of reflections to find a volume suitable for both acoustics and architectural design.

The third iteration included frabricating spatial acoustic prototypes that would act as key elements in the proposed audiotorium.

The fourth and last iteration consisted of the final project design where the complex proposal got put together.

[1]: Circles concept
[2]: Pettsson concept
[3]: Tent concept



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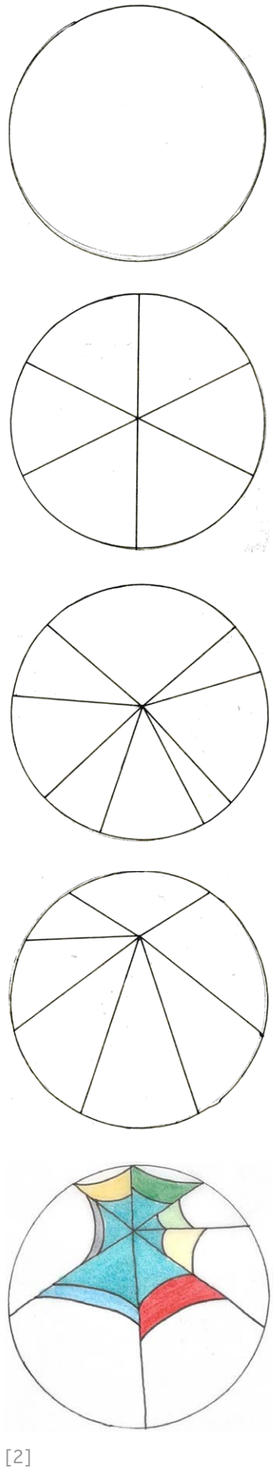

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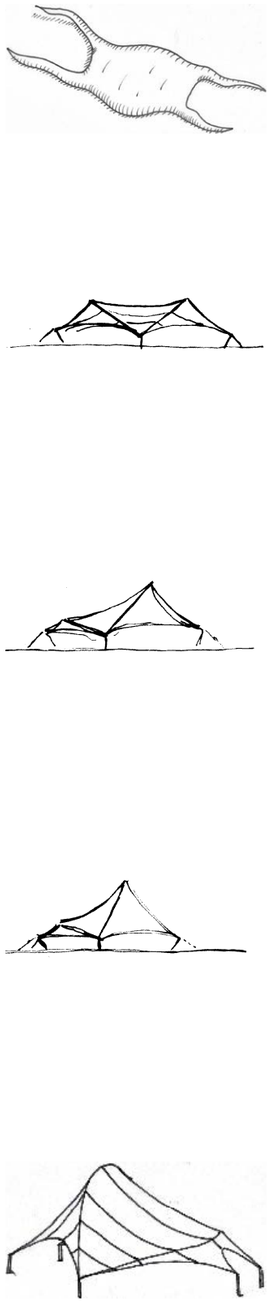

[3]

CONCEPTUAL ACOUSTIC PROTOTYPES

[1]: Prototype of movable cablenet roof
[2]: Prototype of strechable resued sails roof
[3]: Detail model of roof structure
[4]: Detail model of roof structure with sail as exterior surface
[5]: Detail of overlapped reflector panels on interior roof structure

[1]

[2]

[3]

[4]

[5]

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COMPETITION POSTERS

[1]: First poster
[2]: Second poster
[3]: Third poster

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.

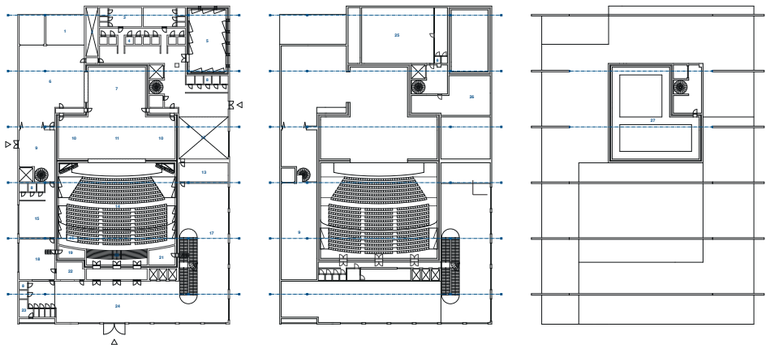
REUSEABILITY

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.



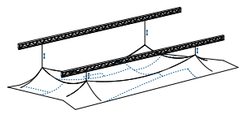
NOISE CRITERIA 15 30 40

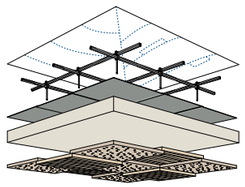
1. Loading Dock
2. Vertical Shaft
3. Chorus Dressing Room
4. Solo Dressing Room
5. Rehearsal Hall
6. Scene Shop
7. Back Scene
8. Restroom
9. Storage
10. Side Scene
11. Proscenium
12. Green Room
13. Kitchen/Bar
14. Opera Hall
15. Office
16. Audio Mix Position
17. Study Area
18. Cloakroom
19. Follow Spot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

[1]

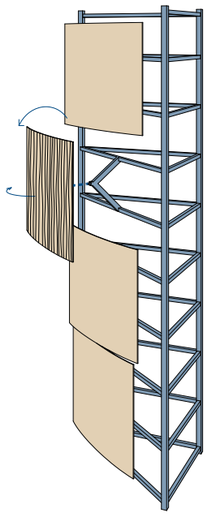
MOVABLE ROOF

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

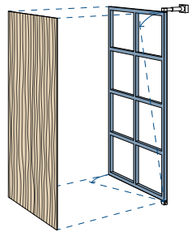


AUDITORIUM

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.



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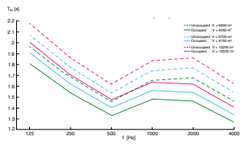
ACOUSTICAL PERFORMANCE

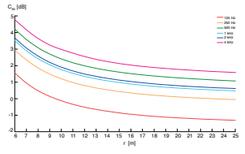
REVERBARATION TIME

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.



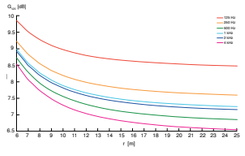
CLARITY

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.



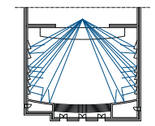
STRENGTH

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.

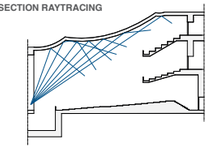


SOUND REFLECTIONS

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.

[3]

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GROUP-SPECIFIC AIMS

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[1]: Lenght section drawing with depth

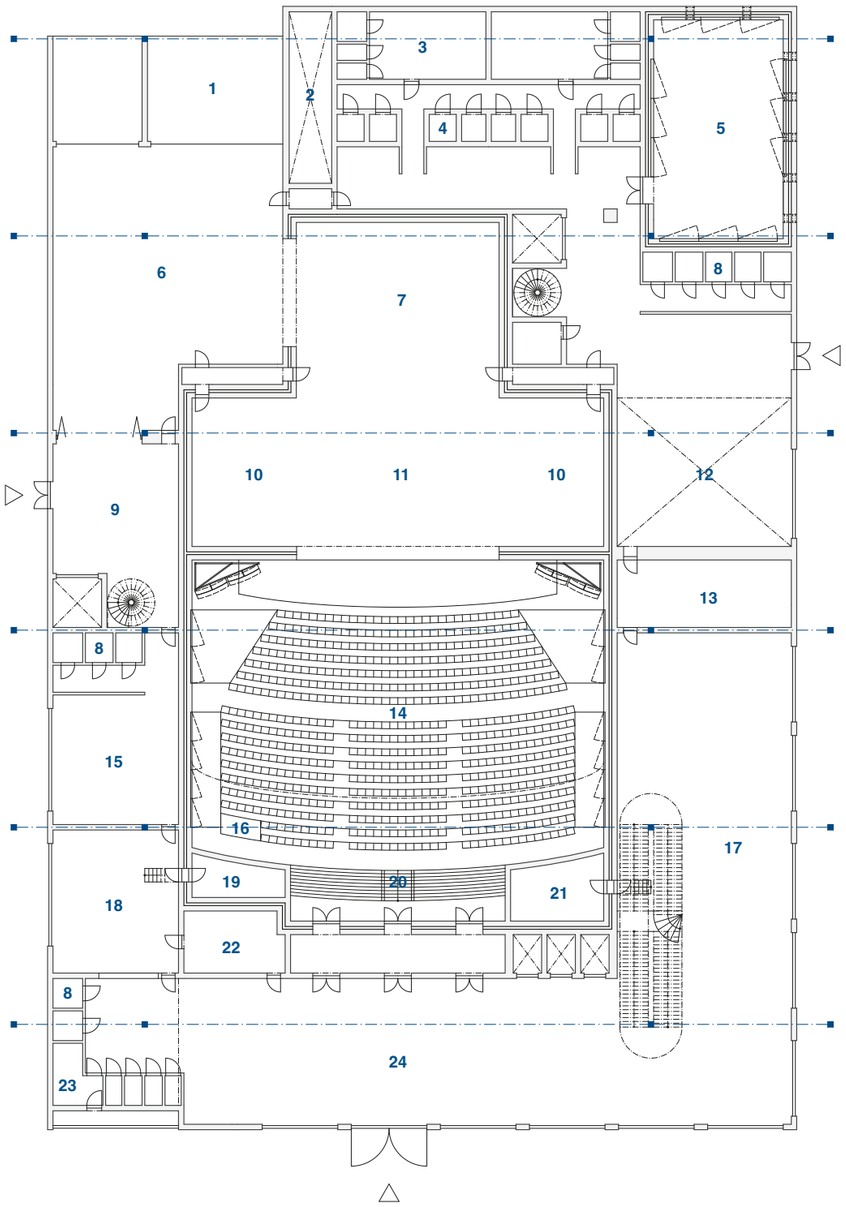
[1]

SITUATION & PLAN

[1]: Entrance floor plan
[2]: First and second floor plan

In the center of Köln, near the Rehn River lies the Cologne University of Music and Dance. One of the world's foremost performing arts schools and one of the largest music institutions for higher education in Europe with its three campuses in Cologne, Wuppertal, and Aachen.

With walking distance from the Aachen Campus lies our proposal for a Opera House in the urban context. The building battles with the noise generated from the surrounding streets and the adjacent Köln Hauptbahnhof.



[1]

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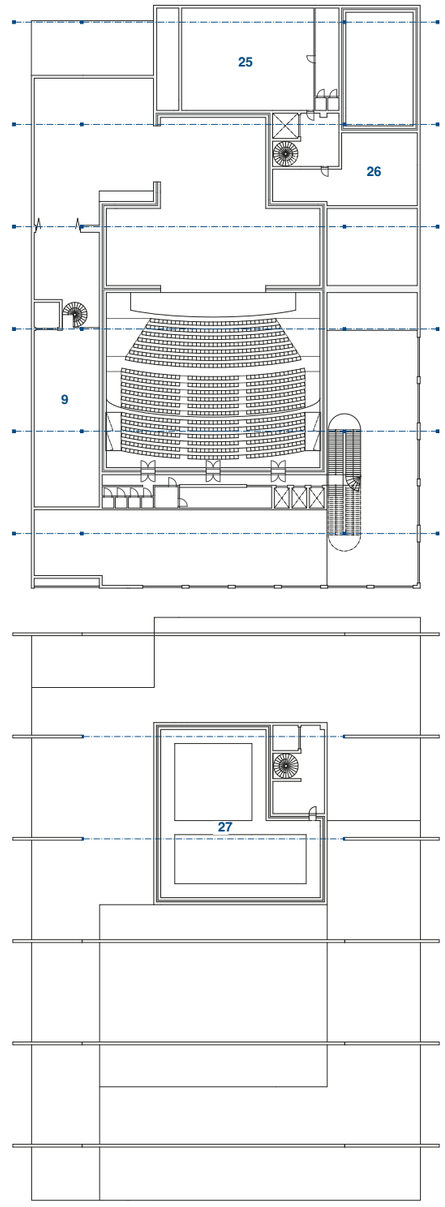

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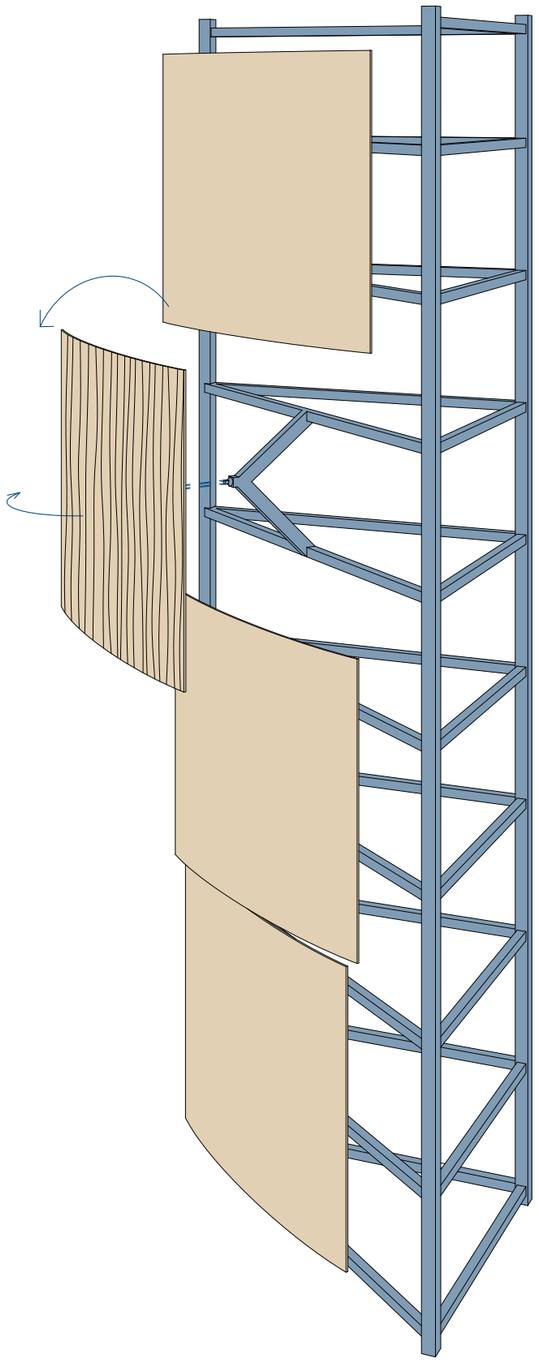
[1]: Exploded view of side stage reflectors
[2]: Exploded view of wall reflectors



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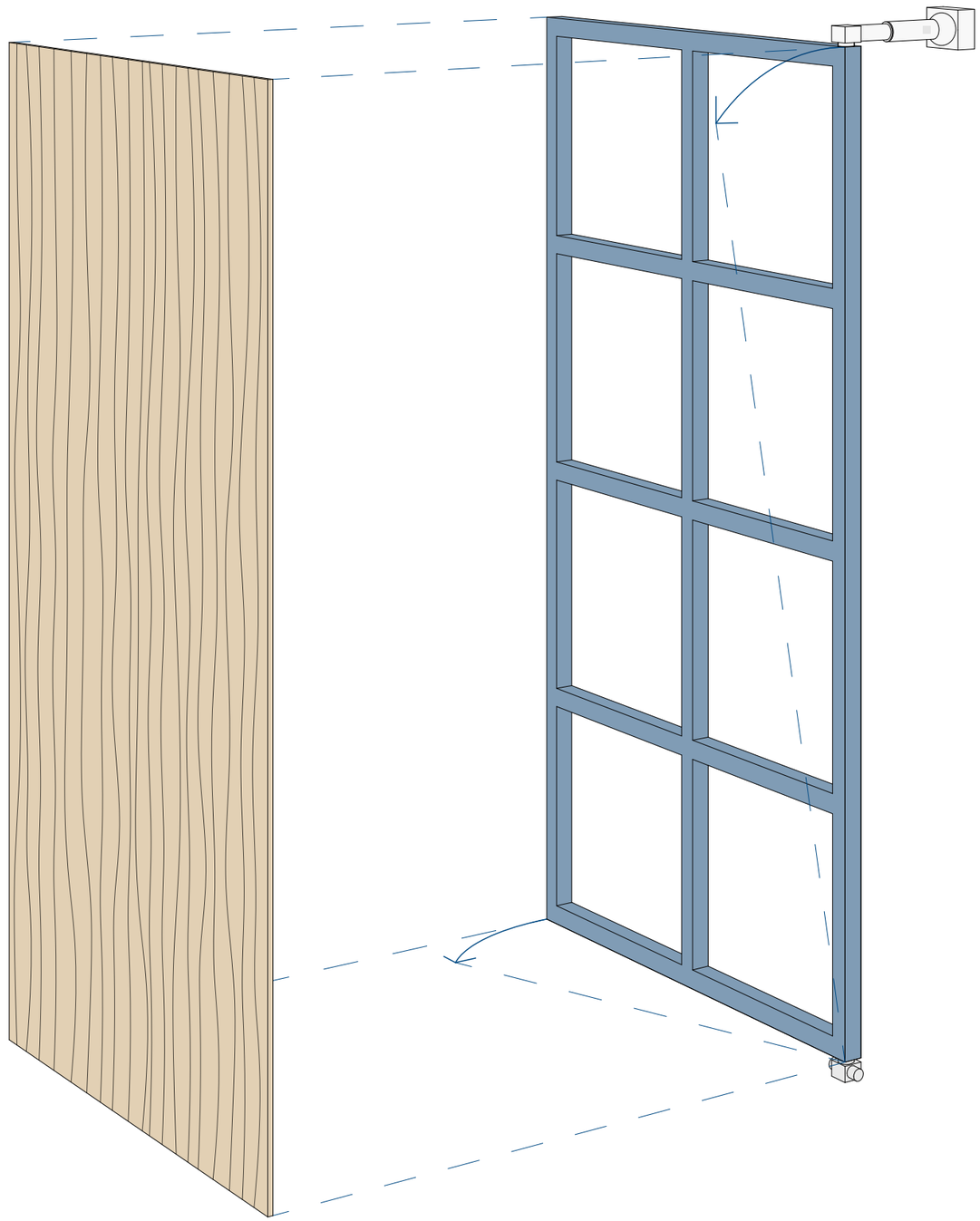

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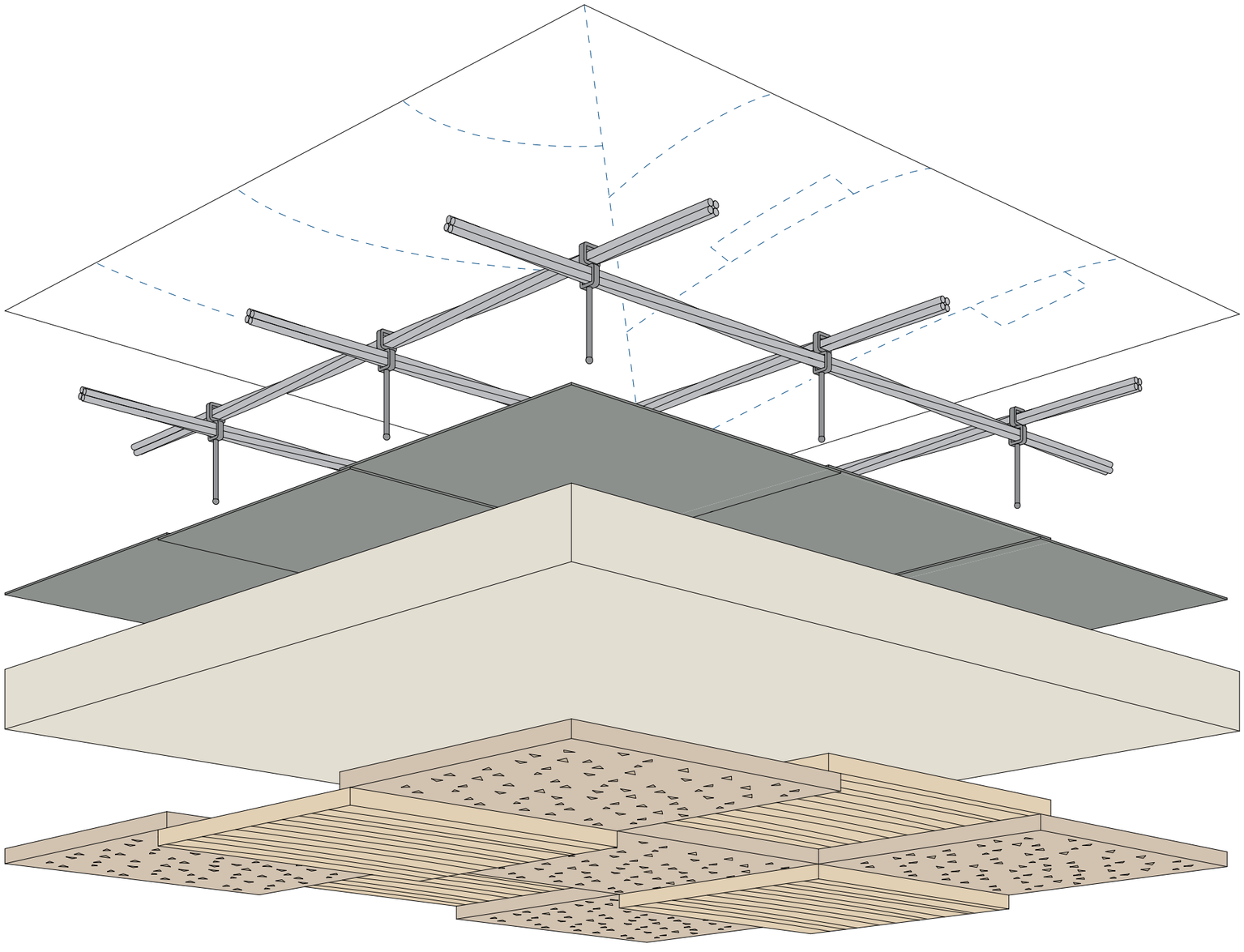
[1]: Exploded detail drawing of roof construction



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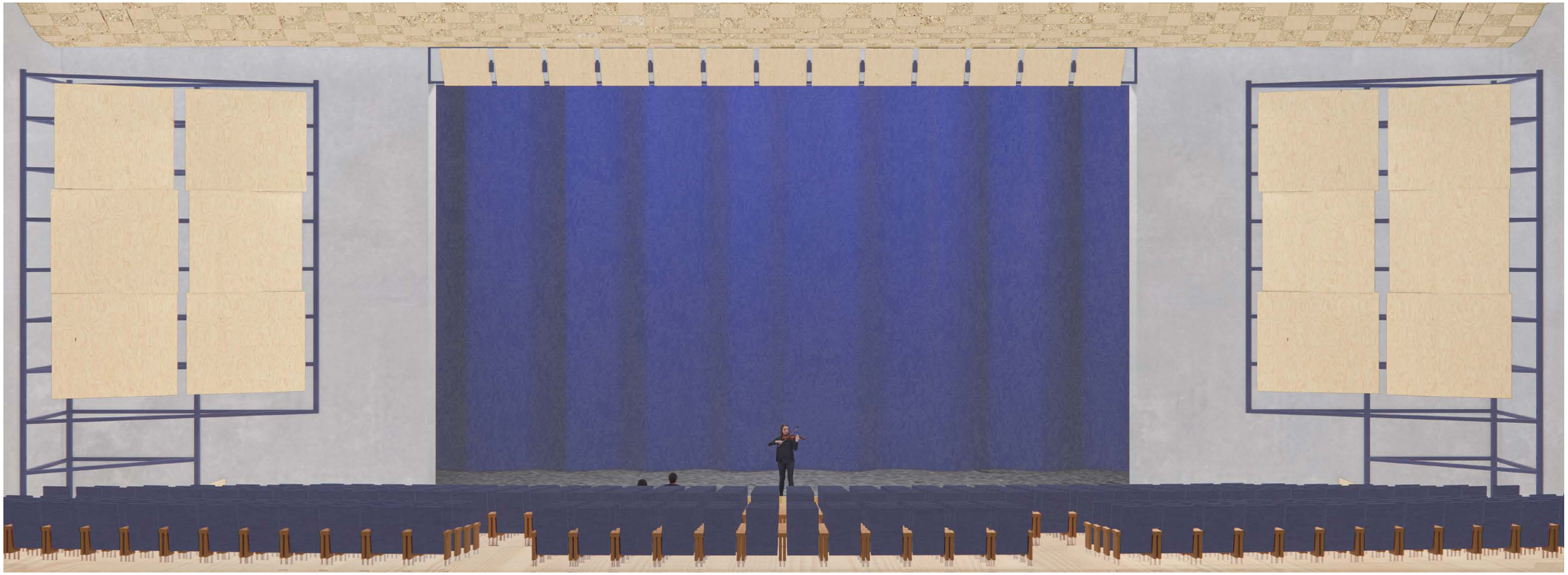

ACOUSTICS

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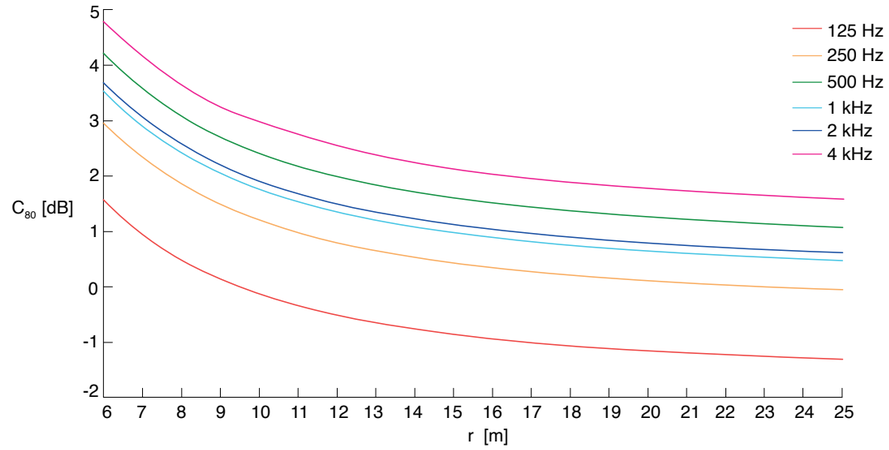
[1]: Graph on strength
[2]: Graph on clarity
[3]: Graph on reverbaration time



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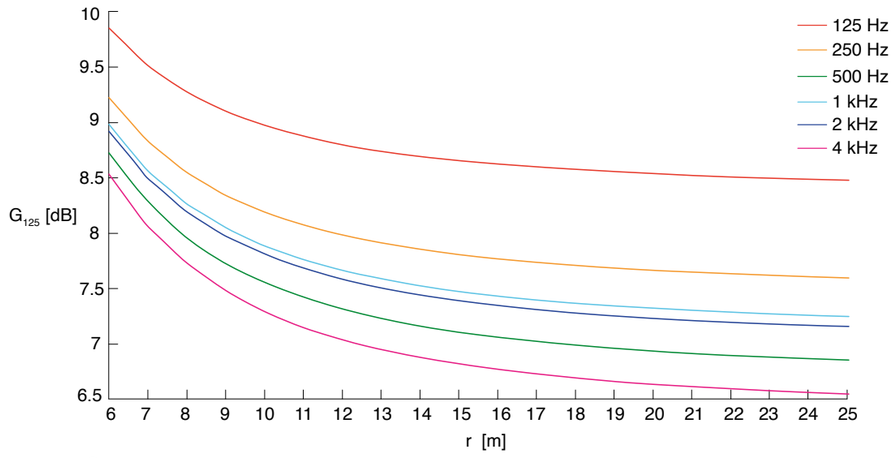

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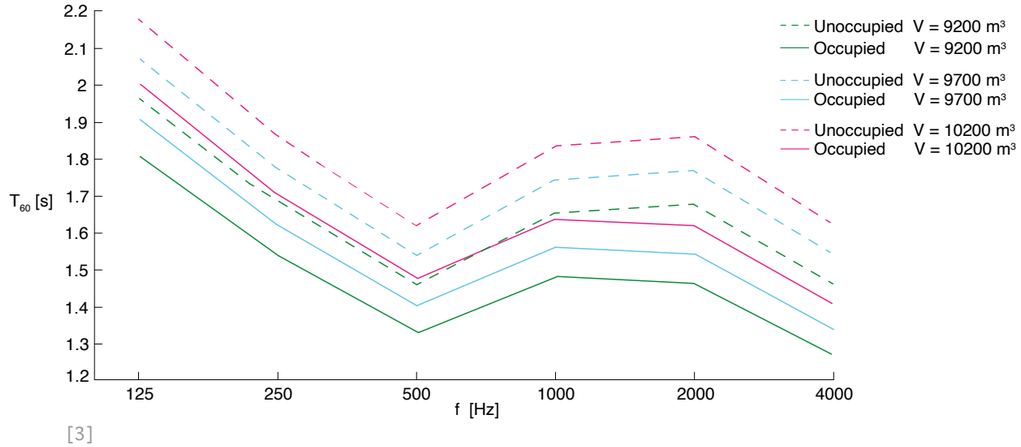

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THOUGHTS ON THE PROJECT

The project aimed to let our core ideas speak for themselves and to maintain purity in the architectural design. As a result, the proposal's appearance may seem somewhat brutal.

We had the opportunity to receive critiques from experienced and renowned architects and acousticians, including Martha Tsigkari from Foster + Partners, who described our project as "cheap and cheerful."

These two words capture what we aimed to achieve. Every component and part of the building has a practical function and serves a purpose beyond decoration, making the building more akin to a piece of machinery.

The design process took a turn when we began organising the rooms and functions for the building. As seen in the conceptual sketches, the early ideas leaned towards a more organic design. However, considering modularity, reusability, and interaction, we realised that a flexible and orthogonal structure would be more suitable. We still managed to integrate organic forms into the project through the auditorium roof, which hangs at four points.

An essential aspect of this project was the cooperative work that went into its development. Collaboration was crucial in bringing together diverse perspectives and expertise, leading to a more robust and well-rounded design. Working closely with our acoustician partner, allowed us to refine our ideas and incorporate valuable feedback at every stage. This collaborative approach not only enhanced the quality of the design but also fostered a sense of shared ownership and pride in the final outcome. The synergy of cooperative work enabled us to push the boundaries of creativity and innovation, ensuring that the project was both practical and visionary.