Seattle opera factory

- Exploring pipe acoustics in architecture

Jonathan Samuelsson

Competition brief and background

The Newman Student Award Fund hosts a student design competition in collaboration with the Technical Committee on Architectural Acoustics (TCAA) and Acoustical Society of America (ASA). The competition brief is as follows.

A college specialized in music and song wants to build a new 1200-seat opera. The building is to serve as a teaching facility for their opera program, host performances and occasionally speeches by the school's president.

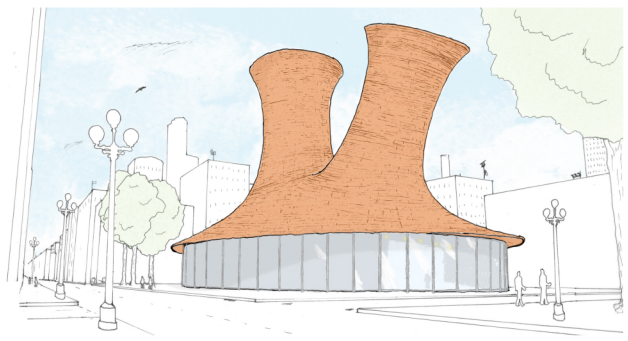
The opera is to be constructed in a downtown city block measuring 90x110 m. Since the background noise level is considerable special care has to be taken in order for it to not disturb the opera's activities.

Collaborators

This work was not done alone as I had a great team consisting of my classmate Henry Wu and Albin Esping from the Sound and vibration master.

Guidance was provided by Morten Lund and Peter Kristensson.

Proposal



SEATTLE OPERA FACTORY

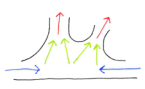
An opera house built from brick, billowing forms, and towers. An opera house where the audience sits in a cylindrical tower of 12 balconies, and where natural light shines in through a glassed skylight. An opera house where the acoustical properties of speaking tubes and trumpets – high clarity and minimal loss of sound – are replicated.

It is a cold rainy day in Seattle and the university board has just announced their plans for an opera house at the university: an unconventional building where the height and size requirements of opera are fully embraced using two towers: one for the stage house, one for the opera hall itself. The towers are enclosed by a brick shell, prestressed with steel cables to enable a hanging form and a stable structure at the same time. Towers evoke the effect of chimneys both visually and physically: their height drives natural ventilation similarly to that caused by a chimney.

Two billowing, almost steaming brick towers, evoking the effect of the factories of old. The **Seattle Opera Factory**, producing musical talents and strong impressions.

Housing an opera hall in a long vertical tower offers acoustical benefits as well, as the form enables a relatively small volume, giving a short reverberation time despite the high seating capacity. The use of bricks enables a variable design, where individual bricks in the wall can be extended or retracted to scatter, reflect, or absorb sound where needed.

Load-bering concept



Chimney concept

Ground floor

4th floor

12th floor

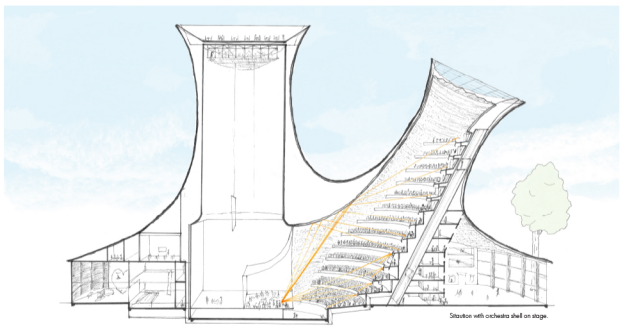
NC 15-20
NC 25-30
NC 35-40

01. Outer lobby
02. Inner lobby
03. Auditorium
04. Stage
05. Rehearsal room
06. Scene shop
07. Loading dock
08. Green room
09. Dressing rooms
10. Offices
11. MEPFIT rooms
12. Educational facilities

Stage control room and Follow spot booth on 2nd and 3rd floors (not visible).

Audio mix position on 4th floor, central on balcony.

Separate foundations for opera hall and rehearsal room



Acoustical qualities

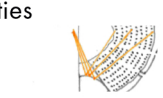
Form and acoustics

The form of the opera hall is based around a tilted, doubly curved cylindrical tower. The tilt helps carry sound upwards more directly compared to a vertical tower, where the sound would have been reflected back to the stage. The doubly curved shape lessens the effect of focus points, otherwise common in forms with convex cross sections. Strong late reflections from focus points are further minimised through the use of scattering walls – the moveable bricks along the walls of the hall can be adjusted to create an uneven surface, scattering the sound waves.

The convex shapes of the ceiling along the pipe distributes early reflections throughout the hall, decreasing the **initial time-delay gap** which is calculated to be less than 35 ms for all positions. This is at lower levels supported by the curved proscenium and balcony railings providing most of the early reflections.

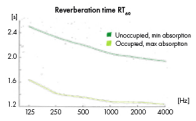
Orchestra pit

A depth of 10 ft (3 m) for the orchestra pit helps lower the sound strength of the orchestra in comparison to singers on stage. The walls of the orchestra pit have an optional curtain that can be rolled down to enhance absorption.



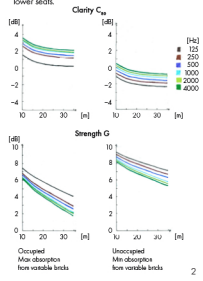
Acoustical parameters

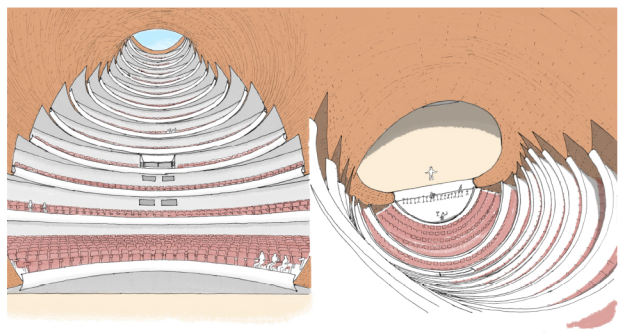
The variable brick walls cover 40% of the auditorium walls. Through them, key acoustical parameters can be varied to adapt for opera, orchestra, and speech.
The **reverberation time** can be changed from 2.2 s to 1.3 s in the mid frequencies. Slightly longer reverberation times in the lower frequencies for a warmer and rounder sound, contrasting the heavy and hard materials used in the hall.
The **strength** is adjusted to fit an appropriate and similar level found in opera halls like Boston and Amsterdam with maximum absorption.
The **clarity** is within 0 to −4 dB range while unoccupied, matching other halls with successful acoustics.



Placement of speakers

The main sound source for the amplified acoustics is at the top of the proscenium, which will distribute the sound for the main floor and first balconies. Speakers will also be placed in the ceiling of each balcony to support a correct timing of the first wavefront for the balconies higher up. Speakers along the First balcony compliment the main speakers and give a surround feel for the lower seats.

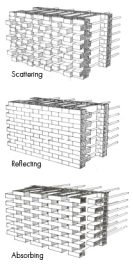




Sound and noise control

Variable bricks

The walls of the auditorium are made of smooth bricks with a low absorption coefficient. Individual bricks can be moved by a mechanical system in order to produce different wall patterns for scattering, reflection, or absorption. The absorption mode for the variable brick walls are achieved when the brick is fully retracting revealing the absorbing foam with a high absorption coefficient.



Acoustics and glass

The sound insulation of the glass roof in the opera hall is solved by two double glazed windows with high sound reduction, one exterior facing and one interior facing separated by an air gap. The walls in the gap are covered with absorbents to prevent the air from resonating as much as possible. The interior window consists of panels in different angles that scatter sound from the stage, preventing concentrated late reflections caused by the large glass area.

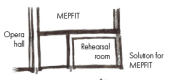
Double glazed glass windows are also used in the facade to accomplish a pleasant background noise level. The rehearsal hall with its stricter noise requirements will have a solid exterior wall.

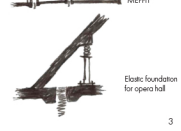
Rehearsal room

To achieve a similar sensation for musicians in the auditorium and rehearsal room the strength is matched as close as possible for both spaces. This requires a short reverberation time of 0.6–0.7 s and is achieved by covering the ceiling and 40% of the brick walls with absorbing panels. If the musicians are in need of a longer reverberation time it can be solved by a digital reverberation where the room is recorded live and the additional reverb is played through speakers. By this the reverberation characteristics of the hall can be simulated in the rehearsal room.

Transmission of sound and noise

The dominant building materials are brick and concrete, which are heavy materials with good insulation for airborne sound. Together with thick walls, the transmission losses through the walls are sufficient to provide low noise levels in the hall. In order to prevent structural transmission, both the opera hall and rehearsal room are built as "room in room" constructions with foundations insulated from each other by dampening polymers. This separates them from noise sources such as the mechanical equipment rooms (MEPFIT) or the scene shop.





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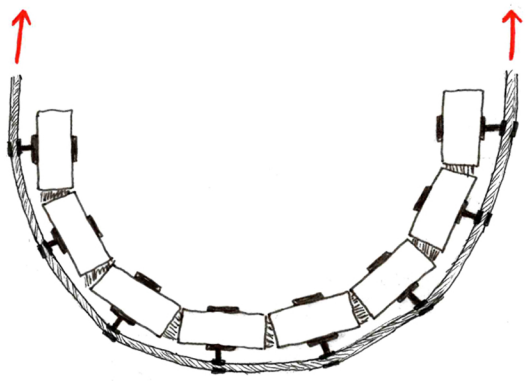
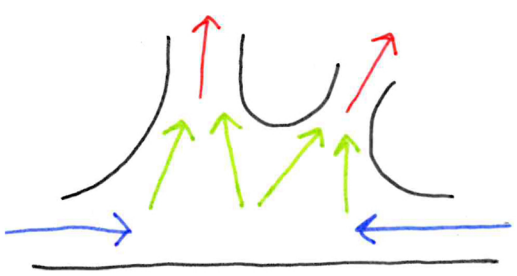


Load bearing concept



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Design process

My first thoughts when starting on this project was that I wanted to capture the monumental with materials that play with light and shape. Inspiration was taken by the works of Peter Zumthor and Pier Luigi Nervi.

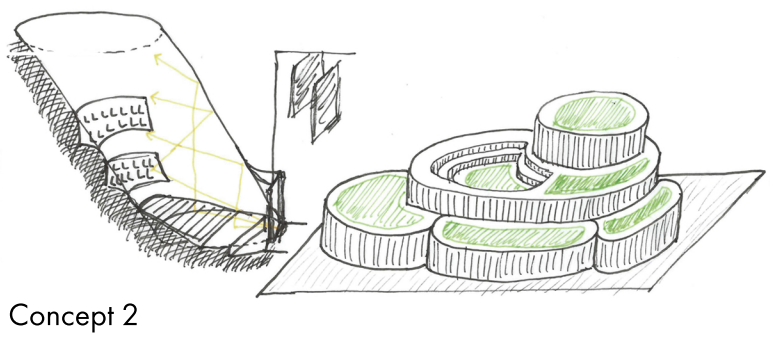
This inspiration produced three concepts. 1 - A hill inspired by the most ordinary of monuments, a hill, with a buried opera to protect it from sound. 2 - A circular opera hall inside a building shaped as a cylindrical collage. 3 - A factory, whale or something completely else that exaggerates the height of the stage house into a tower.

The second and third concept were then merged to create the groundwork for the final concept. An opera hall based on how sound travels through a pipe, carrying itself far with high clarity and the "tower like" exterior of an exaggerated stage house.

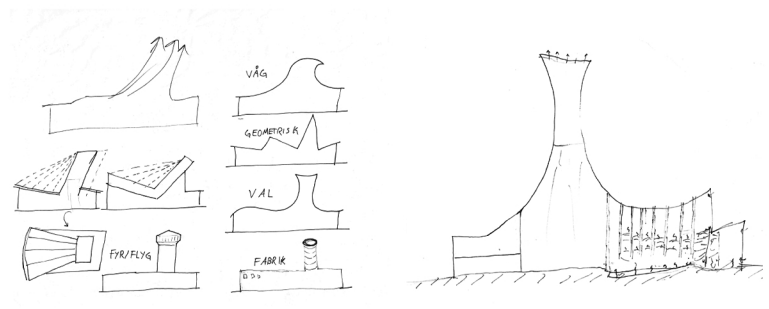
After this stage we explored the acoustical details and how they could be used as architecture. Looking into bricklaying patterns, I got the idea for a variable brick wall. The at this stage the cross section of the opera hall was also constant, meaning a movable roof to increase or decrease the volume of the room was an option that we explored, however later abandoned since it was not needed.

After the acoustical prototypes were complete we decided to go all in and make a hand drawn competition proposal. This heavily influenced the design process afterwards as no details had to be produced in CAD and full attention could be directed towards finding attractive shapes. I really enjoyed working by hand and this also translated to proposal that was easy to understand.

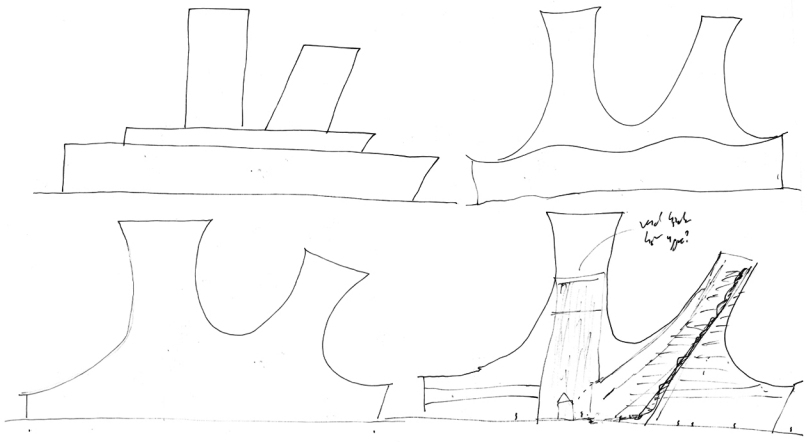
First moodboard



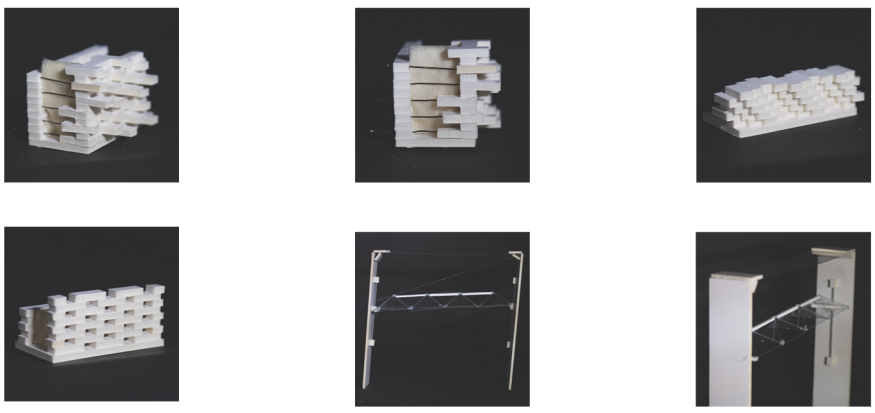
Concept 2



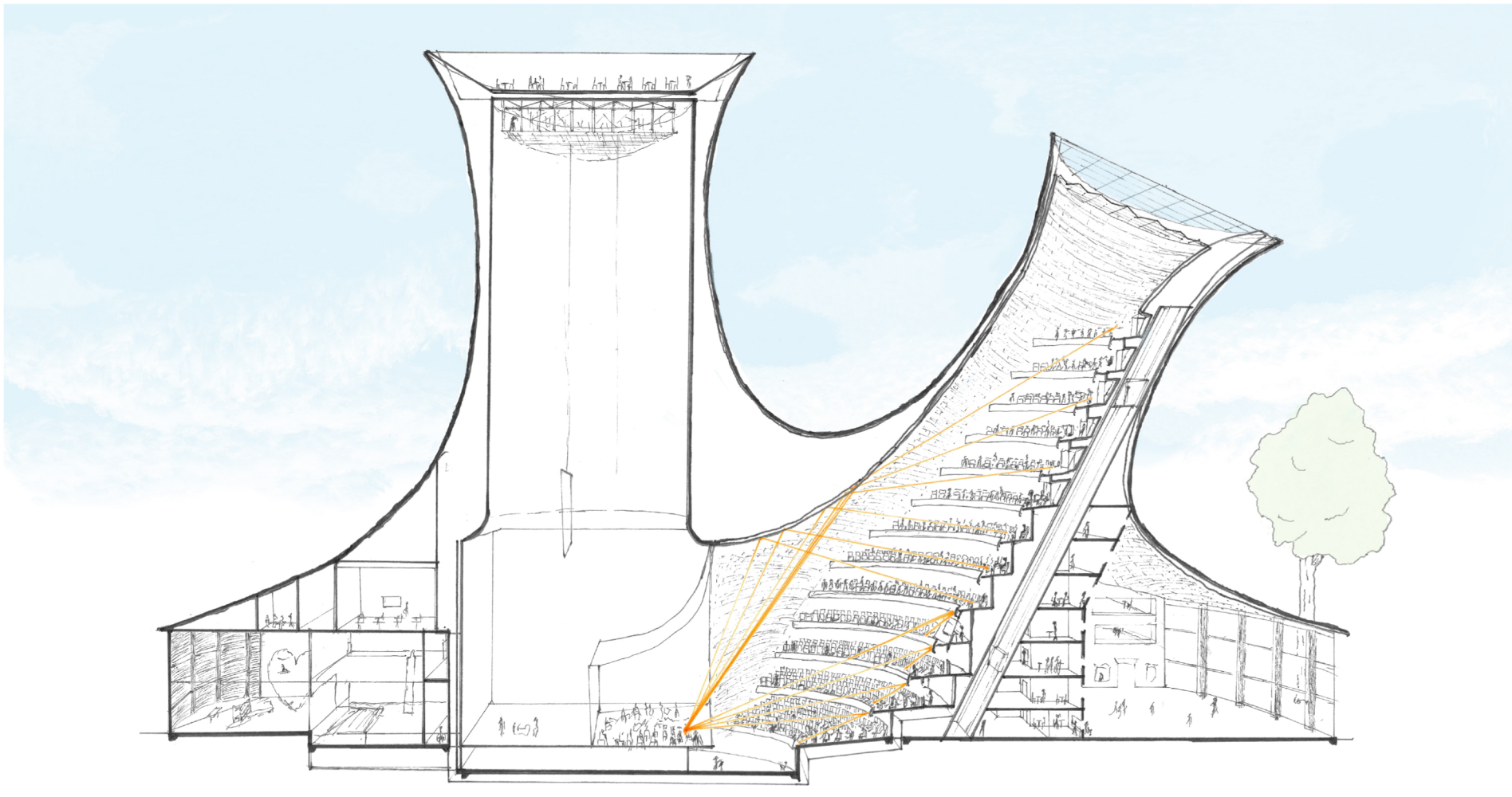
Concept 3



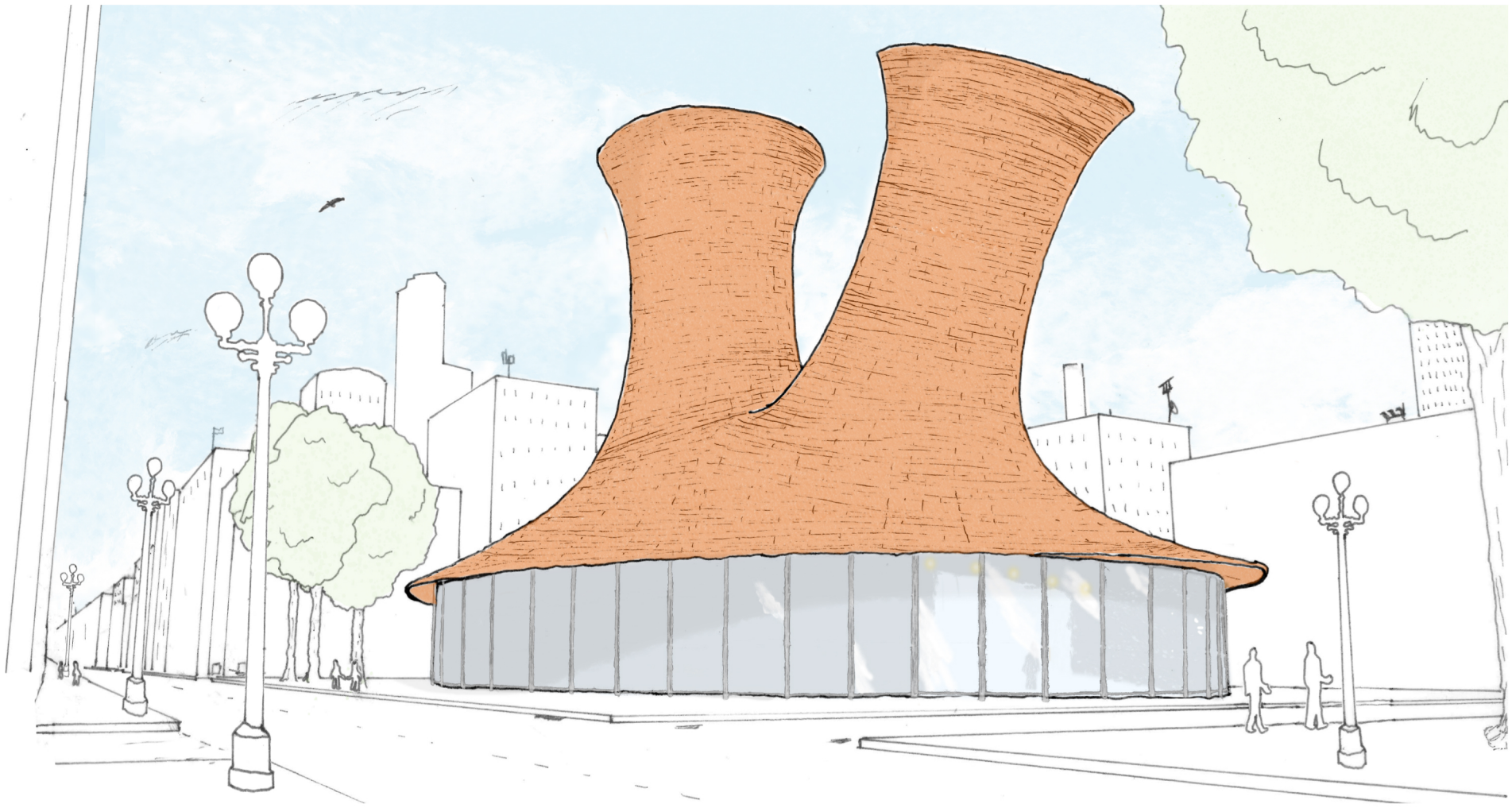
Combination of concept 2 and 3

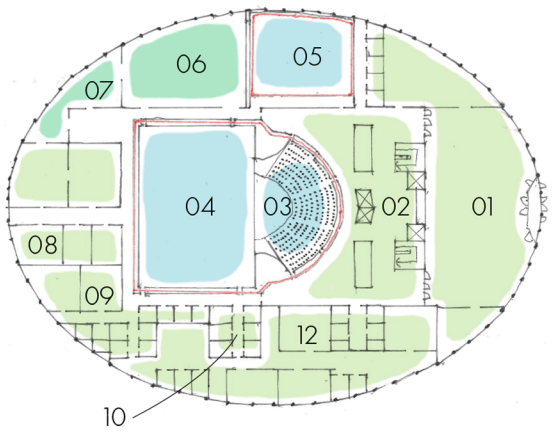


Physical models

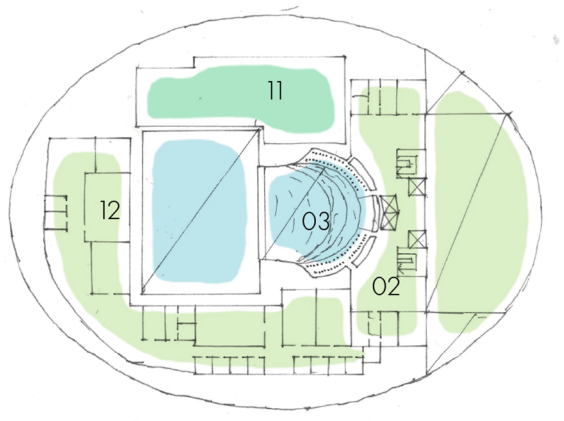


Illustrations

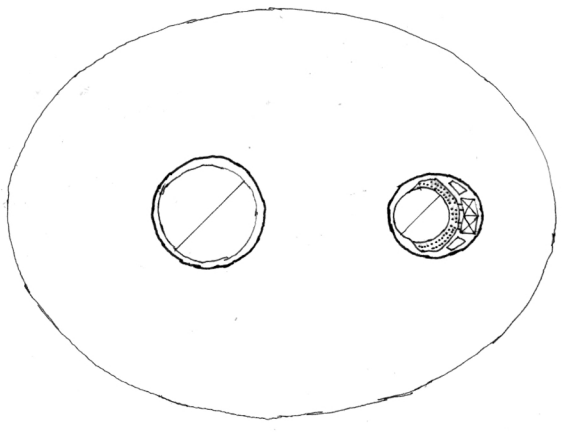




Ground floor



4th floor



13th floor

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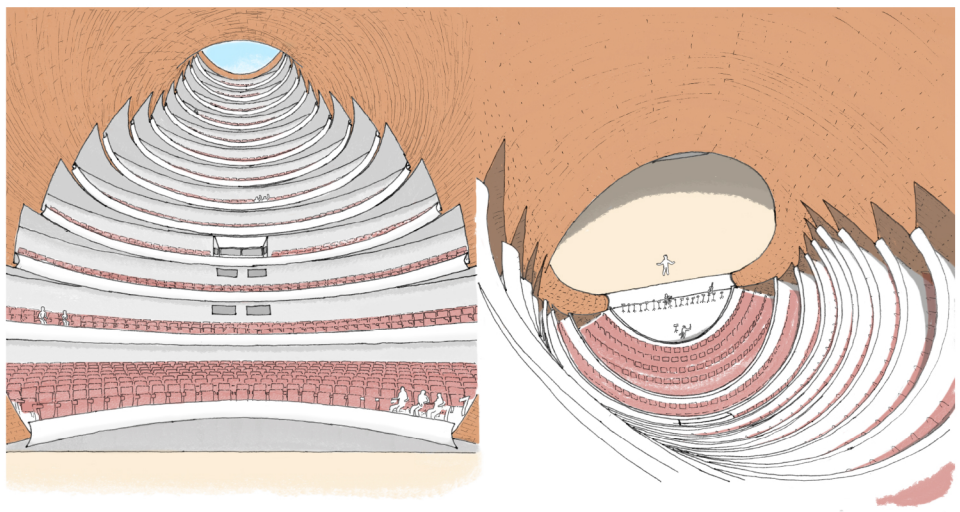

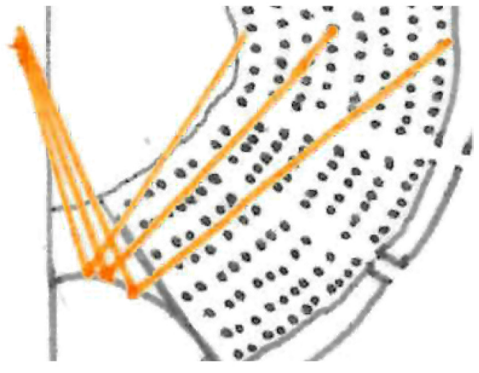

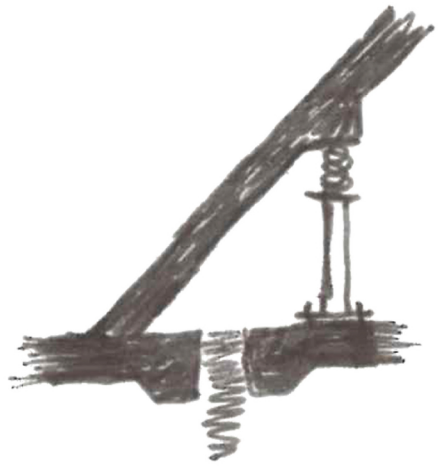

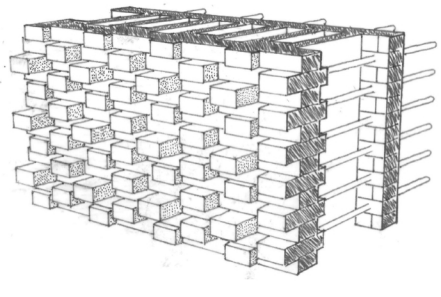

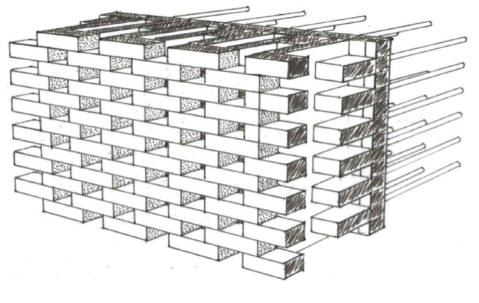

Reflections

Method and design tools

My process was mostly analog, before precision was needed I only did rough sketches by hand and later on when it was needed CAD models were used purely as a framework for detailing by hand.

Not to underestimate the role of computer modelling and parametric design, which created the final form of the opera house as seen in the posters of the design proposal.

Physical models were also built to explore bricklaying patterns in a fast and intuitive way. The brick shaped pieces were easily produced by cutting a grid into a sheet of foam material and assembly became quick and intuitive.

Reflection of proposal quality

Overall I am very satisfied with the final proposal. It is playful in a way that makes me want to visit and experience it should it ever be built. It embodies a simple acoustical concept that we intuitively know and a shape that invites curiosity both from the outside and inside!

The result was far from what I could have imagined from the start and at the same time really close. The initial shapes and concepts are all there together with a strong sense of monumentalism as was my very first wish for the project.

The proposal still lacks details and polishing in the blueprints and plans for how the daily activities of a school could be carried out. The structure of the house is also not entirely solved, I am however convinced that everything is solvable with sturdy walls and pillars supporting the roof as needed!

Lessons learnt and future

In future projects I will try to keep being faithful to the core concept and created spaces that instil emotions. Being faithfull to the core concept really brought out the best in this project together.

The hand drawn approach was a great success and really appealed to everyone who saw it., leaving it open for interpretation instead of a render that gives the impression of everything being exact and decided.