TASK
This project was made as a part of a student competition held by the American Acoustic Association. The task was to make a proposal for an Opera house for a college in Montreal, Canada. The auditorium should be a multipurpose hall made for 1200 persons.

How can the isolation strategy be integrated in the concept of an opera house?

The concept for the opera house is a stone that breaks apart to four separated volumes were one carries a hidden treasure, the opera hall. The concept was chosen to start out with a hard sound isolating shell and to give each volume a different sound isolation and sort the different functions in the volumes according to their noise criterias

The Treasure

The Treasure is the story about a black stone that breaks apart and reveals a hidden inner secret. It is the story of how a college got an Opera House on a noisy lot in downtown Montreal.

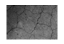
View from inside the lobby

Outside

The story begins on a empty lot in downtown Montreal. A central site in the south parts of Montreal characterised by a noisy environment. To protect the opera from the noisy surroundings the Opera House starts out as a black box, the stone, with thick isolating concrete walls.

The site is characterized by a noisy environment

The opera starts out as a closed volume isolated by thick concrete



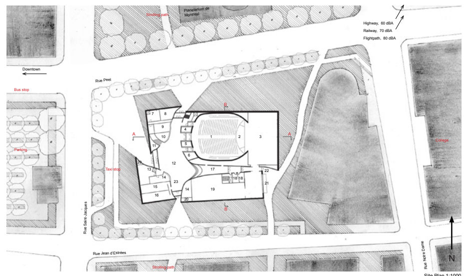
Concrete

The outside of the opera building is made of black concrete. Concrete is a high density material which makes it suitable for isolating the opera from low to high frequency noise.

Noise sources

Around the site for the Opera house there are mainly three big sound sources. The maximum sound pressure levels from the noise sources has been estimated to 80 dBA from the flight-path above, 70 dBA from the railroad and 60 dBA from the interstate highway.

Main floor 1:1000
1. Auditorium 795 m²
2. Orchestra pit
3. Stage 563 m²
4. In house mix 30 m²
5. Lightning Tech. 30 m²
6. Lobby storage 35 m²
7. Kitchen 93 m²
8. Lobby storage 59 m²
9. Bar 43 m²
10. Box office 82 m²
11. Manager office 20 m²
12. Lobby 485 m²
13. Music storage 85 m²
14. Wardrobe 51 + 48 m²
15. WC Gents 80 m²
16. WC Ladies 81 m²
17. Orchestra dressing room 112 m²
18. Solo dressing room 19 m²
19. Scene shop 563 m²
20. Ventilation channel
21. Loading dock
22. Staff entrance
23. Portable stage



Site Plan 1:1000

In between

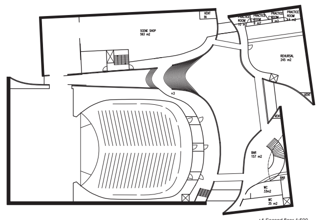
The second chapter of the story is about how the stone breaks apart welcoming the city into its warm glowing inside. It is also about how the stone transform into a functional building with separate functions acoustically isolated from each other.

The hard black stone heavily isolated

The stone breaks apart to form a building and welcome people inside

Pine

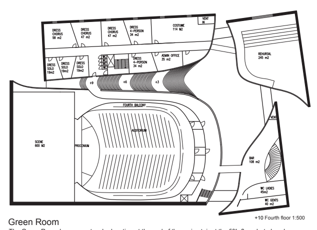
The warm inside of the building is made of wooden lattice of Canadian pine, rising from floor to the ceiling to give a strong vertical feeling to the room. The distances between the wooden slits are varied to form natural openings for visual contact between the lobby and its surrounding rooms.



+4 Second floor 1:500

Lobby

The lobby is the centre of public movement located in the volume that is created when the broken stone pieces are pulled apart. The main vertical communications are distributed by a spectacular stair located between two of the building volumes supported by four elevators, one in each volume. The main stair is also an acoustic isolator that prevent the noise from the path between the stage and the scene shop to leak out in the lobby.



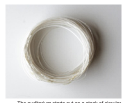
+10 Fourth floor 1:500

Green Room

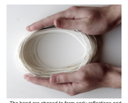
The Green Room has a spectacular location at the end of the main stair at the fifth floor, but also close to the dressing rooms and stage. This intimate room is a space where actors can relax before and after events together with specially invited guests. From the Green Room one will have a good view over the city and at the same time watch people move up and down to the different balconies. The green room has easy access for wheelchairs from the nearby elevator outside the auditorium.

Inside

The end of the story is about the secret of the stone, the sparkling hidden treasure. It is how a pile of circular bands is shaped to form a intimate performance hall with early reflections and a highly diffuse sound field for everyone.



The auditorium starts out as a stack of circular bands



The band are shaped to form early reflections and narrow plan

Copper

The thin copper bands that define the auditorium are attached to an asphalt board to prevent them from unwanted vibrations. The copper has a very low absorption coefficient which gives the walls and balcony fronts a desired high reflection.

One-row Balconies

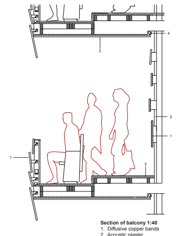
In the Treasure it is all about intimacy and good acoustics as an opera should be, not only for those on the orchestra floor but for all in the audience.

The auditorium therefore has five balconies with only one row of seats per balcony so the audience not have anyone between themselves and the performance giving everyone a personal contact to the actors.

One-row balconies enables everybody to get lots of roof reflections which is important for the acoustic experience. The small balcony-openings increases the amount of reflecting planes giving a high reverberation time and strength.

All this makes the auditorium a very intimate environment. Truly a treasure for all opera lovers.

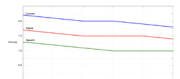
Balcony fronts:
The copper band on the balcony front are tilted downwards close to the scene to get the desired side wall reflections and upwards further back in the auditorium to avoid reflections at the back head. This design resolves the conflict in opera between intimacy and good acoustics.



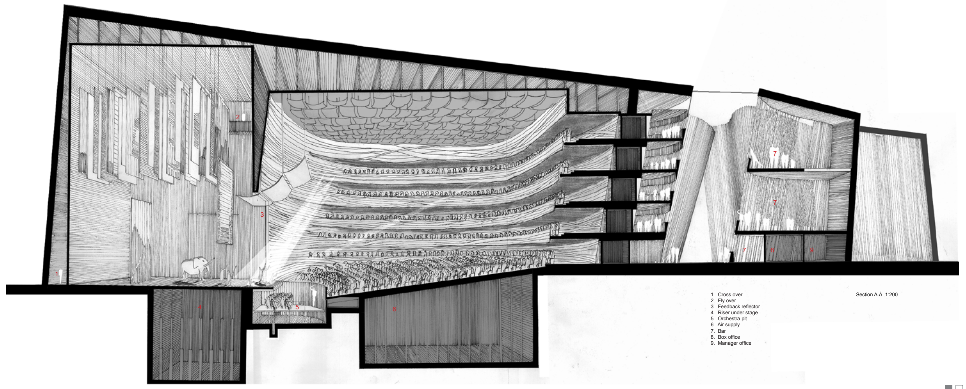
Section of balcony 1:40
1. Diffusive copper bands
2. Acoustic plaster
3. Wooden parquet floor
4. Lamp

The Auditorium

Volume	15 000 m³
Number of seats	1 212 seats
Number of seats on balcony	510 seats
Auditorium area	792 m²
Stage area	563 m²
Average room height	19 m
Average room width	21 m
Distance to the most remote listener	31 m



Reverberation time for Concert, Opera and Speech

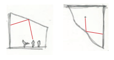


1. Cross over
2. Fly over
3. Feedback reflector
4. Riser under stage
5. Orchestra pit
6. Air supply
7. Bar
8. Box office
9. Manager office

Section A.A. 1:200

Rehearsal Room

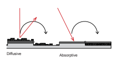
The Rehearsal Room has easy access from the lobby and dressing rooms. The room has no parallel walls and a slightly tilted ceiling to avoid flutter echo. Wood panels of different depth with porous absorption behind small gaps are used as ceiling for good absorption and scattering. Portable stairs works both for chorus practice and as seating for lectures and small performances. Inside the lowest steps, Helmholtz resonators can be opened or closed depending on required absorption for the lower frequencies.

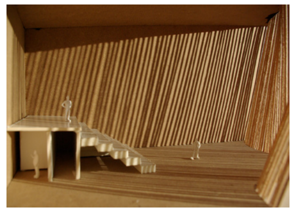


No parallel surfaces to avoid flutter echo

Rehearsal wall

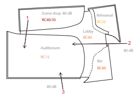
The multifunctional Rehearsal Room has hinged panels on the walls with one hard diffusive wooden side and one absorptive side to change the reverberation time of the room. The slightly curved front wall of laminated double glazed windows is highly reflective. This helps the reverberation time to be around 1.5 seconds. By pulling out a heavy curtain in front of the glass wall the reverberation time will be reduced to around 0.9 seconds.





Isolation strategy

Instead of each room have a different noise criteria each volume has one. The volumes are acoustically isolated from each other and are standing on separated ground floors to reduce structure borne sound.



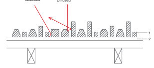
1. From scene shop to auditorium
To isolate the auditorium from the noisy scene shop two single concrete walls with a STC 45 is used. The critical sound isolation is therefore the sound traveling through the doors. The scene shop is therefore divided into two parts to get an extra protecting door from the noisy parts, each door reduces 25 dB and also the stage tower helps isolating.

2. From outside via lobby to auditorium
Outdoor noise has a maximum sound level of 80 dBA which is mainly produced by airplanes. A glass envelopment with STC 45 protects the lobby from the surrounding noise. The lobby has an maximum sound level of 60 dBA. One single concrete wall with air locks prevents the noise to reach the auditorium which has a background noise of RC 15.

3. From outside to auditorium
To get the desired background noise level in the auditorium the outside noise is reduced by a double concrete wall with STC 65.

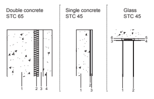
Lobby wall - diffuser

The lobby is dominated by mid frequency sound made from people talking. To diffuse the sound field the walls in the lobby are covered with a wooden panel of various cross sections. The panel is supported by an absorbing fibreboard to lower the reverberation time.



1. Pine of various cross sections
2. Absorbing panel

Sound isolating envelopments



Double concrete 1:20
1. Concrete 250 mm
2. Low density fibreglass 50 mm
3. Air 50 mm
4. Concrete 100 mm

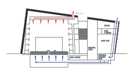
Single concrete 1:20
1. Concrete 150
2. Gypsum 9 mm
3. Fibreboard 9 mm

Glass 1:20
1. Laminated glass 10 mm
2. Laminated glass 7 mm
3. Neoprene foam
4. Cloth wrapped fibreglass
5. Wood window frame
6. Mastic sealant

To get the glass roof absorptive, a third layer of 0.2 mm plexiglass, with microperforated holes will be installed at a distance of 600 mm. This will increase the absorption and give a lower reverberation time in the lobby.

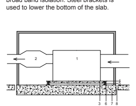
Ventilation

The fresh air is taken in from the roof at level of 20 meter and is let out in a big space under the auditorium. It sips in to the concert hall mainly by vents under the chairs at a speed of 1,5 m/s so that no disturbing noise is created. At the outlet there is a muffler preventing sound to get in to the auditorium.



Air handler

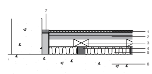
The air handlers stands on a separated concrete slab, supported by springs in combination with neoprene pads for a broad band isolation. Steel brackets is used to lower the bottom of the slab.



Air handler1:100
1. Air handler
2. Silencer
3. Concrete base
4. Steel bracket
5. Vibrate damping springs
6. Neoprene pads
7. Floating floor
8. Rubber isolation

Floating floor

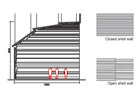
At stage and in rehearsal room a wooden floor surface is required. To give the floor the required sound isolation it is supported by a springily fibreglass structure of various density. The floor has an approximate sound isolation at 64 dB for IIC and 62 dB for STC. The floor is suitable for dance performances.



Floating floor 1:20
1. Oak
2. Two layers of plywood with staggered joints glued nailed to wood sleepers, 22mm +22mm
3. Wood sleeper 50 mm x 100 mm
4. High-density fibreglass blocks, side 50 mm, cc 300
5. Low density fibreglass blanket 50 mm
6. Structural concrete floor 300mm
7. Caulk

Shell

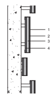
The shell wall with a weight of 20 kg/m² is built as two separate pieces, which can be adjusted to give variable acoustics. The curved copper bands are placed irregularly to give a reflective and diffusive surface. The shell roof is hanged from the stage tower to be easily removed.



Section of orchestra shell

Copper wall

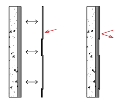
The walls in the auditorium are covered with copper band of various width to give the auditorium a high reflective and diffusive surface. The bands are made of a thin layer of copper foil attached on an asphalt board to add mass to the foil and the felt layer transforms the energy into heat.



1. Copper foil 0.8 mm
2. Asphalt 10 mm
3. Felt 25 mm
4. MDF - board 18 mm

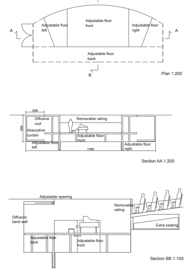
Low frequency absorber

To reduce the reverberation time for speech, variable absorbers are installed in the walls close to the stage. The heavy absorbing wall behind the copper bands is pulled away to let the bands work as a membrane absorber for undesired low frequency sound waves around 125 Hz.

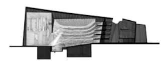


Orchestra pit

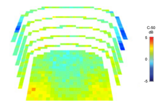
A movable ceiling section in the orchestra pit creates an adjustable opening, which regardless of performance, give a good balance between the orchestra and the singer on the stage. The movable pit floor will adjust the height of the orchestra and since the different floor sections can be adjusted separately the volume of the pit may be adjusted as well. When the pit is not in use, i.e. concert and speech mode, the railing can easily be removed and three extra rows of seats may be used instead. The walls are diffuse and may be changed into more absorptive by pulling out a heavy curtain in front of the walls.



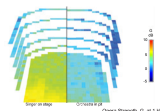
Opera



Ceiling height at 22 m above the audience floor. Convex reflectors are installed below the ceiling with adjustable height. Opera pit has adjustable pit ceiling size and floor level for easy balance adjustments between singer on the stage and orchestra in the pit. The mean balance between singers and the orchestra is 3 dB.
Reverberation time 1.5 seconds.

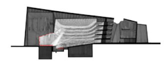


Opera Clarity, C50, at 1 kHz

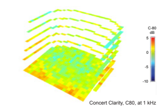


Opera Strength, G, at 1 kHz

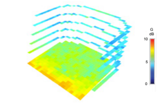
Concert



Ceiling and reflectors height kept as in opera mode. The orchestra is placed on the stage where the stage shell is installed. By removing the pit railing, extra seats can be added in the orchestra pit for audience.
Reverberation time 2.0 seconds.

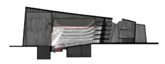


Concert Clarity, C80, at 1 kHz

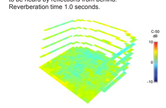


Concert Strength, G, at 1 kHz

Speech



A heavy curtain is pulled out just below the fifth balcony to act as a lower ceiling at a height of 14 meters above the audience floor. The reflector panels closest to the stage are lowered to a position below the new ceiling. The front wall will act as low frequency absorber as in the detail. A metal wall, "fire curtain", will close the stage and support the speaker to be heard by reflections from behind.
Reverberation time 1.0 seconds.



Speech Clarity, C50, at 1 kHz

THE TREASURE

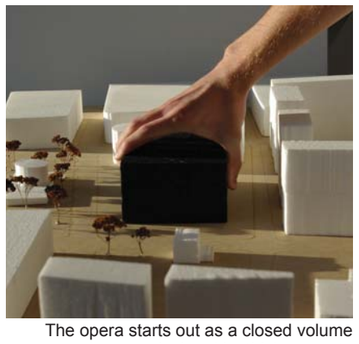
Project	Opera House
Site	Montreal Canada
Course	Bachelor’s degree project
Time	6th semester year 2013
Professors	Morten Lund Mendel Kleiner
Project type	Team of three persons
Tools	Autocad Rhinoceros 4.0 -Grasshopper InDesign CS5 Photoshop CS5 Lacercutter

The Treasure is a story of a black stone that breaks apart and reveals a hidden inner secret. It is the story of how a college got an Opera House on a noisy lot in downtown Montreal.

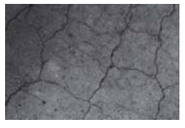
Outside

The story begins on an empty lot in downtown Montreal. A central site in southern Montreal characterized by a noisy environment. To protect the opera from the noisy surroundings the Opera House starts out as a black box, the stone, with thick isolating concrete walls.

The site is characterized by a noisy environment



The opera starts out as a closed volume isolated by thick concrete



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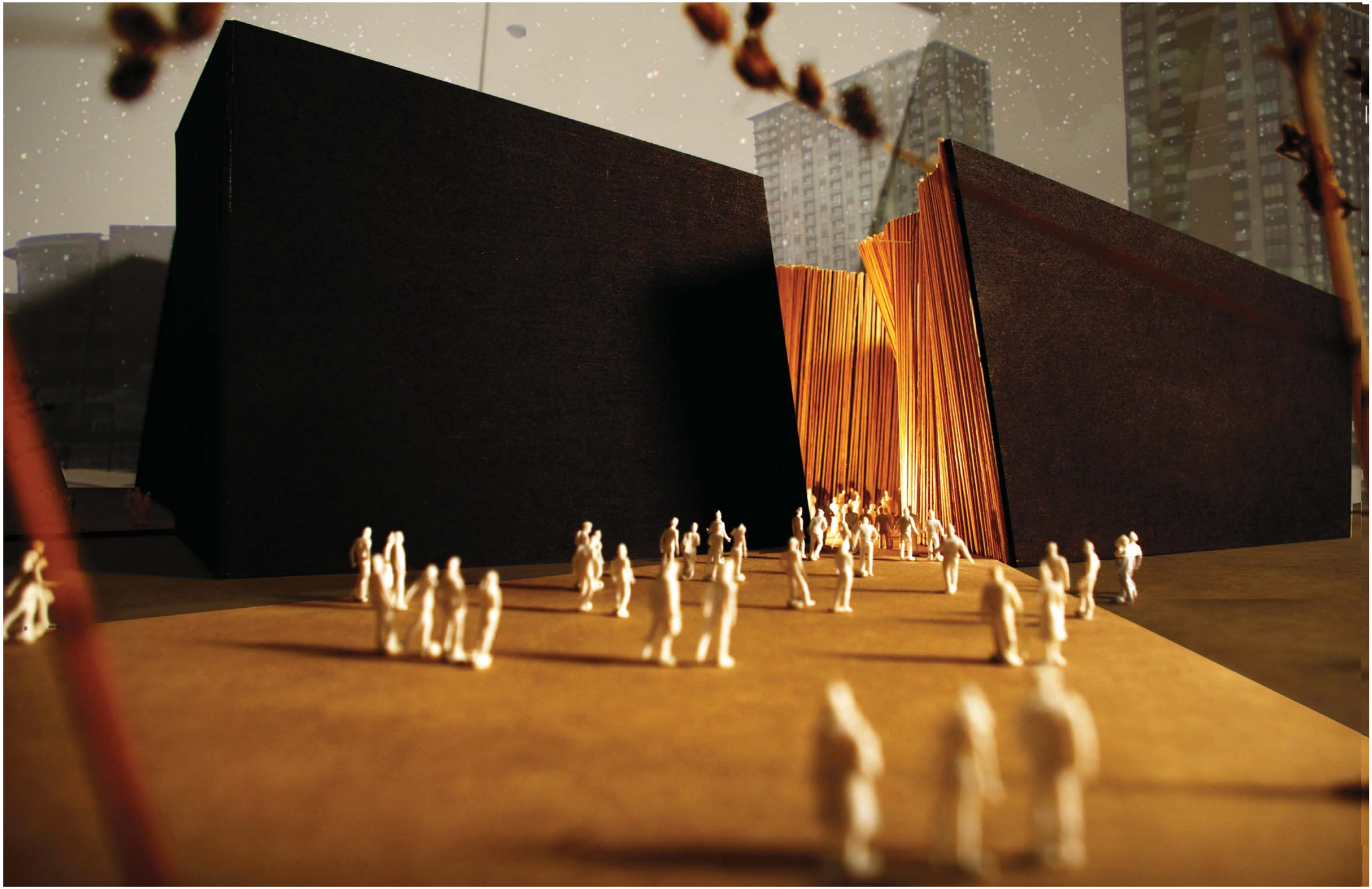

Exterior view from North West, model photo

In between

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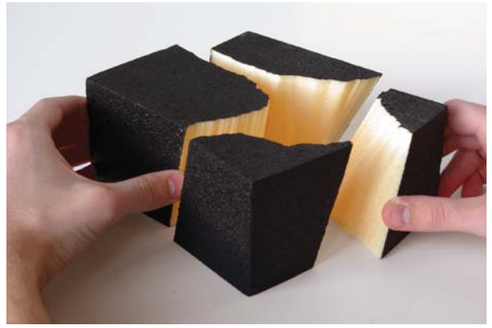
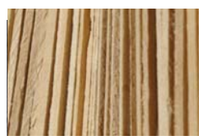
The hard black stone heavily isolated



The stone breaks apart to form a building and welcome people inside



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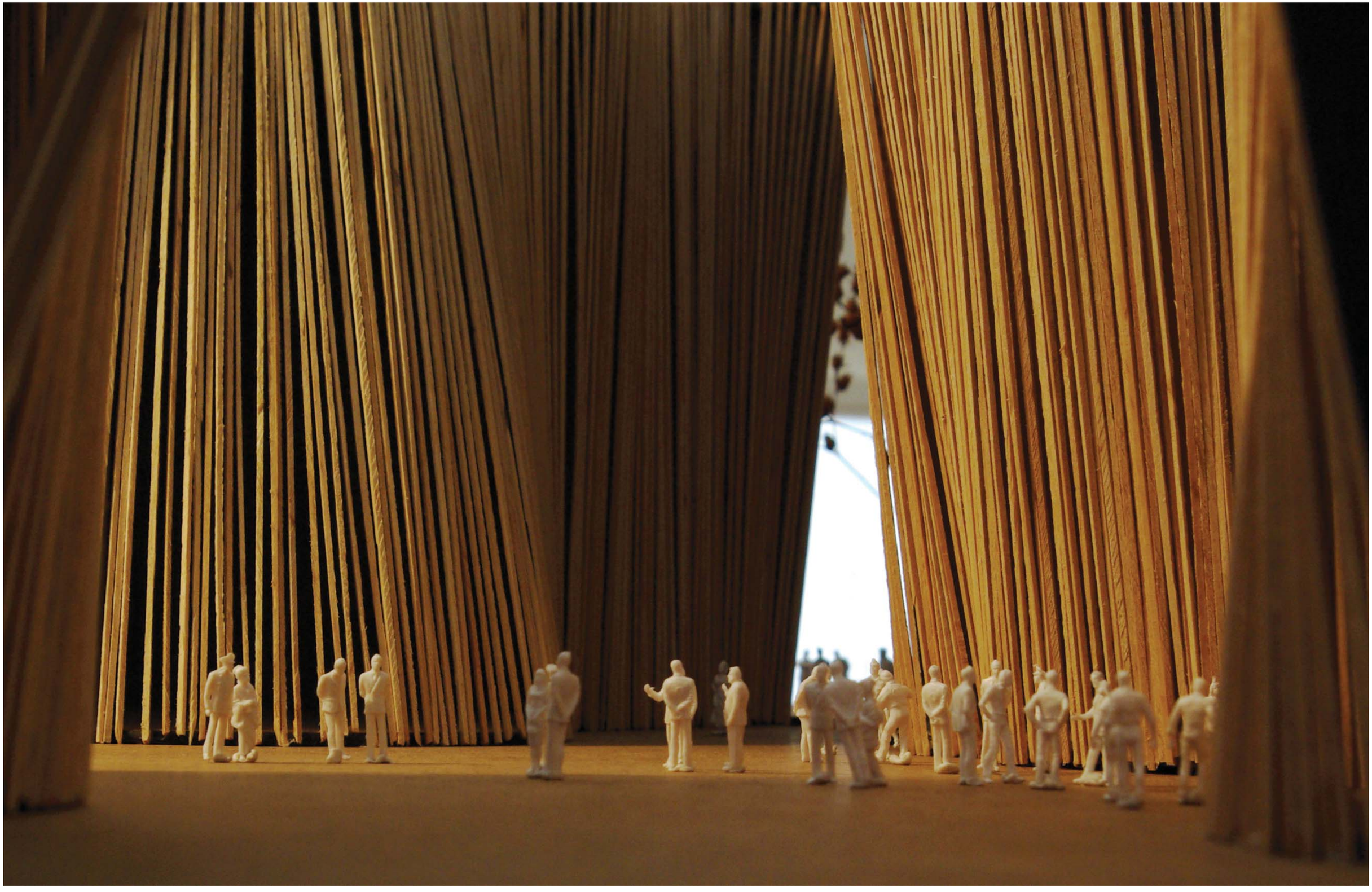

View from inside the lobby, model photo

Inside

The end of the story is about the secret of the stone, the sparkling treasure, hidden in one of the stone pieces. It is how a pile of circular bands is shaped to form an intimate performance hall with early reflections and a highly diffuse sound field.

The auditorium starts out as a stack of circular bands

The band are shaped to form early reflections and a narrow plan

Copper

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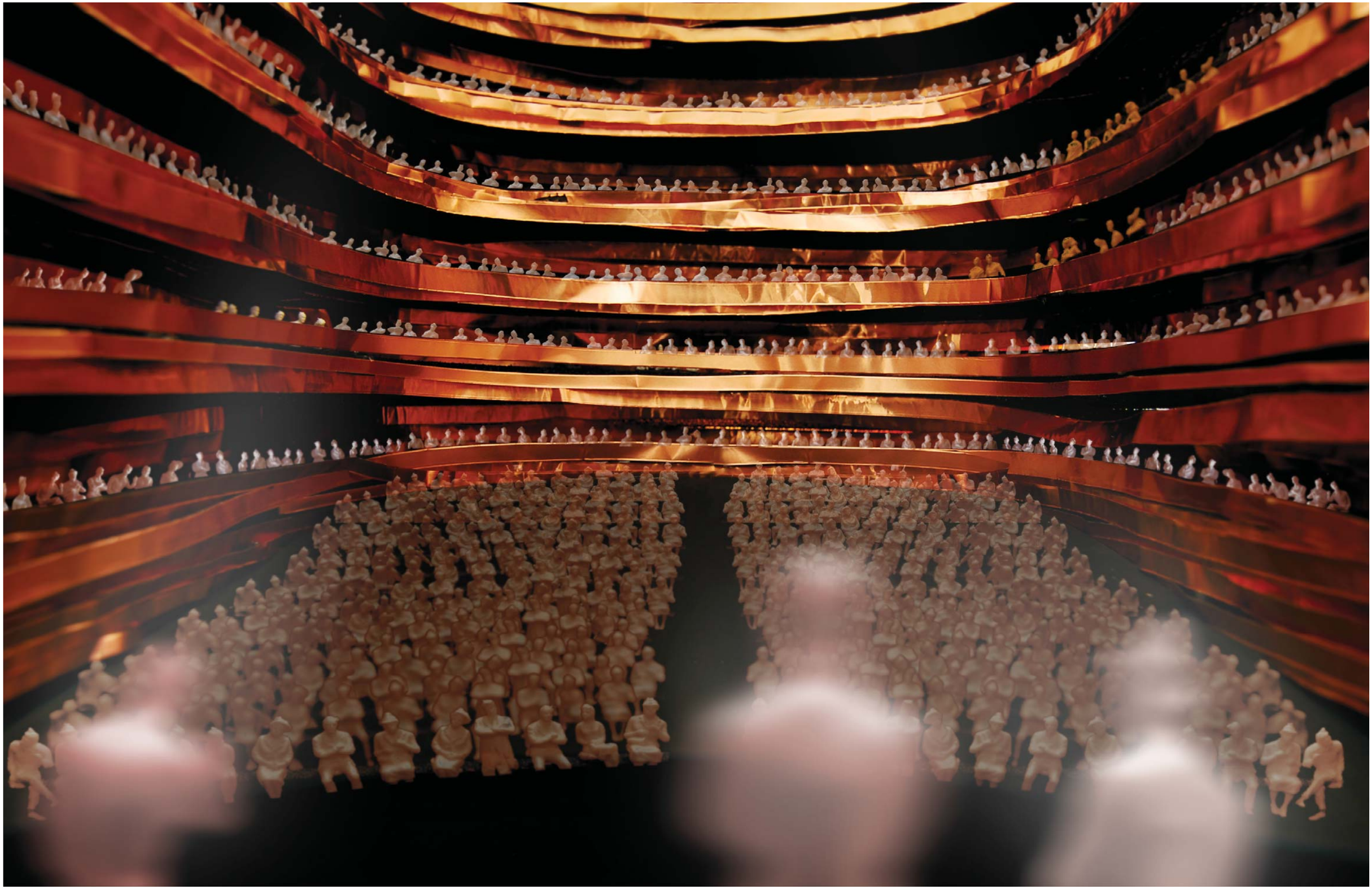
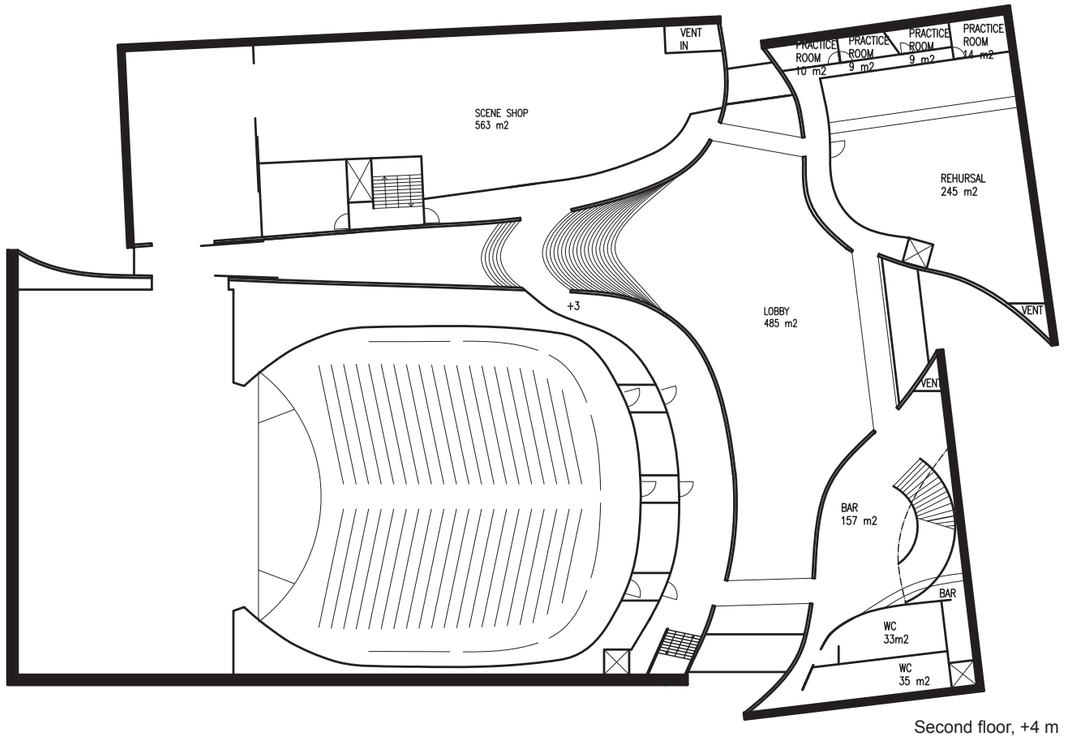
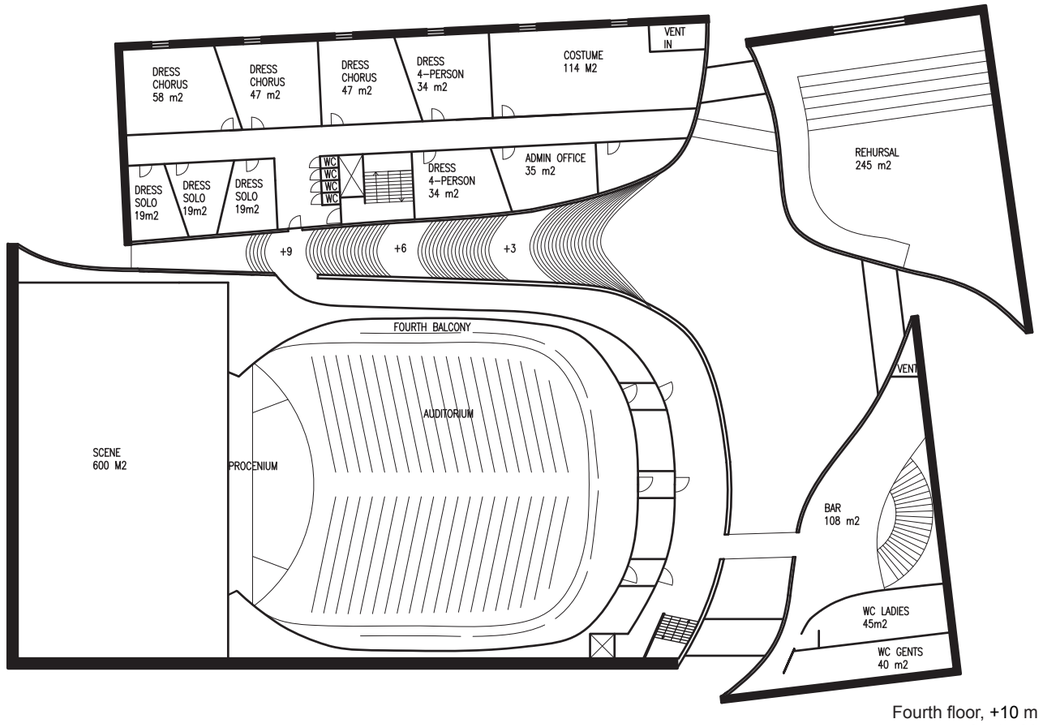


Auditorium from stage, model photo



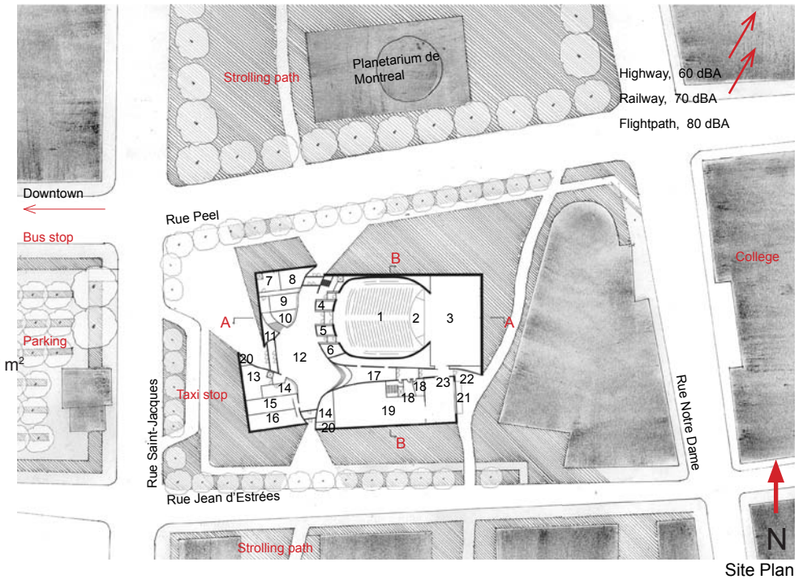
Second floor, +4 m
scale 1:500



Fourth floor, +10 m
scale 1:500

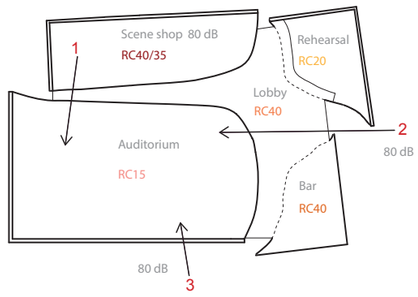
Siteplan

Main floor 1:1000
1. Auditorium 795 m²
2. Orchestra pit
3. Stage 563 m²
4. In house mix 30 m²
5. Lightning Tech. 30 m²
6. Lobby storage 35 m²
7. Kitchen 93 m²
8. Lobby storage 59 m²
9. Bar 43 m²
10. Box office 82 m²
11. Manager office 20 m²
12. Lobby 485 m²
13. Music storage 85 m²
14. Wardrobe 51 + 48 m²
15. WC Gents 80 m²
16. WC Ladies 81 m²
17.Orchestra dressing room 112 m²
18. Solo dressing room 19 m²
19. Scene shop 563 m²
20. Ventilation channel
21. Loading dock
22. Staff entrance
23. Portable stage



Site Plan
scale 1:2000

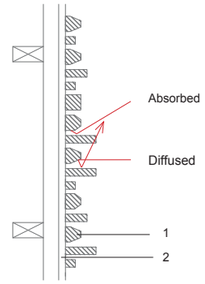
Sound isolation strategy



dubbel concrete envelopment
single concrete envelopment
glass envelopment
wooden lattice wall

Instead of each room having different noise criterion each volume has one. The volumes are acoustically isolated from each other and are standing on separated ground floors to reduce structure borne sound.

Lobby wall - diffuser

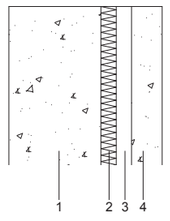


1. Pine of various cross section
2. Absorbing panel

The lobby is dominated by mid frequency sound made from talking people. To diffuse the sound field the walls in the lobby are covered with a wooden panel of various cross sections. The panel is supported by an absorbing fiberboard to lower the reverberation time.

Sound isolating envelopments

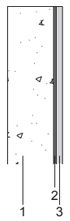
Double concrete
STC 65



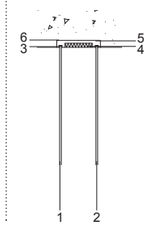
Double concrete 1:20
1. Concrete 250 mm
2. Low density fibreglass 50 mm
3. Air 50 mm
4. Concrete 100 mm

Single concrete 1:20
1. Concrete 150
2. Gypsum 9 mm
3. Fiberboard 9 mm

Single concrete
STC 45

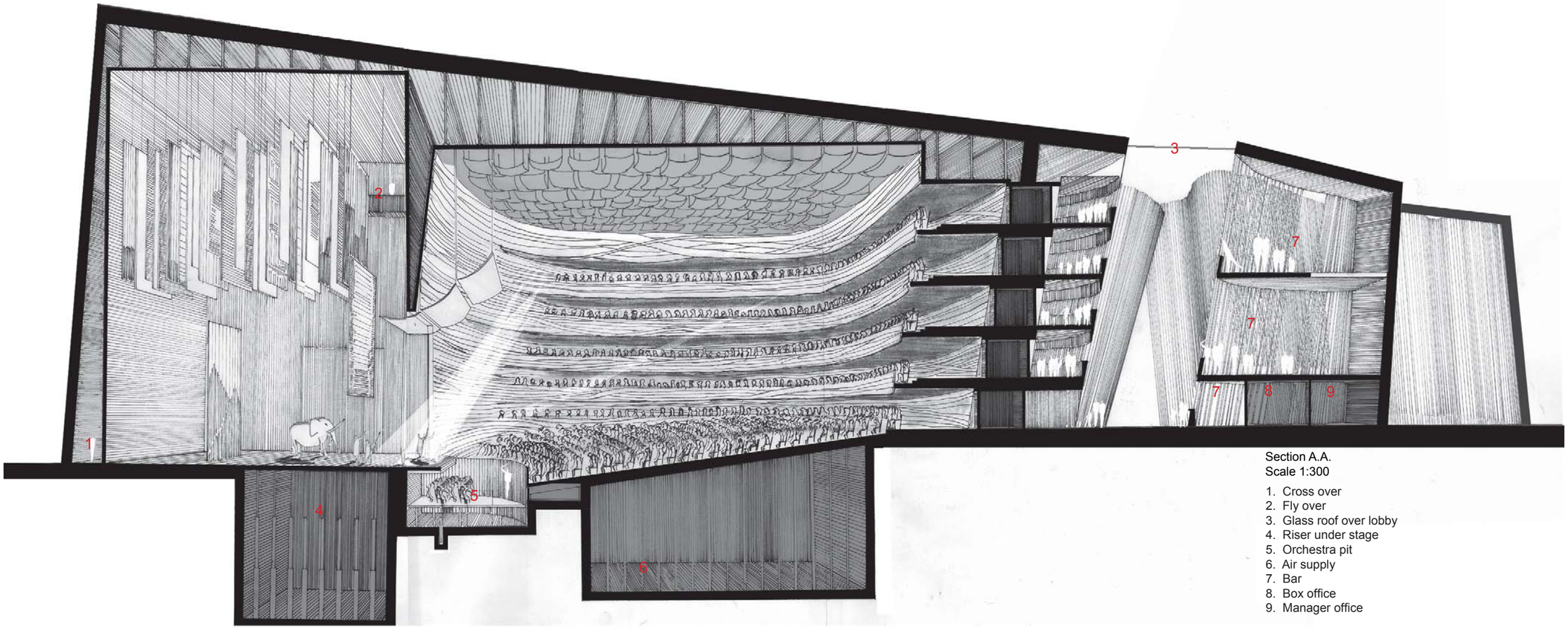


Double glass
STC 45



Double glass 1:20
1. Laminated glass 10 mm
2. Laminated glass 7 mm
3. Neoprene foam
4. Cloth wrapped fiberglass
5. Wood window frame
6. Mastic sealant

To get the glass roof absorptive, a third layer of 0.2 mm plexiglass, with micro perforated holes will be installed at a distance of 600 mm. This will increase the absorption and give a lower reverberation time in the lobby.



Section A.A.
Scale 1:300

1. Cross over
2. Fly over
3. Glass roof over lobby
4. Riser under stage
5. Orchestra pit
6. Air supply
7. Bar
8. Box office
9. Manager office

One-row Balconies

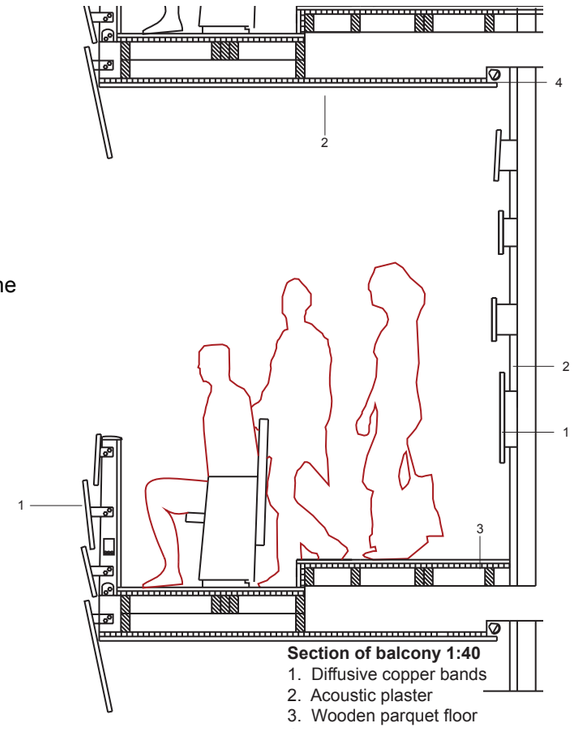
In the Treasure it is all about intimacy and good acoustics as an opera should be, not only for those on the orchestra floor but for all in the audience.

The auditorium therefore has five balconies with only one row of seats per balcony, so the audience at the balconies does not have anyone between themselves and the performance, providing everyone a personal contact to the actors.

One-row balconies enable everyone to experience lots of roof reflections, which are important for the acoustic experience. The small balcony openings increase the amount of reflecting planes, giving a high reverberation time and strength.

All of this makes the auditorium a very intimate environment. Truly a treasure for all opera lovers.

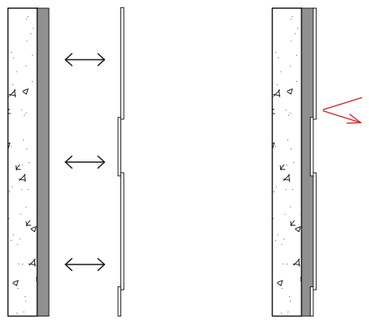
Balcony fronts:
The copper bands on the balcony fronts are tilted downwards close to the stage to obtain the desired side wall reflections and upwards in the rear of the auditorium to avoid reflections at the back head.



Section of balcony 1:40
1. Diffusive copper bands
2. Acoustic plaster
3. Wooden parquet floor
4. Lamp

Low frequency absorber

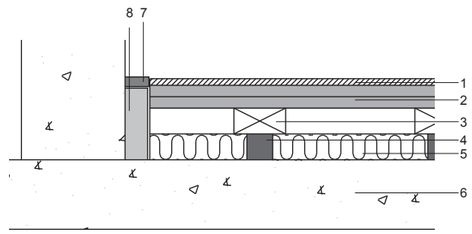
To reduce the reverberation time for speech, variable absorbers are installed in the walls close to the stage. The heavy absorbing wall behind the copper bands is pulled away to let the bands work as a membrane absorber for undesired low frequency sound waves around 125 Hz.



Absorptive Reflective

Floating floor

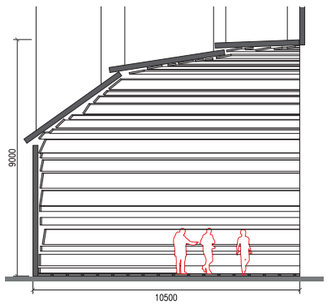
On the stage and in the rehearsal room a wooden floor surface is required. To give the floor the required sound isolation, it is supported by an elastic fiberglass structure of various density. The floor has an approximate sound isolation of 64 dB for IIC and 62 dB for STC. The floor is also suitable for dance performances.



Floating floor 1:20
1. Oak
2. Two layers of plywood with staggered joints glued and nailed to wood sleepers, 22mm +22mm
3. Wood sleeper 50 mm x 100 mm
4. High-density fiberglass blocks, side 50 mm, cc 300
5. Low density fiberglass blanket 50 mm
6.Structural concrete floor 300mm
7. Caulk
8. Perimeter isolation board

Shell

The shell wall with a weight of 20 kg/m^2 is built as two separate pieces, which can be adjusted to give variable acoustics. The curved copper bands are placed irregularly to give a reflective and diffusive surface. The shell roof is hung from the stage tower to be easily removed.



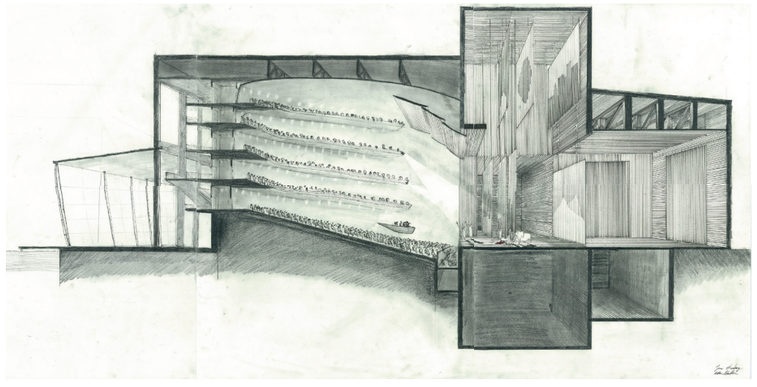
Orchestra shell

STUDIEBESÖK

Kandidatprojektet började med studiebesök med guidade turer i Göteborgsoperan, Konserthuset i Göteborg och i Oslos omtalade operahus. Besöken gav förutom inspiration även en viktig inblick och förståelse för verksamheten samt en känsla för byggnadens storlek och problematik.

Studiebesök i Oslos nya opera

Intriör i Oslos nya opera

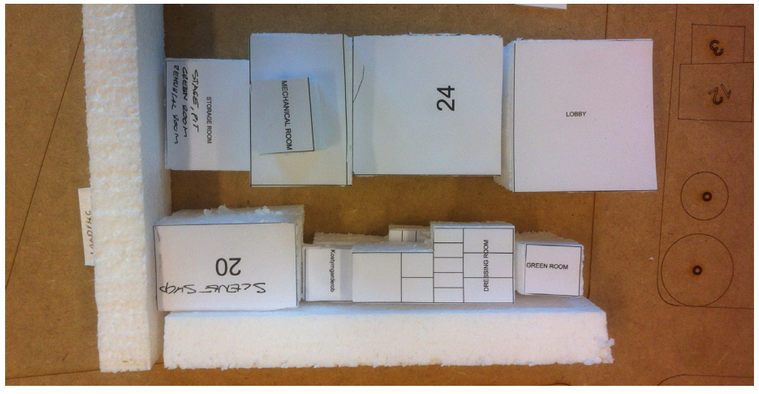


Handritad sektion över Göteborgsoperan

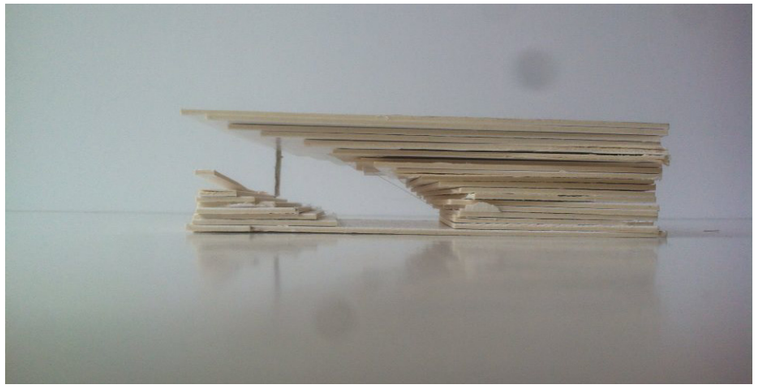
KONCEPTFAS

För att hitta ett koncept gjorde vi ett stort antal modeller i vit kartong. Från modellerna valde vi ut tre modeller som vi studerade vidare. Vi utvecklade de tre modellerna i nya material för att få ett nytt perspektiv på modellerna. Vi fastnade för ett koncept med en delad volym som gav intressanta möjligheter. Konceptet gav en akustiskt fördel genom att kunna skapa olika akustiska klimat i de olika delarna. Samtidigt skapades en intressant rumsligt kontrast mellan ute och inne.

Konceptmodeller i vit kartong



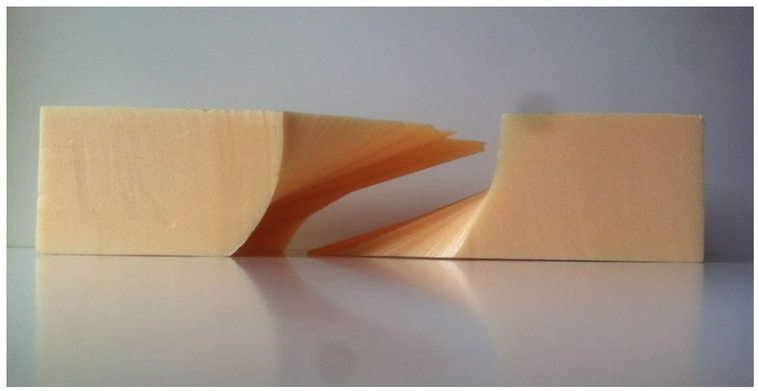
Volymstudie av rumssamband



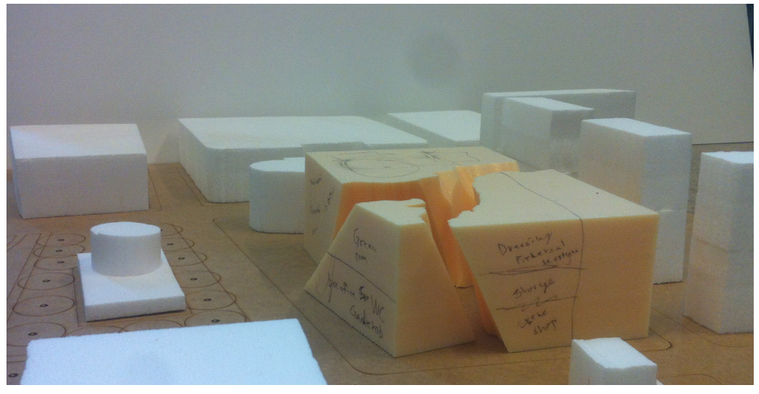
Utveckling av konceptmodell, foam, 1:500

PROCESS

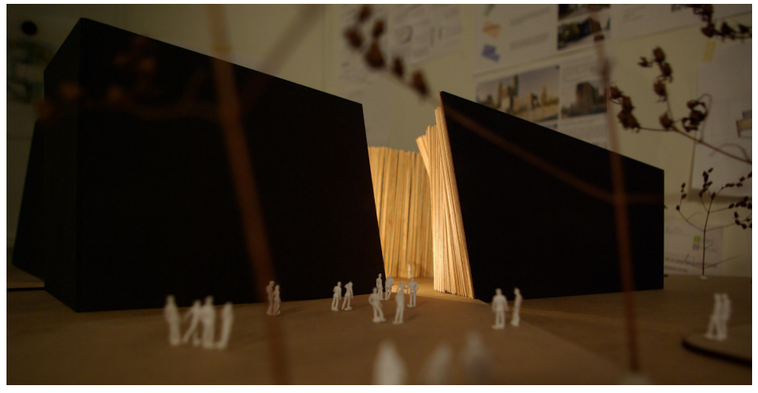
När vi väl bestämt oss för konceptet med en sten som bröts sönder började vi undersöka delarnas storlek och utseende. För att snabbt få upp ett antal alternativ arbetade vi med foam och glödtråd. Vi hade svårt att bestämma oss hur många delar byggnaden skulle vara uppdelad i men efter att ha testat olika varianter fastnade vi tillslut för en byggnad delad i fyra volymer. Genom att erbjuda flera öppningar in till ytan mellan volymerna skulle ett mer dynamisk rum skapa där besökaren blev tvungen att ta ställning till riktning.



Konceptmodell, foam, 1:500



Konceptmodell, foam, 1:500



Presentationsmodell, 1:100

REFLEKTION

Kandidatprojektet var ett mycket roligt och lärorikt projekt. Genom att projektet hade stort fokus på akustik öppnades för mig nya dimensioner inom rumsbildning som jag tidigare inte funderat särskilt mycket på. Trots sin storlek känns projektet väl genomarbetat och jag tror att byggnaden skulle fylla sitt syfte mycket väl. Styrkan i projektet ligger i sitt koncept som väl anpassar sig till platsens förutsättningar. Dessutom känns planlösningen både rationell och intressant.

I projektet valde vi att lägga stort fokus på konsertsal där förslaget delvis har nått hög detaljeringsnivå. Andra delar har på bekostnad av detta fått stå tillbaka. Exempelvis är utformningen av övningsrummet projektets svaghet som skulle behöva ittereras för att kännas självklar.

Avslutningsvis är jag mycket nöjd med beslutet att arbeta till så stor del i modell, ett beslut som också gav oss bra kontroll över tidsplaneringen.