

BACHELOR THESIS
ARCHITECTURE AND ENGINEERING
2024

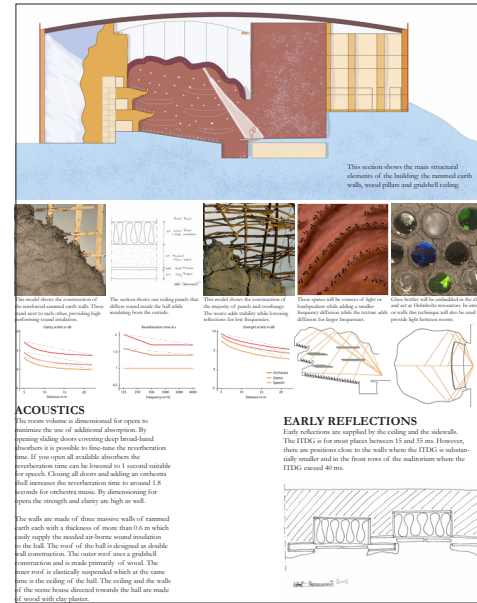
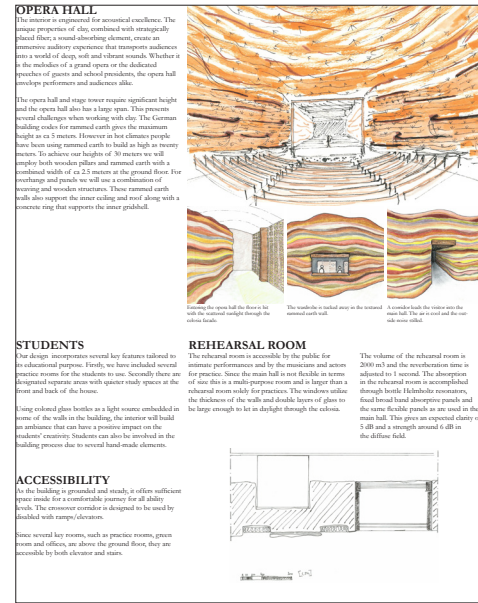
Drawing inspiration from traditions of Mexican craftsmanship, our façade incorporates celocia – a technique of using bricks with perforations – to create a visual connection between the exterior and interior spaces of the opera hall. As sunlight filters through the perforations, casting intricate patterns of light and shadow, guests are welcomed with an joyful play of light. Entering reveals the warmth of the layered rammed earth interior – a material steeped in the hues of Mexico’s landscape. The interior is engineered for acoustical excellence. The unique properties of clay, combined with strategically placed fiber; a sound-absorbing element, create an immersive auditory experience that transports audiences into a world of deep, soft and vibrant sounds. Whether it is the melodies of a grand opera or the dedicated speeches of guests and school presidents, the opera hall envelops performers and audiences alike.

- Isabell Norrby



OPERA OF CLAY - Isabell Norrby

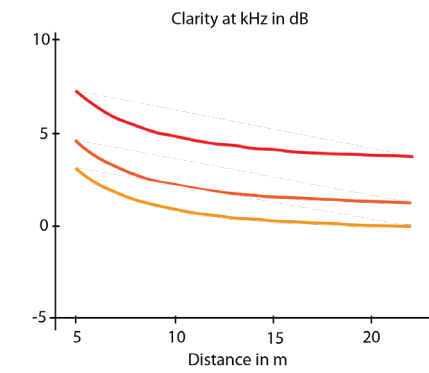
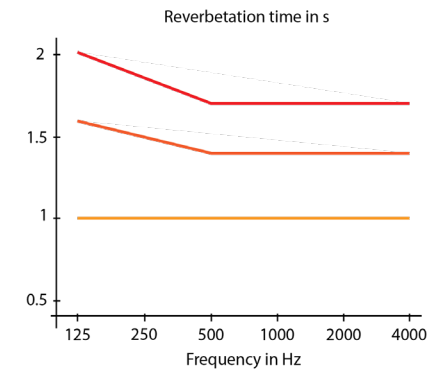
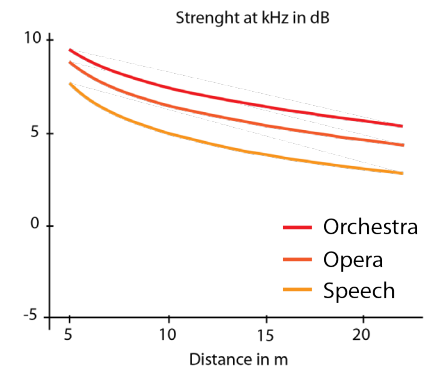
Posters for the acoustical and architectural competition



Acoustics

The room volume is dimensioned for opera to minimize the use of additional absorption. By opening sliding doors covering deep broad-band absorbers it is possible to fine-tune the reverberation time. If you open all available absorbers the reverberation time can be lowered to 1 second suitable for speech. Closing all doors and adding an orchestra shell increases the reverberation time to around 1.8 seconds for orchestra music. By dimensioning for opera the strength and clarity are high as well.

The walls are made of three massive walls of rammed earth each with a thickness of more than 0.6 m which easily supply the needed air-borne sound insulation to the hall. The roof of the hall is designed as double wall construction. The outer roof uses a gridshell construction and is made primarily of wood. The inner roof is elastically suspended which at the same time is the ceiling of the hall. The ceiling and the walls of the scene house directed towards the hall are made of wood with clay plaster.



Strenght

Strenght is defined as the power carried by sound waves per unit area. In this hall the strenght will shift depending on the absorbtion levels of the walls.

Reverberation Time

Reverberation time has a big impact on the audiences experience. A lower reverberation time means a more direct sound and thus better for speech. The longer reverberation time the better suited for opera and orchestra.

Clarity

Calculated clarity for this opera hall was aimed to be high for both speech and opera. The clarity was heightened with absorptive panels at the back of the hall, behind the audience.

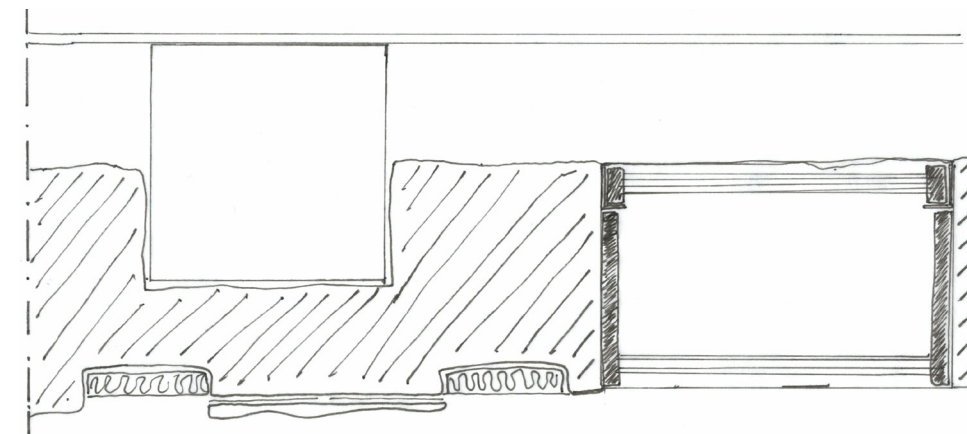
Politics of building techniques used by the poor:

The reason for choosing this material was to explore a way of building that seems to be overlooked in western culture but is slowly making its way to the conventional market. Clay has been used for housing as long as humans have existed. Used because of its simplicity and easiness to shape. Not only, but widely used in hot climates because of the stable construction, availability and temperature regulating capabilities.

For centuries, in cities that started civilization, ground earth has been used in big, complex structures, as in Iraq and Yemen. But is regularly seen as unclean and uncivilized in the western eye. A huge incomprehension of this versatile substance.

Traditional house building - craftsmanship passed on from generation to generation -, engineers designing palaces of clay and mosques, should

be equally respected as the people today building with wood and concrete. Understanding a material and designing something so long lasting should not be disregarded so easily. It is a time to stop undervaluing the knowledge depending on whos it belongs to. For the challenges we will face in the future, we are in need of every expertise there is in the world. And who better to teach us than the people with the generations of trial.



Rehearsal Room

With our material comes many challenges and structures that were very intriguing to look more into. How to solve a disconnected room for the rehearsal hall was one of them. A room that is disconnected from the outside walls lower the sound noise drastically since no frequencies can pass through the thick walls. The facade is a thin seethrough wall of celosia, and is not at all sound isolating. But thanks to the structure walls of clay, this becomes the important barrier and is thick enough to withstand low frequencies.

The process for our design;

The project for our bachelor thesis was based on a design competition in architecture and acoustics. This year our assignment was to shape an opera hall on a university campus with the purpose of finding new innovative solutions to make the hall exiting and acoustically and structurally exiting. My group partner and I decided early on that we wanted our focus to be on materiality, sustainability and craft. The material we fell in love with quickly was clay.

Since there is not wide-spread use of clay as a structural building material in Sweden the research beforehand was crucial. Clay offered benefits for the shaping and acoustically exploratory qualities. Such as noise insulation, absorption, sculpting possibilities, moisture control and diffusive capabilities.

To start the project we needed to dive into a material we have not been introduced to before in the house building education. We started with a lot of research and had conver-

sations with three invested people, one expert is from Mexico and these conversations were incredibly informative and positive. Their names are Lena Falkheden, David Escobar and Shea Hagy.

We picked the location of our project because of the country's climate and there is a heritage of working with clay and adobe structures in Mexico. After consulting the expert from Mexico the decision was Monterrey since the risk of earthquakes is small. But also the city is not as quite exposed to the extreme weathers as other big cities in Mexico. It was also in that conversation we made the final decision to also use a rammed earth technique with supporting embedded pillars as the structural material of the building.

This was a critical decision since the height and span needed was around thirty meters. With his council we made the structure with several walls supporting the ceiling and a combined width of three meters at the

lowest level and reducing in width at the top.

Our project started with creating acoustic prototypes to explore sound dynamics within our building. Our objective was to devise innovative acoustic solutions, prompting us to draft plans and construct models that addressed both structural and acoustic elements. Despite the absence of our acoustics student in the second phase, we persevered independently. We prioritized the use of minimal new materials for our models, sourcing:

- Sticks from natural surroundings
- Bottles from social events
- Blue clay donated by a local construction site
- Leftover air-dry modeling clay
- Sawdust from the workshop
- Scrap wood pieces
- Sewing thread
- Found wire

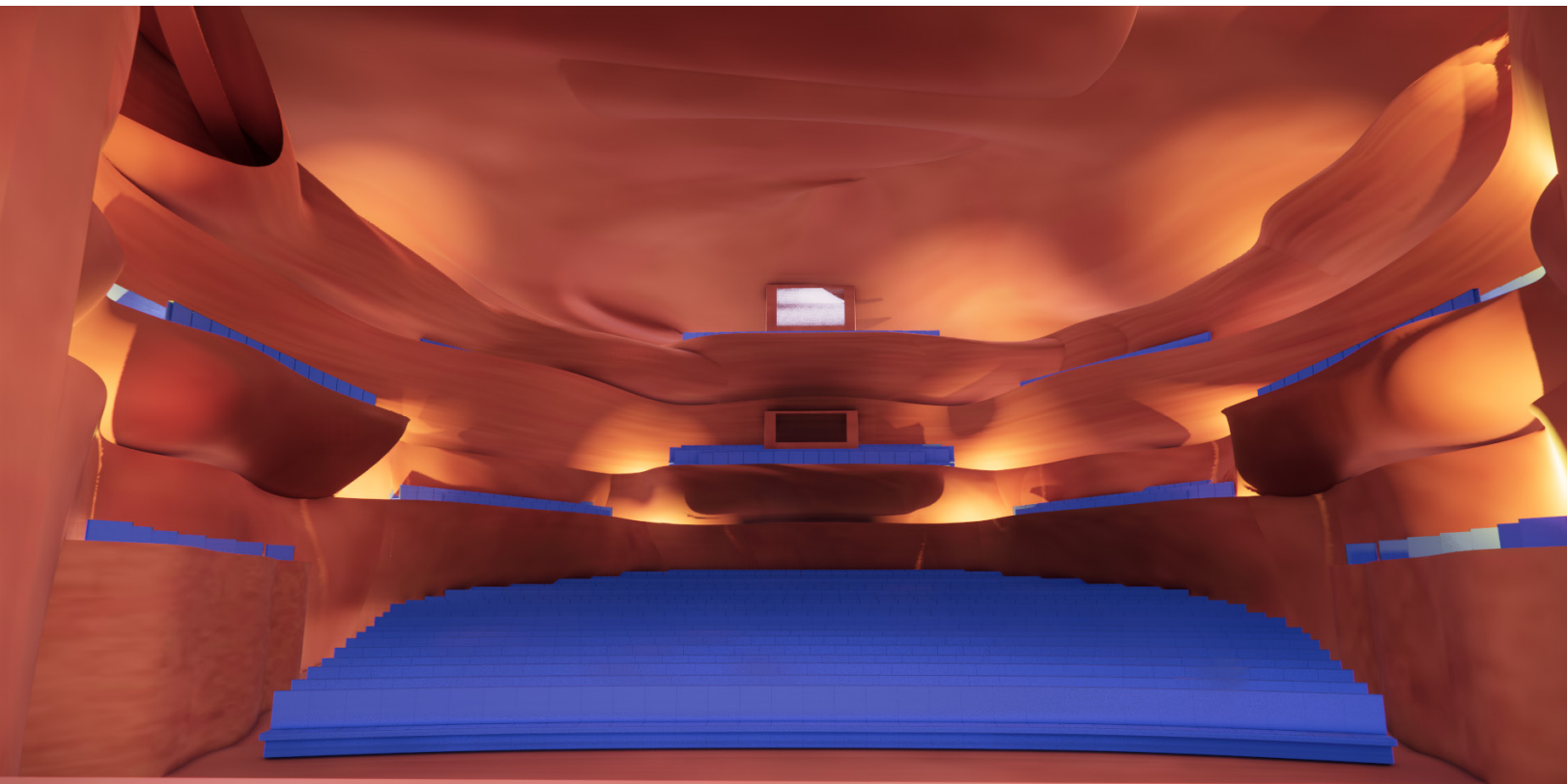
Structurally, our focus was on ensuring the models were self-supporting while meeting acoustic criteria. We experimented with various construction techniques, such as weaving sticks to enhance strength and stability. This blend of natural materials and found objects resulted in resilient and innovative structures.

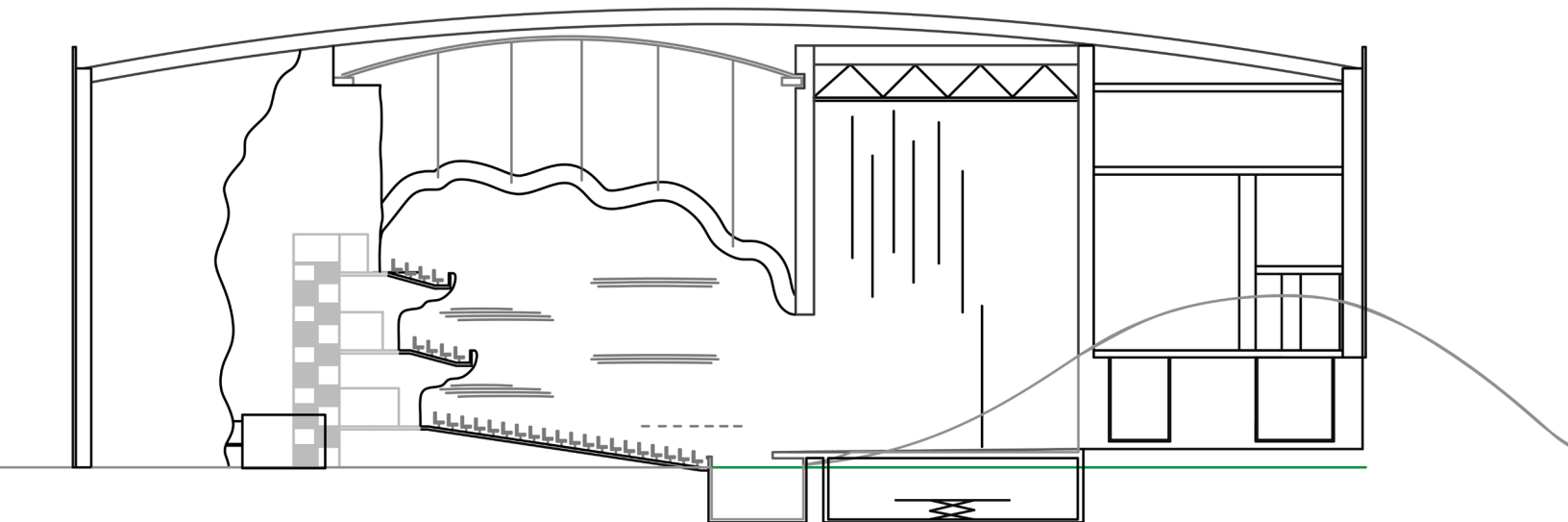
Two months into the project, we produced preliminary posters comprising texts, images, and sketches. These were presented at a gallery critique, where peers and instructors gave feedback and suggestions for improvement. The iterative structure of the course, with regular feedback, was instrumental in refining our concepts. Although it would have been beneficial to have more preliminary studies prior to starting, the ongoing process was highly educational.

Engaging with physical models deepened our material understanding. Our clay models often cracked until we incorporated sawdust, which reduced cracking and altered the texture.

We used a combination of digital and hand-drawn images to convey the warmth of the clay and a grounded aesthetic. Renderings often give a too strong feeling of completeness, whereas handmade images invite imagination, so we tried to balance the different images. Our digital model was used to create plans and sections, with a Grasshopper script ensuring adequate seating. Using Revvit, we were able to construct the facade for the rendering.

Our methodology in studying building materials emphasized hands-on experimentation and iterative design. By testing the limits of each material, we got a greater understanding of their structural and acoustic properties. This approach allowed us to understand the strengths and weaknesses of various materials, guiding us toward more sustainable and effective architectural practices.





Reparation and care for a building:

Buildings constructed from rammed earth and clay possess the remarkable ability to last for centuries, yet their age is often unidentifiable because its always repaired and reconstructed. Would it not be the greatest love letter to architecture from a people. Constantly fixing and ensuring a long lasting life. Certain materials are better than others for this.

Some examples are mass timber, stone, masonry, solid concrete blocks, bamboo, woven structures, and clay. These materials can be repurposed for other projects, extending their lifecycle. As discussed in Upscaling Earth, clay and earth buildings can be recycled indefinitely if free from chemical additives, making them a model of sustainability.

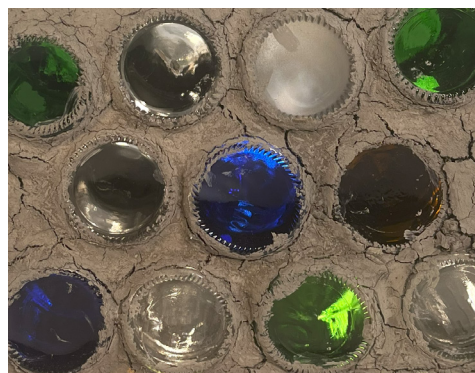
Upscaling Earth, Material Process Catalyst, Anna Herlinger, Lindsay Blair Howe, Martin Rauch, 2019, gta Verlag ETH Zürich



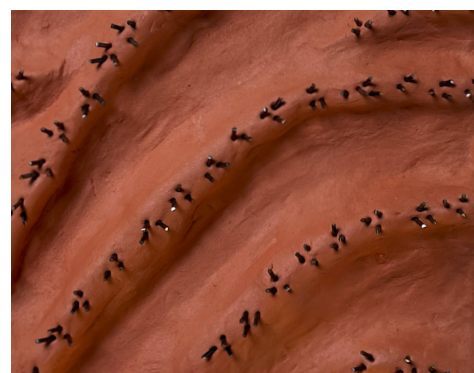
This model shows the construction of the reinforced rammed earth walls. These stand next to each other, providing high performing sound insulation.



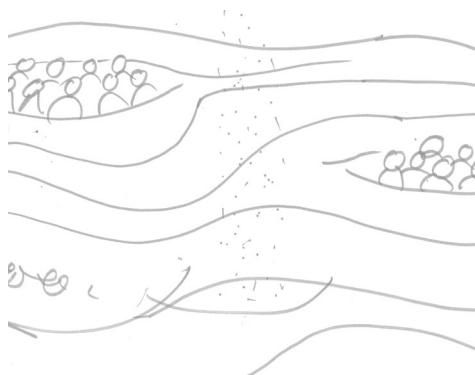
This model shows the construction of the majority of panels and overhangs. The weave adds stability while lowering reflections for low frequencies.



Glass bottles will be embedded in the clay and act as Helmholtz resonators. In interior walls this technique will also be used to provide light between rooms.

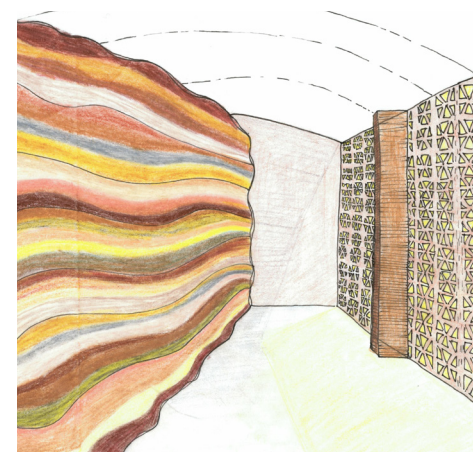
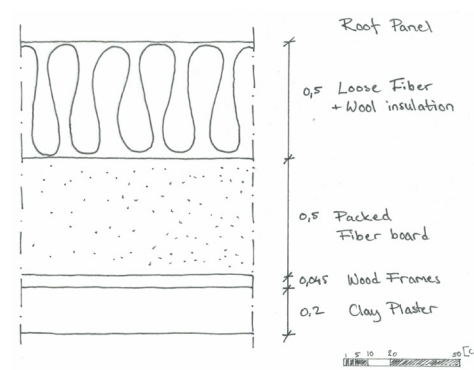


These spines will be sources of light or loudspeakers while adding a smaller frequency diffusion while the texture adds diffusion for larger frequencies.

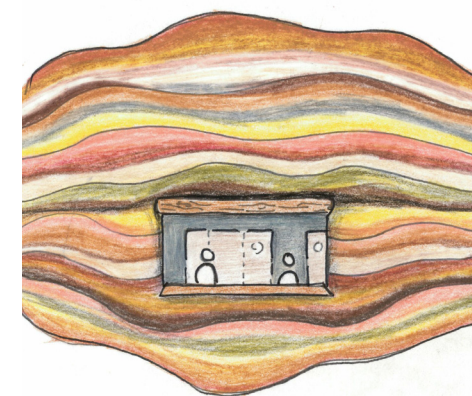


Balconies are integrated into the curved walls. Light shines from the spines embedded in the clay.

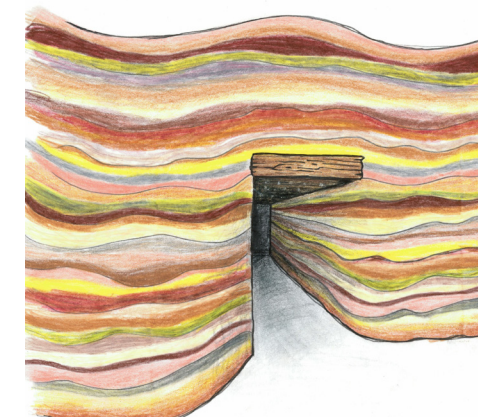
The section shows our ceiling panels that diffuse sound inside the hall while insulating from the outside.



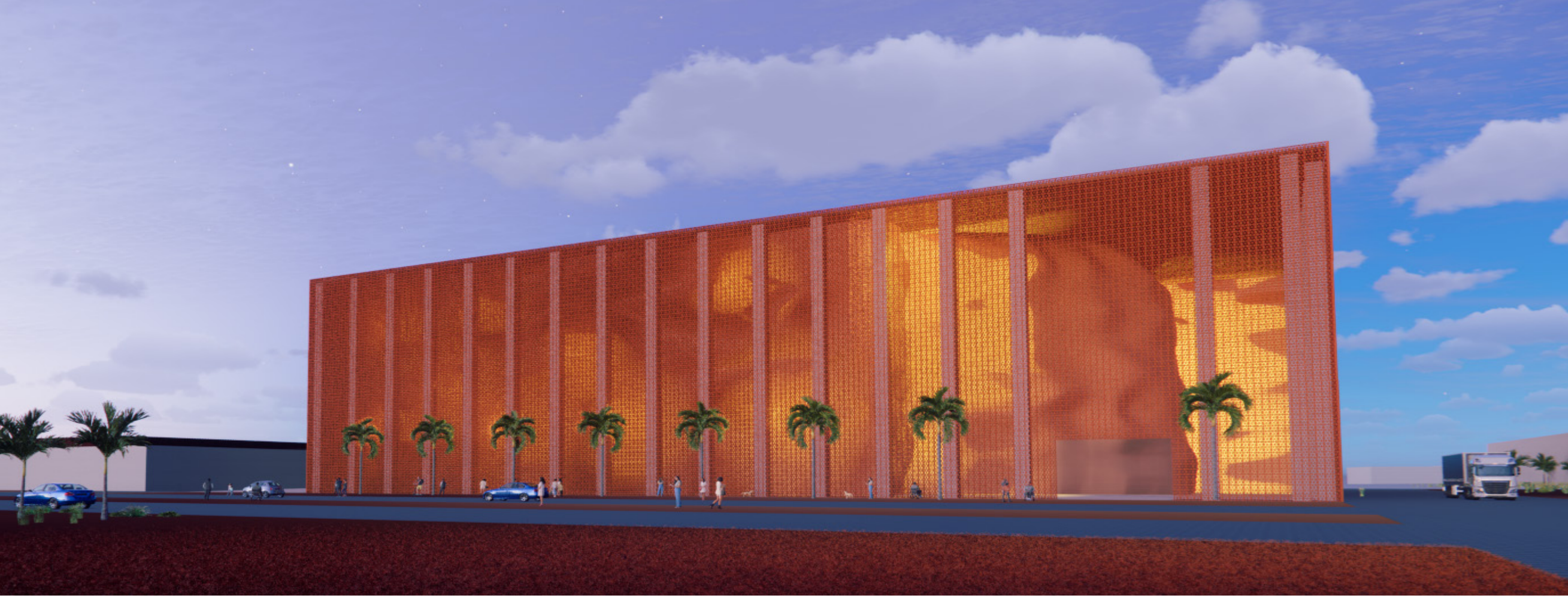
Entering the opera hall the floor is hit with the scattered sunlight through the celosia facade.



The wardrobe is tucked away in the textured rammed earth wall.



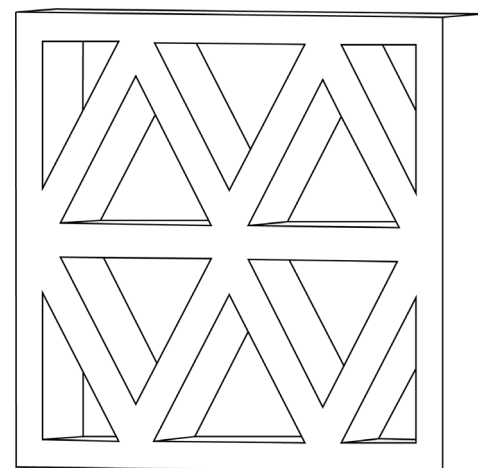
A corridor leads the visitor into the main hall. The air is cool and the outside noise stilled.



The use of traditional craftsmanship in the design:

The climate of Mexico need smart designs to create livable spaces that are hidden from the strong sun. Drawing inspiration from traditions of Mexican craftsmanship, our façade incorporates celocia – a technique of using bricks with perforations – to create a visual connection between the exterior and interior spaces of the opera hall. As sunlight filters through the perforations, casting intricate patterns of light and shadow, guests are welcomed with an

joyful play of light. Entering reveals the warmth of the layered rammed earth interior – a material steeped in the hues of Mexico’s landscape. This material is made of natural clay of course but burned to resemble the funktionallities of a regular brick. Today the material mostly used for these bricks are concrete, but we suggest a more reliable material that is easier to find and realises far less greenhouse emissions.



Collaboration

Collaboration was an important aspect of the project as it was one of the aims for this course. I feel incredibly fortunate to have worked with my partner Ella Ekman as well as our instructors and mentors. I have learned so much from the people around me. Unfortunately our acoustics student was often absent and after several attempts at working together our instructors recommended to continue without him. This impacted our design process and progress in the beginning and middle of the project. It did turn by the end

of the project. We had constructive conversations with and help from our acoustics teacher, who had previously worked with clay plaster and was very enthusiastic about the project. Ella and I worked very well together, encouraging each other and fueling the others’ curiosity. Our ideas built on the others’ and we communicated openly about our needs and priorities. This project is a result of our great teamwork and clear communication. I am very proud of the work we presented.