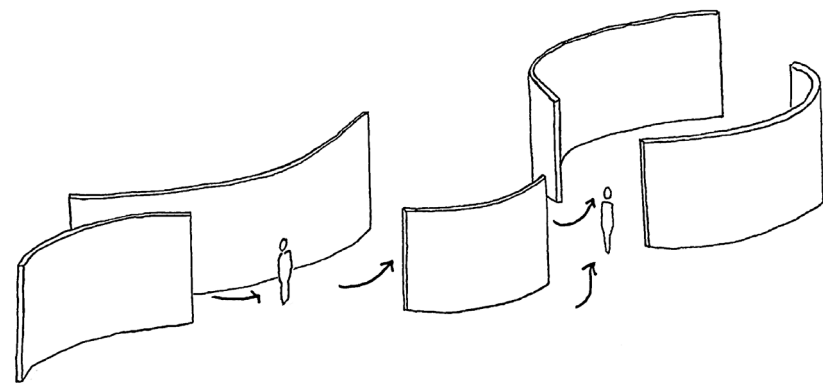


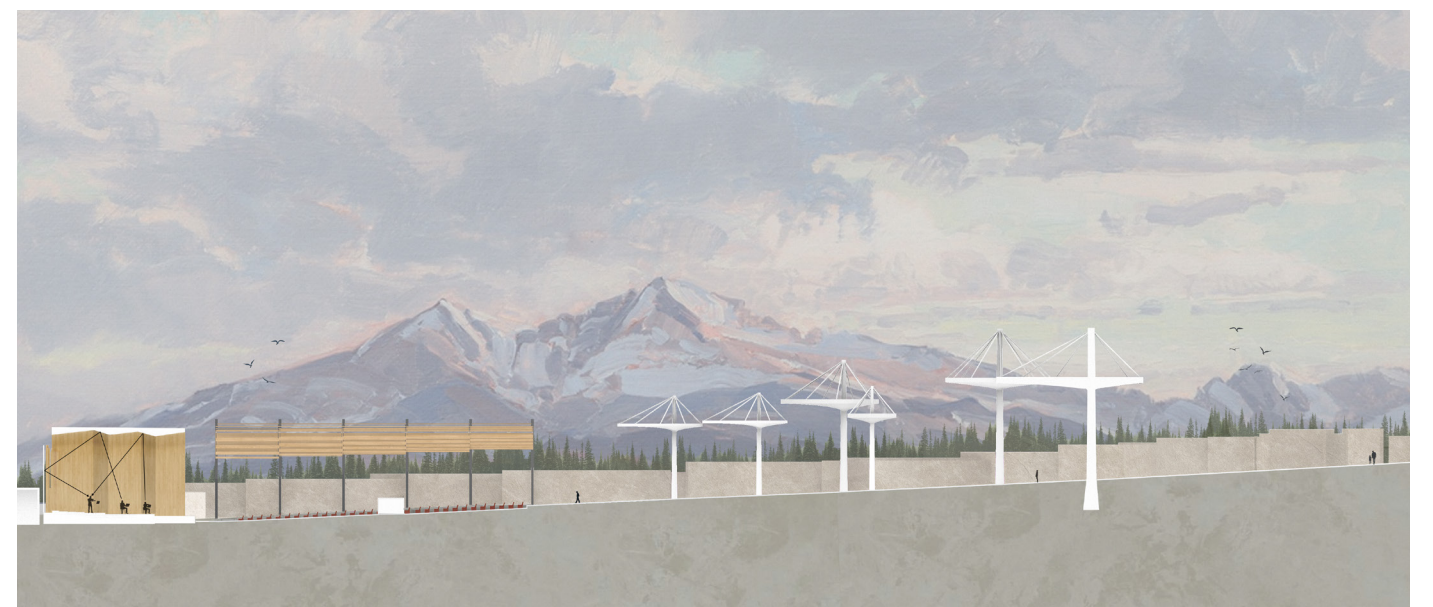
The Wave Auditorium

An Adaptable Venue

Project Portfolio - ACEX16
Bachelor Thesis in Architecture and Engineering
Mattias Johansson in cooperation with Timea Schmidinger



Chalmers University of Technology
Department of Architecture and Civil Engineering
Division of Architectural Theory and Method
Gothenburg, Sweden 2026



ARCHITECTURAL ACOUSTICS

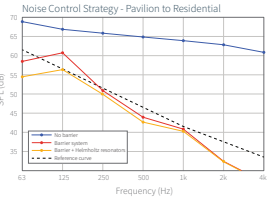
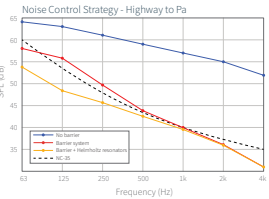


WAVE AUDITORIUM

Mattias Johansson, Tímea Schmidinger, Jelena Trifunović

SITE
Located within an open landscape in Colorado, the project is positioned on a natural slope between a river to the north, a major interstate highway to the east and residential areas are located to the southwest. The terrain shapes the pavilion's organization and orientation, while also introducing acoustic challenges related to sound propagation across the site.

Target SPL at residential area - Reference curve							
Frequency (Hz)	63	125	250	500	1k	2k	4k
SPL (dBZ)	62	57	52	47	42	38	34

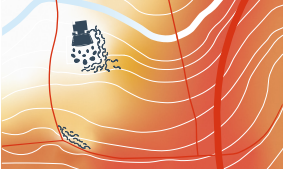


Competition board, page 1

NOISE

Environmental noise is primarily generated by the interstate highway. Additional challenges include the potential amplification and funneling from the northeast due to the landscape and river. The mechanical equipment room in BOH introduces additional vibration and noise.

Wall modules are placed close to the receiver to reduce noise levels, achieving the target value of NC-35 on site. The same approach is applied to the residential edge to reduce SPL during performances. The results indicate improved acoustic conditions on stage, while highlighting the limitations of noise control in open conditions.



Sound field study of noise at 500 Hz



MODULES

The modules of convex and concave wall segments together form a noise reducing barrier around the southeast side of the pavilion. Each module consists of two distinct layers: a reflective concrete surface and an absorbing layer made of gabions filled with light clay and covered with vegetation. The reflective side faces the interstate, where it primarily reduces mid- to high-frequency noise. To address lower frequencies, Helmholtz resonators tuned to 63 Hz and 125 Hz are integrated into the upper sections of the walls.

On the lawn side, the design prioritizes sound absorption that supports a clear listening experience during performances. Terraced steps enhance sound attenuation while also creating informal seating areas. The modules are an acoustic as well as an architectural concept where the sequence leading into the pavilion becomes a part of the musical experience.

BACK OF HOUSE

Back of house is organized around two main flows: performer circulation and logistical access. This creates a clear internal structure and reduces overlap between artists, staff, deliveries, and technical operations. Performers arrive by the dressing rooms toward the green room and stage, while loading and technical support are handled through a separate service route connected to storage and stage access. Dressing rooms serve a multipurpose function and can also be used as rehearsal spaces when needed.

The plan is also arranged with acoustic zoning in mind. More sound sensitive functions, such as dressing rooms and practice spaces, are placed further away. Loading, storage, and MEP services are grouped separately to support calmer conditions. Rather than relying on isolated rooms alone, the layout works through adjacency, separation, and distance to create calmer conditions where they are most needed.

Noise criteria are assigned to different rooms to ensure appropriate acoustic conditions for their specific functions. Rehearsal rooms are more sensitive to sound and therefore require stricter criteria, while the stage and covered auditorium align with the overall NC-35 target for the site.

ADAPTABLE CONCEPTS

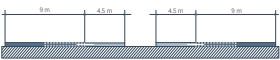
Adaptability defines the pavilion's design strategy. It is developed to accommodate varied performance formats, audience configurations, and shifting weather conditions through a unified architectural and acoustic system. Rather than relying on a fixed solution, the pavilion integrates adjustable elements that enable transitions between orchestral performances and amplified concerts, while responding to sun, shade, and rain.

This approach creates a venue that responds to both artistic and environmental demands. Flexibility extends beyond function to shape spatial qualities, strengthening the relationship between architecture, acoustics, and climate. Audience experience and performance conditions can be adjusted over time rather than being fixed to a single permanent state.

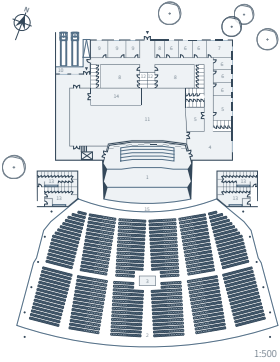
SEATED AUDITORIUM

The seating layout is designed to support both orchestral and amplified modes through a system of laterally adjustable sections. This allows the audience area to shift from fully seated configurations to mixed seated and standing arrangements as needed. This aligns closely with project's core strategy of adaptability.

An increased number of seats introduces additional absorptive surfaces during orchestral performances. For amplified events, opening sections creates a denser and more energetic audience condition closer to the stage. The changing layout also influences the acoustic character of the space, as the balance between seated and standing areas varies with each event.



	NC-20	NC-35	NC-45
1. Stage			450 m²
2. Under Roof Auditorium			3048 seats
3. FOH			13 m²
4. Green Room			110 m²
5. Rehearsal Rooms			80 m²
6. Dressing Rooms			120 m²
7. Star Dressing Room			38 m²
8. Orchestra Locker Rooms			158 m²
9. Office Space			72 m²
10. Loading Dock			72 m²
11. Storage Room			560 m²
12. BOH Restrooms			140 m²
13. Public Restrooms			211 m²
14. MEP			75 m²
15. Technical rigging zone			



1:500

Competition board, page 2

Competition Brief

The bachelor project was based on a student design competition for a new 13,000-seat outdoor music pavilion for a city orchestra. The venue was to function as a summer home for orchestral performances, while also supporting touring acts such as pop and rock concerts. The programme included 3,000 covered seats, a 10,000-person lawn, stage areas, back-of-house functions, dressing rooms, storage, loading and technical spaces.



GRID FOR LARES

The electroacoustic system is organized through two distinct placement strategies for the seated auditorium and the lawn. Audio is mixed to achieve a level of 95 dBZ for the audience.

Under the suspended roof, loudspeakers are arranged in a uniform grid, supporting a controlled and consistent listening environment. On the lawn, the system shifts to a larger-scale grid. Speakers are mounted on freestanding masts, positioned to keep listeners within an effective range of reinforcement. This approach ensures sound coverage across a more informal audience area, accommodating concentrated listening near the masts as well as more relaxed use further back.

The masts help organize the lawn by defining local gathering zones of varying densities. The curved wall elements shape more intimate microclimates on the lawn, creating sheltered pockets with a calmer and less dense character.

Competition board, page 3

ACOUSTIC SHELL

The acoustic shell is designed with two performance modes: orchestra mode and rock mode. Walls and parts of the roof is directed backward, this supports on stage acoustics and natural ensemble hearing for orchestra mode. In open mode, rotating rear wall panels open up the back of the stage. This increases the effective sound absorption and helps reduce reverberation time, creating a cleaner and drier acoustic conditions better suited for amplified sound.

A choir riser at the rear of the stage can be installed or removed as needed. The rear wall can also be moved forward to create a smaller stage mode for more compact performances.

RETRACABLE ROOF

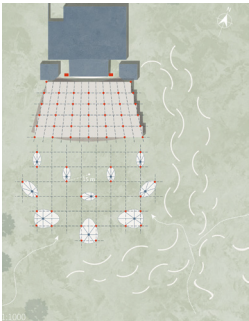
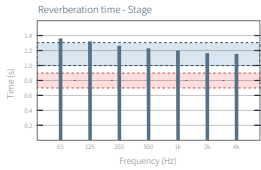
The retractable roof is both an architectural and environmental device. It consists of wooden plank elements guided by a cable mechanism, allowing the roof to shift between a loose open position and a tensioned closed position. In its open state, the suspended structure filters daylight and provides shade, giving the pavilion a lighter and more open character than a fully closed roof. This strengthens the experience of being outdoors while still defining the spatial character of the seated auditorium. In its closed state, the roof creates a more sheltered and clearly defined room condition that allows the pavilion to respond to changing weather and performance needs.

PUBLIC FUNCTIONS

Public functions are distributed through the pavilion as part of the overall spatial sequence. Rather than relying on one fixed entrance, the project allows visitors to enter through multiple openings between the curved wall elements, creating a more gradual transition into the performance space. Public restrooms are placed on both sides of the stage, while the walls can also support informal functions such as merchandise, food, and drink.

Raytracing analysis of the stage in closed and open mode.

ITDG is estimated to range between 25-35 ms, with the roof and rear wall providing the earliest reflections.



A central part of the task was to integrate architecture with acoustic performance. The design had to address on-stage hearing for musicians, sound reinforcement for large audiences, traffic noise from the surrounding site, and the impact of event sound on nearby residential areas. The brief therefore focused on how spatial organization, structure, landscape and noise control could work together as part of the architectural proposal.

REFLECTION



Context

The music pavilion is placed in an urban park context, similar to Slottsskogen in Gothenburg. It is close to public transport and connected to the city, while still being surrounded by ponds, vegetation and open park spaces that support biodiversity. The landscape creates a gradual transition from the urban surroundings to the pavilion. Sculptural wall elements shape this movement and form smaller social spaces, conversation pits and pauses along the path. These walls also work acoustically by reducing unwanted urban noise and limiting how sound spreads from the stage. Together, the park landscape and wall modules create a more protected and controlled sound environment, while keeping the pavilion open, public and connected to the city.

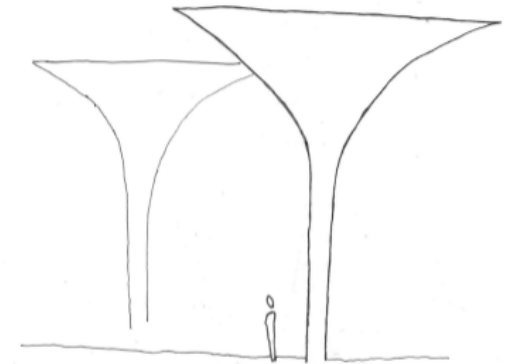


Design Methodology

Our design methodology has been guided by adaptability as the central principle. Rather than designing the pavilion in a fixed state, we have developed it as a system that can shift between different uses, weather conditions and acoustic needs.

The pavilion can support different performance modes, such as rock concerts and orchestral music. This is achieved through modules with built-in flexibility. The roof, stage and auditorium can respond to different spatial and acoustic situations, while the wall modules provide adaptable noise protection through their placement.

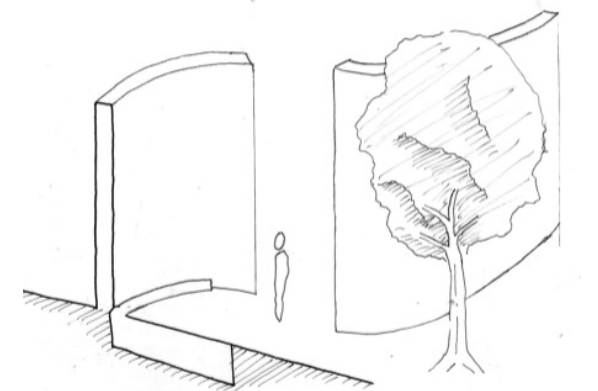
Models and acoustic diagrams have been used as tools to test and communicate how form, structure, climate and sound interact. Sustainability has also shaped the method through minimal ground intervention, lightweight construction and material-efficient systems, including hybrid wall elements with potential use of local, low-impact materials such as clay.



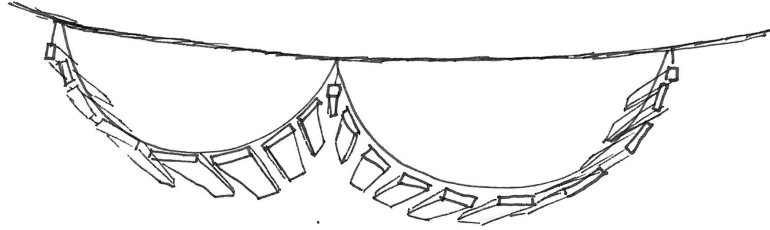
Architectural Qualities

The architectural qualities of the proposal are based on atmosphere, spatial sequence, light, performance-responsive acoustics and the relation to the landscape. The same adaptability that has guided the design methodology also shapes the experience of the pavilion: it can create different spatial characters depending on how it is used, while still maintaining a clear architectural identity.

The landscape is treated as an active part of the proposal. Instead of leaving the remaining site as generic parkland, the project introduces a system of ponds and planting that supports urban biodiversity in Slottsskogen. This creates habitats for birds, insects and varied vegetation, while also strengthening the calm and atmospheric qualities of the pavilion's surroundings.



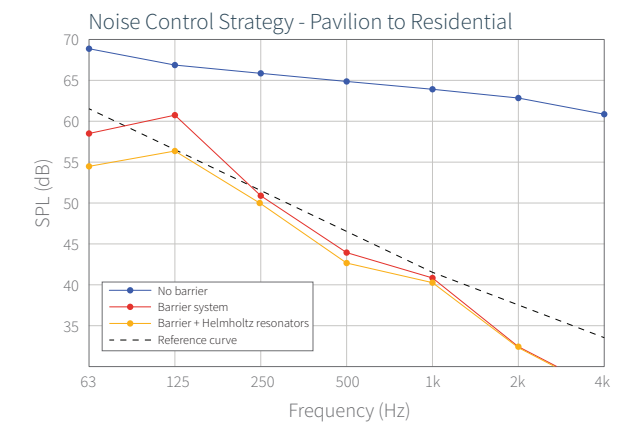
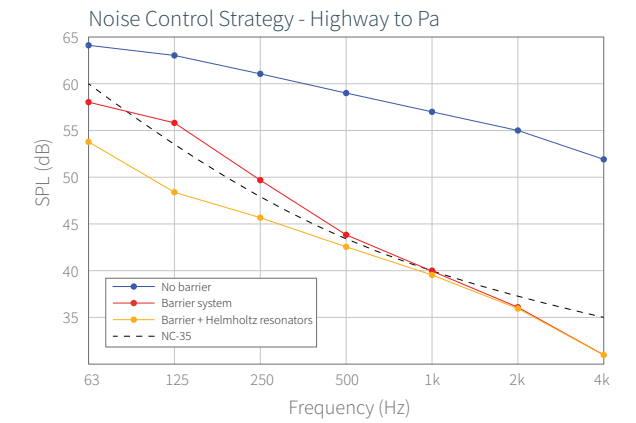
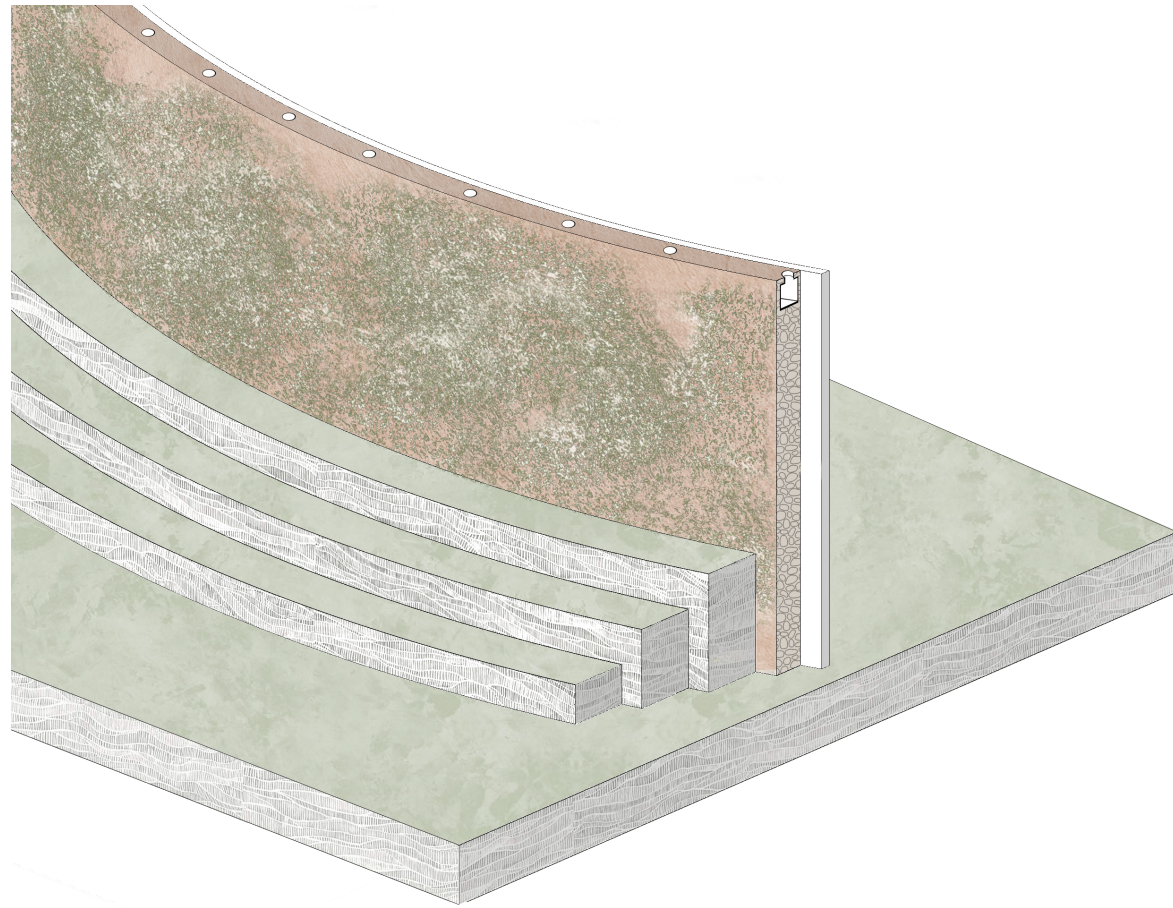
THE MUSIC PAVILION



One of the main qualities is the roof and its two modes. In both positions, the roof defines the room, but in different ways. When opened, it creates a lighter and more porous atmosphere, allowing filtered daylight to enter the space. When closed, it becomes more protective and concentrated, strengthening the sense of enclosure. This changing play of light is one of the key architectural gestures of the project. A similar principle is used in the back wall of the stage. It can open up to let in filtered light and frame a view towards the surrounding landscape, connecting the performance to the nature.

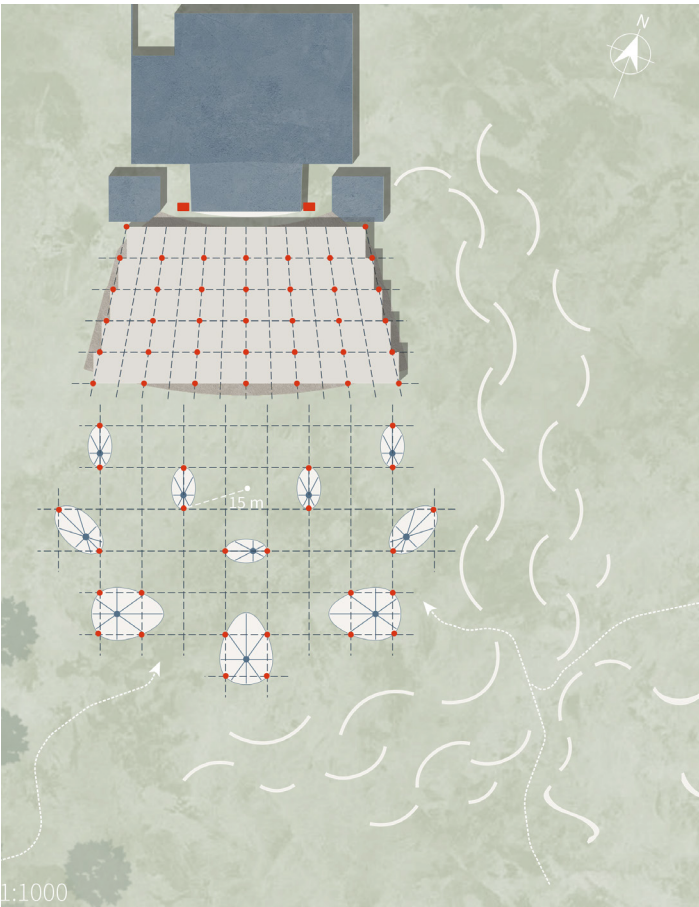


NOISE STRATEGY - BARRIERS AS ARCHITECTURE



The wall elements contribute to the spatial experience by creating a sequence of rooms, passages and openings. Movement through these openings becomes part of the experience of the pavilion. From certain directions, the project is perceived through diagonal sightlines, creating a gradual approach rather than an immediate reveal. From the south-east, a diagonal axis through the landscape frames the approach to the pavilion and strengthens the sense of arrival. Around the pavilion, tilted and curving wall segments form smaller spaces that support informal meetings, pauses and conversation.

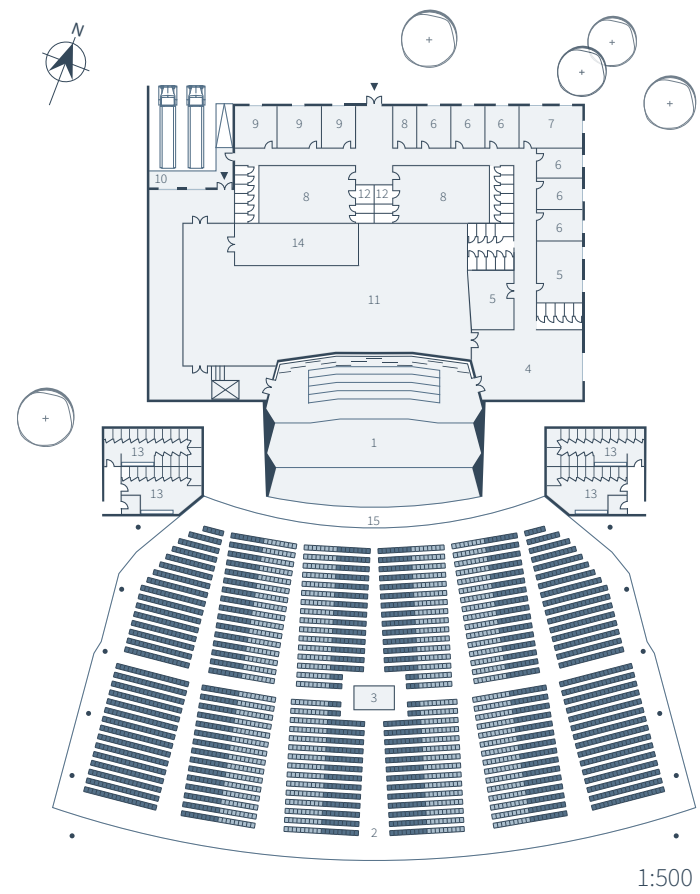
ACOUSTIC PERFORMANCE



The electroacoustic system is adapted to two audience situations. Under the suspended roof, speakers are placed in a regular grid to create a more controlled listening environment for the seated auditorium. On the lawn, the speakers are instead organized on freestanding masts in a larger grid, giving sound reinforcement to a wider and more informal audience area.

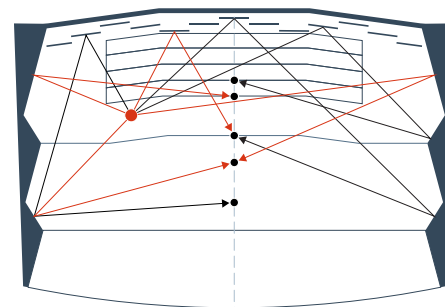
The masts also help structure the lawn by creating smaller gathering points, while the curved wall elements form more sheltered and intimate spaces. Together, the sound system, masts and walls support different ways of listening and using the park during performances.

NC-20	NC-35	NC-45
■	1. Stage	450 m ²
■	2. Under Roof Auditorium	3048 seats
■	3. FOH	13 m ²
■	4. Green Room	110 m ²
■	5. Rehearsal Rooms	80 m ²
■	6. Dressing Rooms	120 m ²
■	7. Star Dressing Room	38 m ²
■	8. Orchestra Locker Rooms	158 m ²
■	9. Office Space	72 m ²
■	10. Loading Dock	
■	11. Storage Room	560 m ²
■	12. BOH Restrooms	140 m ²
■	13. Public Restrooms	211 m ²
■	14. MEP	75 m ²
■	15. Technical rigging zone	

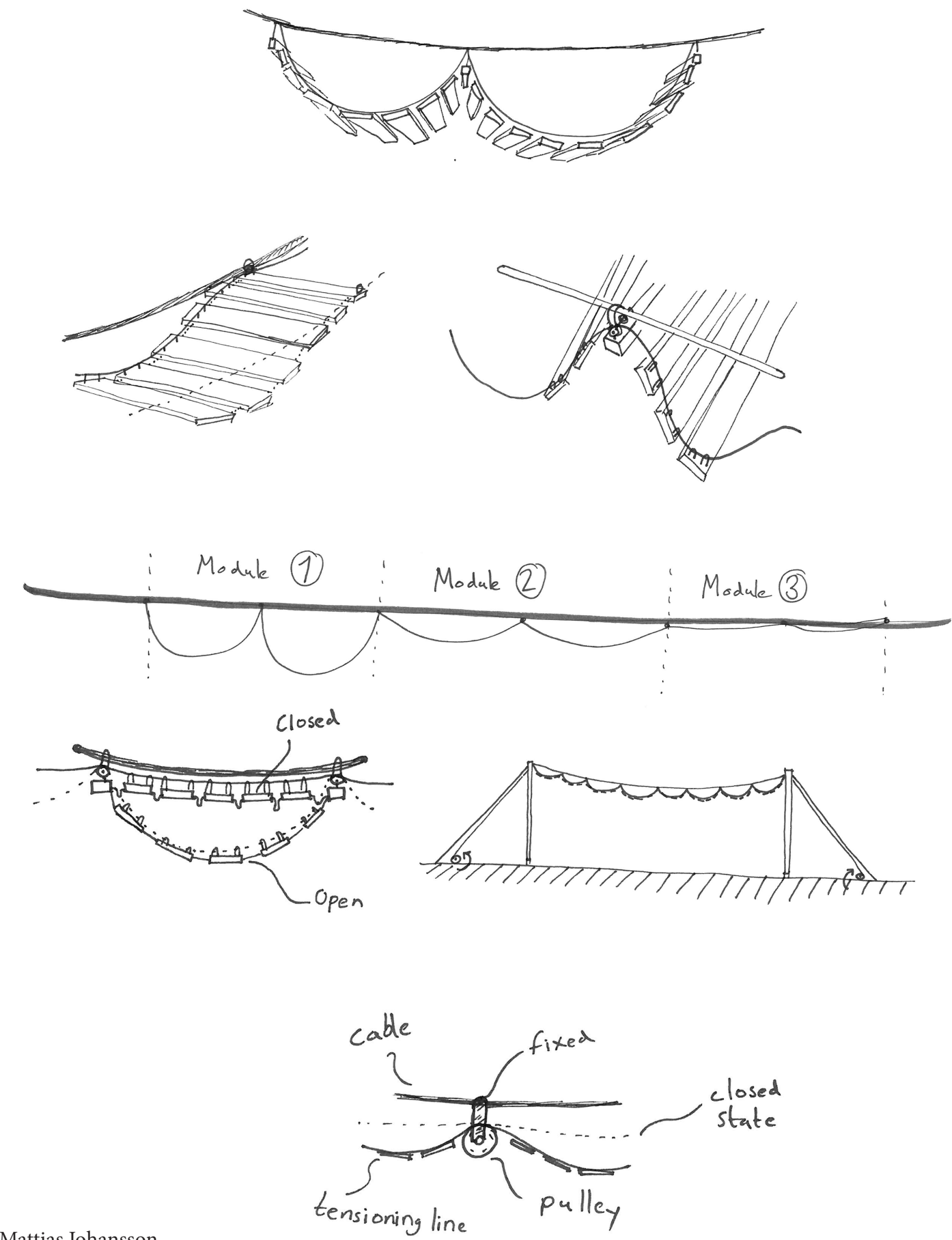


The acoustic shell is designed for two main performance modes: orchestra and rock. In orchestra mode, angled surfaces direct sound back toward the performers, supporting natural ensemble hearing. A removable choir riser can be added at the rear of the stage when needed.

In rock mode, rotating rear wall panels open the back of the stage and increase sound absorption. This creates a drier acoustic condition that works better for amplified music. The rear wall can also move forward to make a smaller and more intimate stage setting.



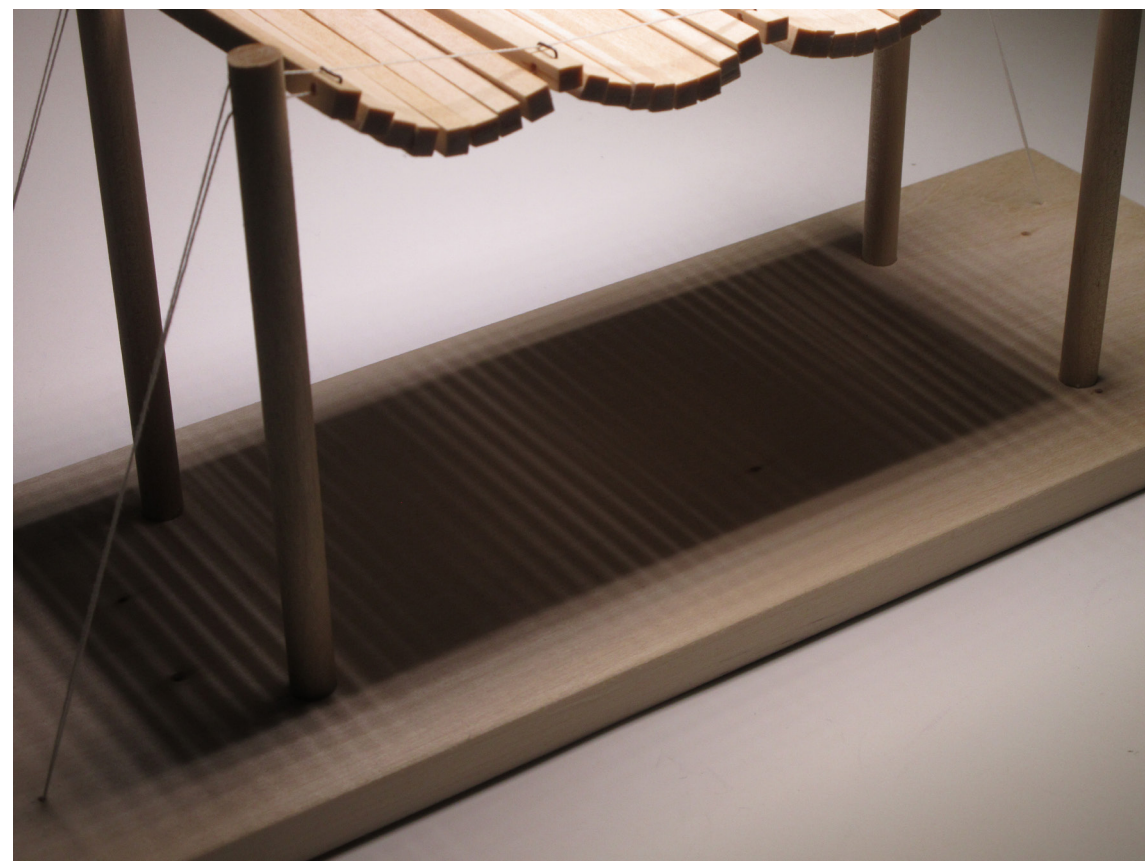
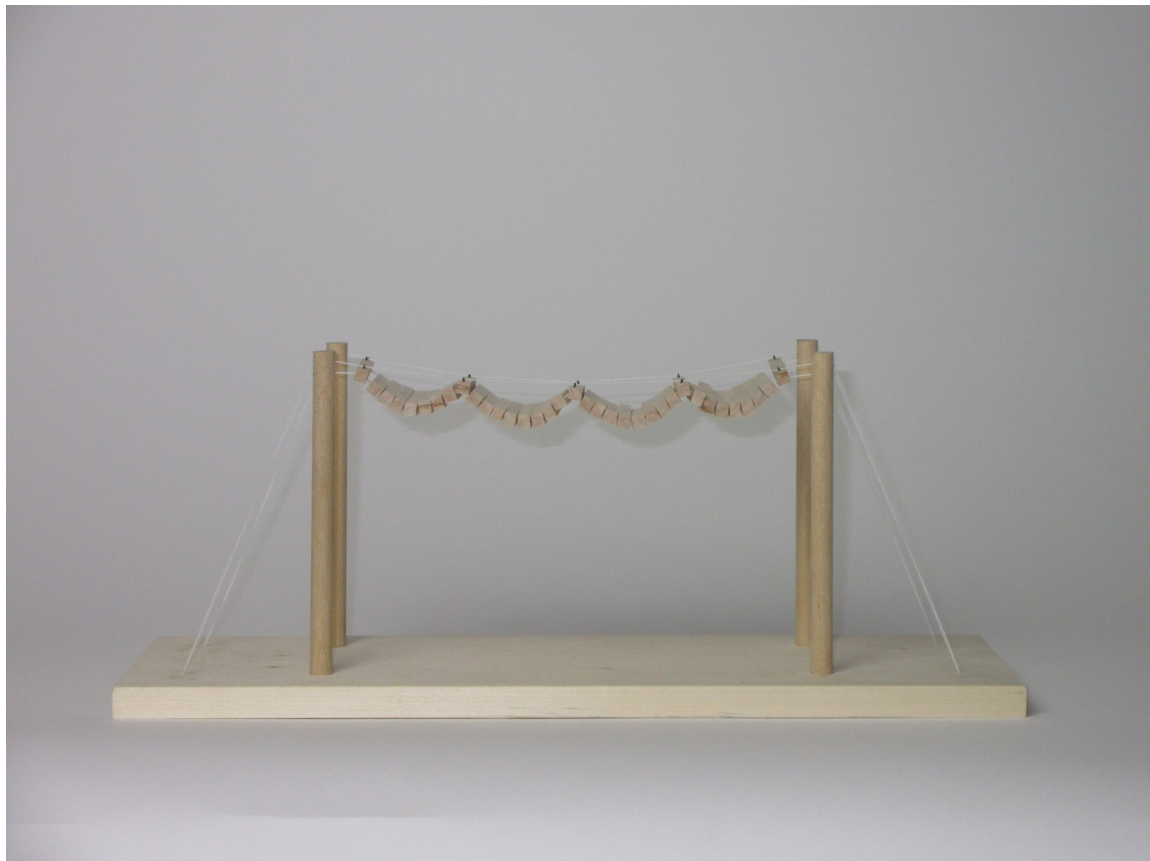
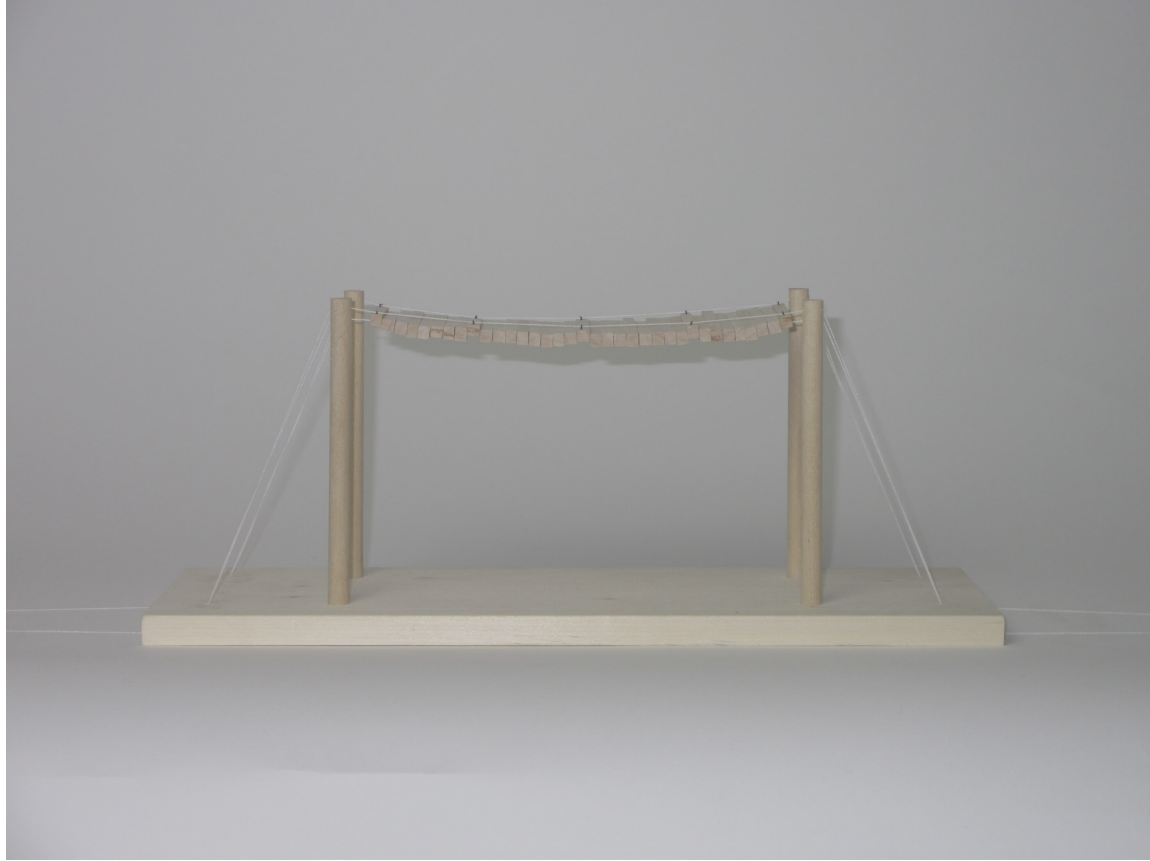
MECHANICAL & STRUCTURAL CONCEPT



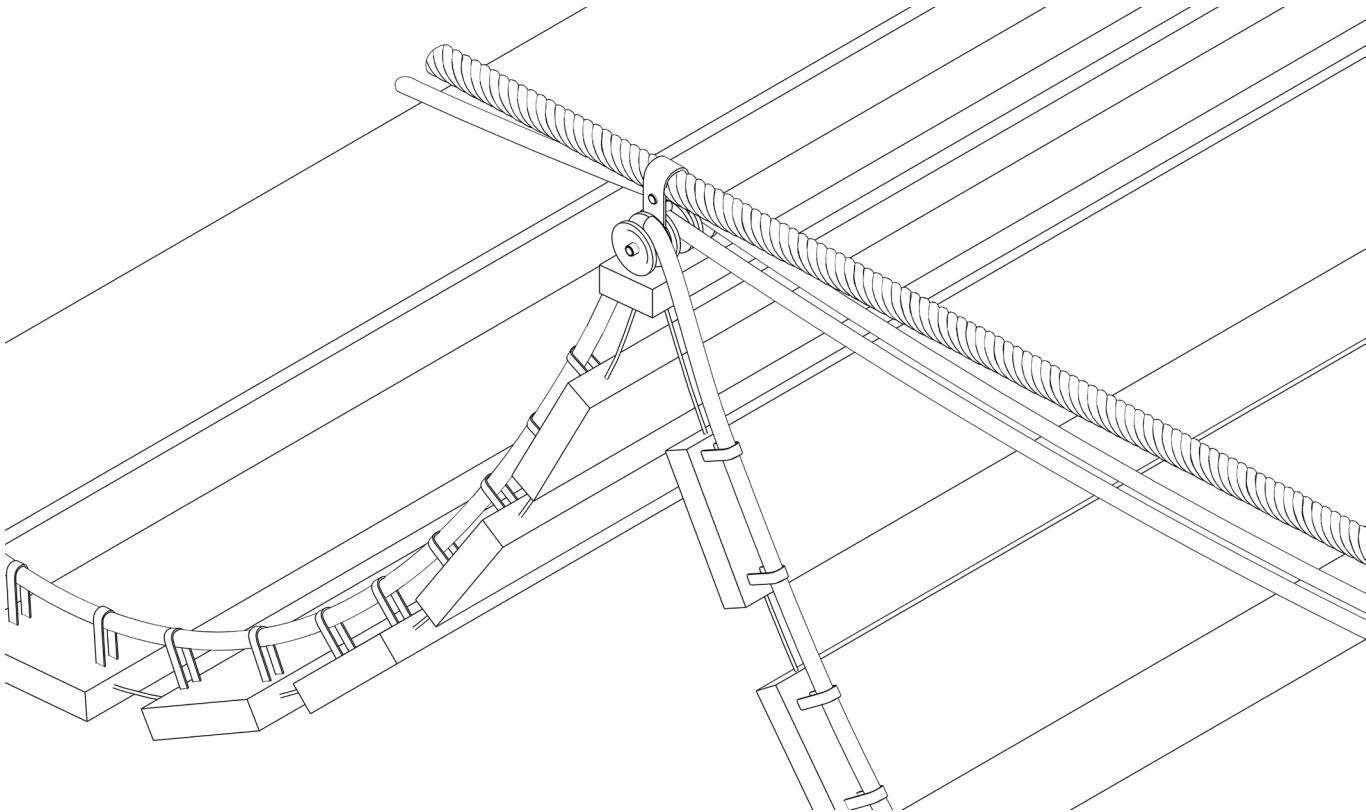
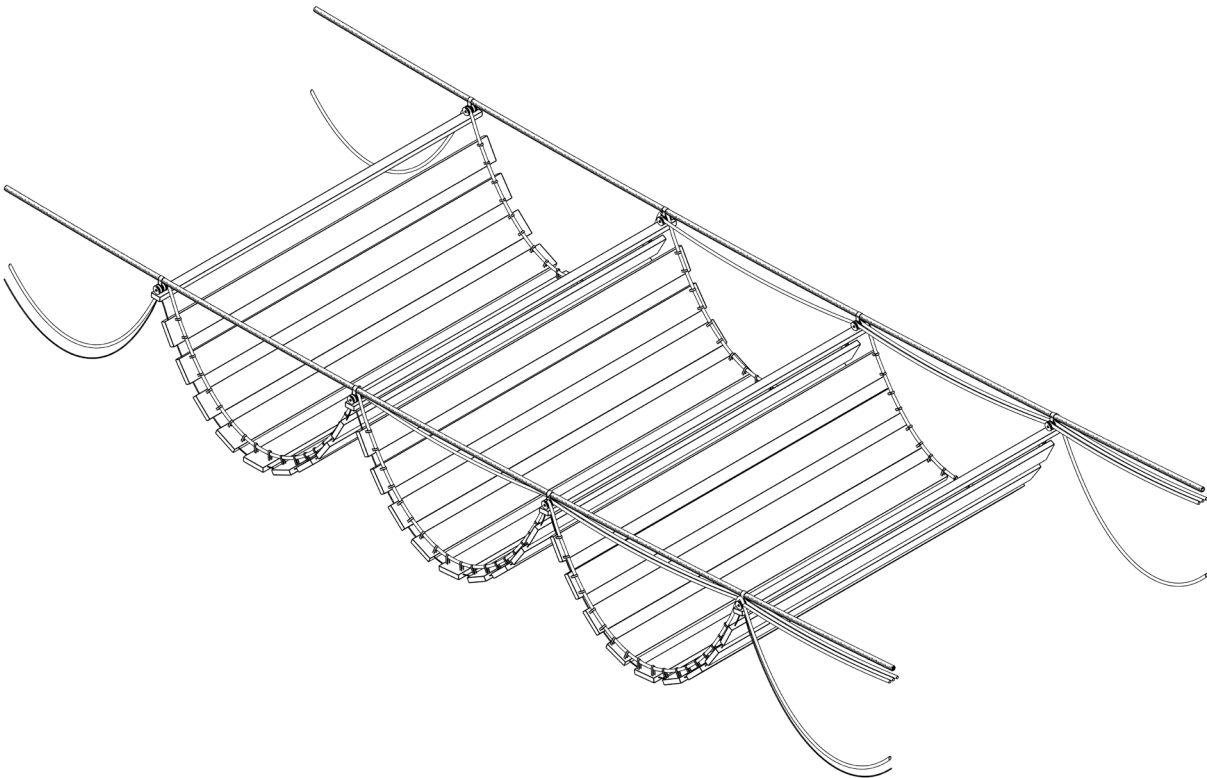
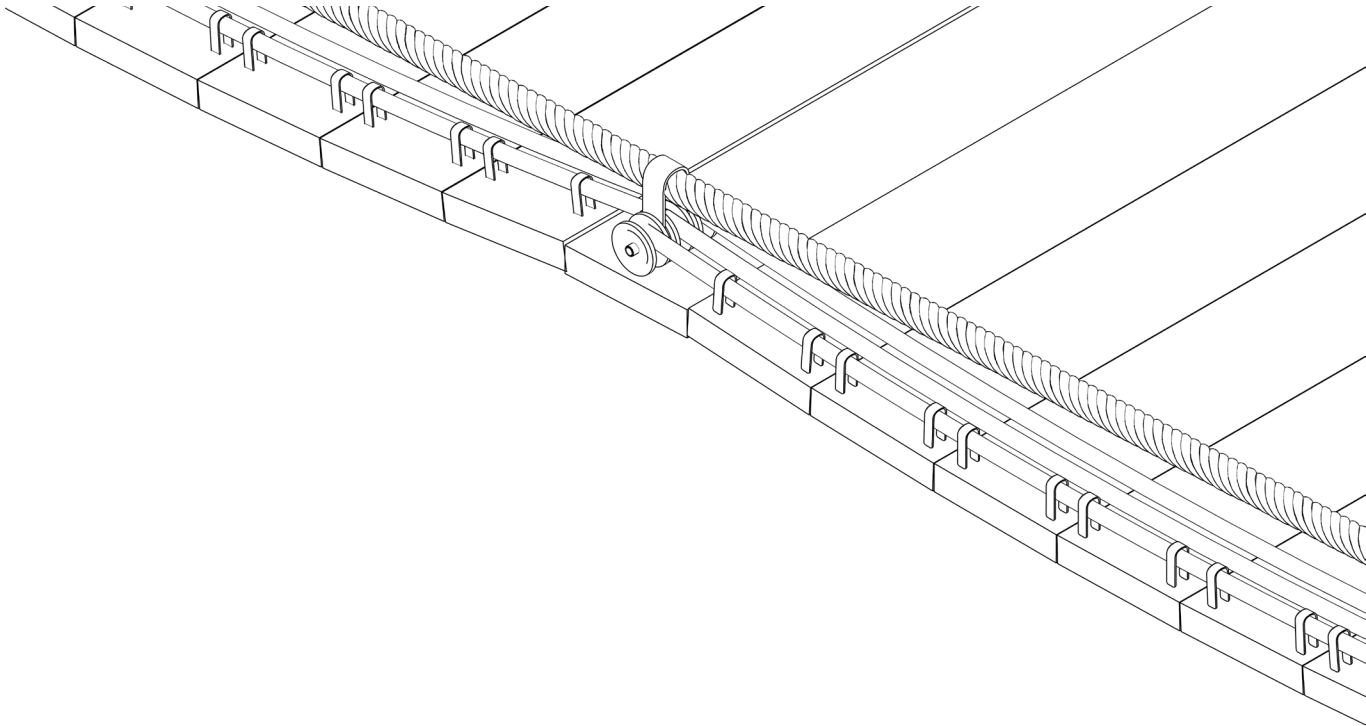
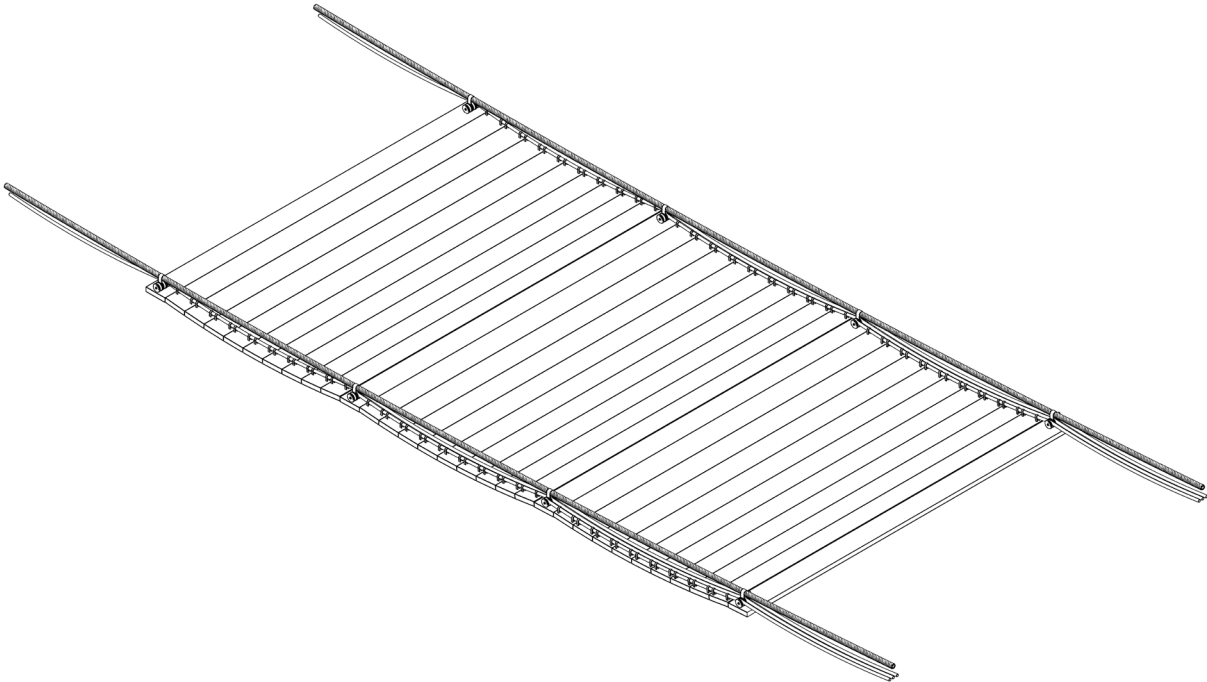
```
1 %% Simple preliminary model for openable suspended roof
2 clc; clear;
3
4 % ---- Geometry ----
5 L_global = 48; % Horizontal span of global cable [m]
6 S_global = 48.2; % Actual cable length of global cable [m]
7 f_global = 2; % Sag of global cable [m]
8
9 n_bays = 16; % Number of local bays
10 L_bay_h = L_global/n_bays; % Horizontal projection per local bay [m]
11 f_rope = 0.1; % Local sag / drop in lower rope [m]
12 theta_motor = pi/4; % Angle of motor / pulling rope relative to horizontal [rad]
13
14 c_trib = 5; % Total tributary width over two global cables [m]
15 c_trib_per_cable = c_trib/2;
16
17 % ---- Plank / rib ----
18 b_plank = 0.25; % Plank width [m]
19 h_plank = 0.06; % Plank height / thickness [m]
20 I_plank = b_plank*h_plank^3/12;
21
22 % ---- Material ----
23 rho_plank = 440; % Density of spruce [kg/m^3]
24 g = 9.82; % Gravitational acceleration [m/s^2]
25 E_parallel = 13700e6; % Modulus of elasticity GL32c [Pa]
26 E_steel = 200e9; % Modulus of elasticity of steel [Pa]
27
28 % ---- Load ----
29 q_h = c_trib_per_cable * h_plank * rho_plank * g; % [N/m]
30 q_global = q_h * (S_global/L_global); % [N/m]
31 q_rib = b_plank * h_plank * rho_plank * g; % [N/m]
32
33 % ---- Global cable, simplified symmetric model ----
34 H_global = q_global * L_global^2 / (8*f_global); % Horizontal force [N]
35 V_global = q_global * L_global / 2; % Vertical support reaction [N]
36 T_cable_support = sqrt(H_global^2 + V_global^2); % Maximum cable force [N]
37
38 % ---- Local lower rope, simplified symmetric model ----
39 V_rope = q_global * L_bay_h / 2; % Vertical reaction [N]
40 H_rope = q_global * L_bay_h^2 / (8*f_rope); % Horizontal force [N]
41 T_rope_support = sqrt(H_rope^2 + V_rope^2); % Maximum rope force [N]
42
43 T_motor = H_rope / cos(theta_motor); % Motor / pulling force [N]
44
45 % ---- Safety factors ----
46 SF_cable = 5;
47 SF_rope = 10;
48
49 T_cable_support_SF = T_cable_support * SF_cable;
50 T_rope_support_SF = T_rope_support * SF_rope;
51 T_motor_SF = T_motor * SF_rope;
52
53 % ---- Local rib / plank bending ----
54 L_rib = c_trib;
55 d_rib = 5*q_rib*L_rib^4 / (384*E_parallel*I_plank); % Deflection [m]
56
```

----- GEOMETRY -----	----- GLOBAL CABLE -----
Global span: 48.0 m	Horizontal force H = 93.7 kN
Number of local bays: 16	Vertical support reaction V = 15.6 kN
Local bay, horizontal projection: 3.00 m	Maximum cable force at support T = 95.0 kN with SF5 = 475.1 kN
Local sag of lower rope: 0.10 m	
----- RIB -----	----- LOWER ROPE -----
Rib span = 5.0 m	Horizontal force H = 7.3 kN
Rib deflection = 8.6 mm	Vertical reaction in local bay V = 1.0 kN
Deflection ratio L/d = 584	Maximum rope force in local bay T = 7.4 kN with SF10 = 73.9 kN
	Required motor force = 10.4 kN with SF10 = 103.5 kN

PHYSICAL MODEL



ROOF MODULE



Architecture and Engineering

During three years at Architecture and Engineering, I have developed a broad understanding of both architectural design and technical systems. The programme has introduced me to an interdisciplinary way of working, where architectural ideas are developed together with structural systems, climate, acoustics and other performance-based aspects.

An important part of this has been performance-driven design. For me, this means designing architecture that is not only visually convincing, but also responds to technical demands. Acoustic qualities, indoor climate, structural systems and material efficiency can all influence the design from an early stage, instead of being treated as separate additions later in the process.

Solving complex problem

The education has also taught me how to handle complex projects through an iterative process. Design ideas are rarely solved directly, but need to be tested, adjusted and developed over time. Through drawings, models, calculations and analysis, I have learned to move between architectural ideas and technical reasoning, and to evaluate both the concept and how it performs in practice.

After three years, I take with me both knowledge and a way of working. The programme has shown me the value of combining different disciplines, and how technical understanding can support the design process rather than limit it.