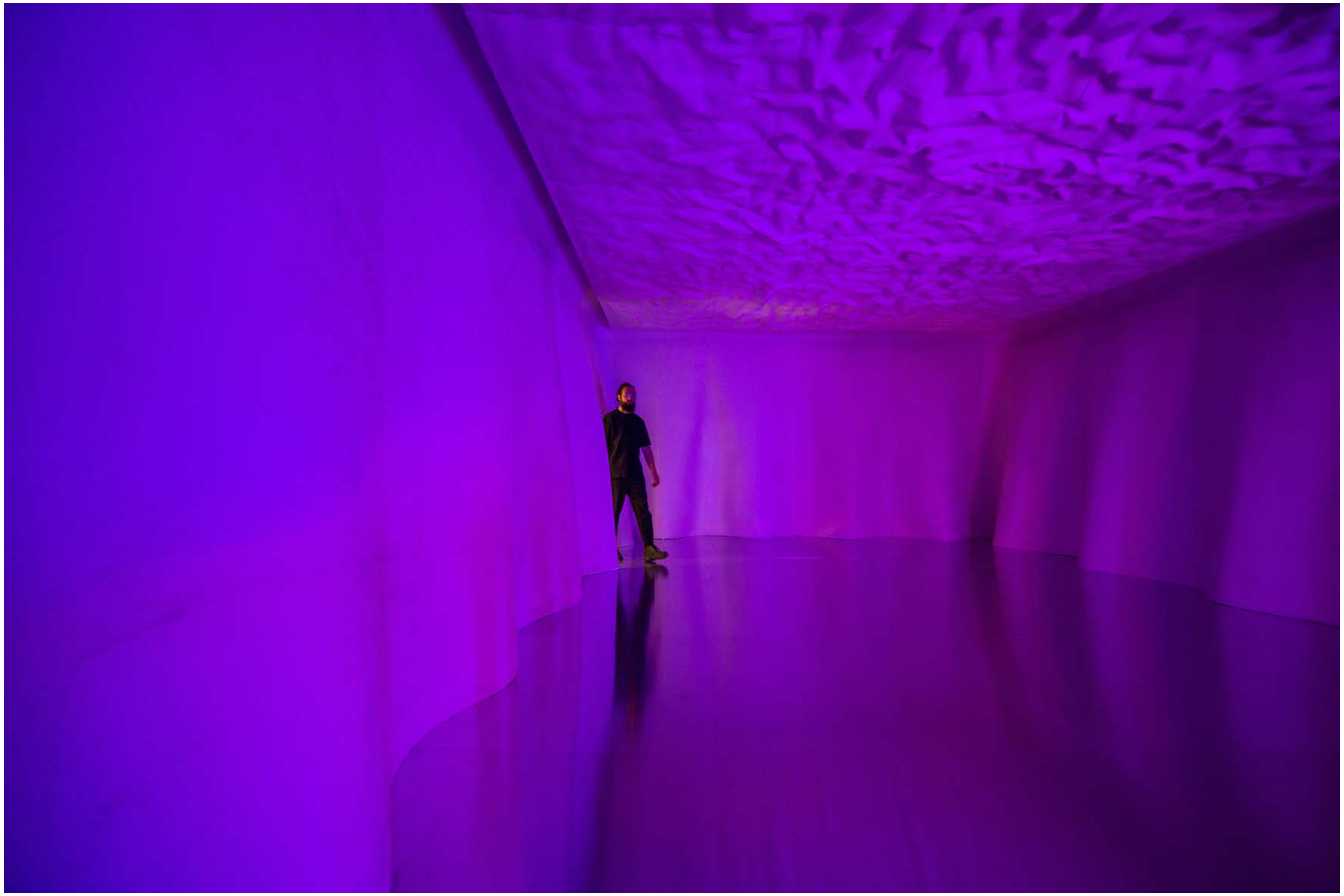
A CONCERT SPACE FOR A GRAND PIANO

MIKE GUYER
PHILIPPE BLOCK
MARTIN LACHMANN

STEFAN LINIGER 14 932 586 // FREE DIPLOMA HS21



A CONCERT SPACE FOR A GRAND PIANO

To design, build and curate a concert space for a grand piano in scale 1:1 is the topic of my diploma.

It's my vision to create an aesthetic impression of ephemeral movement in architecture by developping a new fabrication method for double curved shell elements in concrete.

Backed by acoustical research it's my goal to achieve a unique symbiosis of sound and space through the tectonics of the shell elements to create an acoustically outstanding space for musical encounters around a grand piano.

By merging sustainable building technologies with architectural design and music as a publicly shared passion, I hope to stimulate the discourse on the acoustic argument in architecture and open up new design possibilities in fabrication technologies.

The novel experience of the concert space will be celebrated with a series of concertsand performances from both professionals and students to share the love for music and creation.

MOTIVATION

Classical piano music has been my inspiration and passion from an early age on - if my hands no longer wanted to devote to practicing, they tried to shape things in the small workshop at home. This quest continues to this day.

The allure of drapery - the symbolic velvet curtain of a theater or a silken dress caught by a breeze, is nothing new to sculpture nor architecture. Yet, being able to create it as a static element in an simple procedure offers new possibilities to designers.

Thereby I strive to interweave different disciplines in arts and sciences to explore new ways of creation.

FABRICATION

FABRICATION
//
INTRODUCTION

Membranes as formwork:

A single reuseable mold for different complex shell geometries offers many possibilities:

Be it for cast materials like concrete and gypsum or laminated materials like fabrics or veneer, a flexible mold system can produce a myriad of different double curved shapes very quickly.

The whole process produces almost zero waste and can maintain minimal but continous material thickness.

Situating the work in the current field of academic research on flexible formworks presents a good opportunity to evaluate its potential strengths in future applications.

FABRICATION // REFERENCES

Double curved shell structures provide an interesting solution to span and cover large areas with a minimal amount of material yet maintaining structural strength.

As masoned vaults they often cover the isles of churches, together with the use of reinforced concrete or steel cable structures they experienced a renaissance in civil engineering throughout the 20th century.

Yet the construction of such elements proves to be difficult, as the double curved surfaces demand a mould divided into small sections and a close meshed scaffolding system to support the structure under construction.

Researchers around the globe strive to find new ways of fabrication for double curved structures, be it in reusable textile formworks supported by cable-net-structures or machines prefabricating smaller elements later to be assembled on site.

All the fabrication methods are labour-intense:
masoned vaults demand highly skillled labourers, wide span concrete structures need complex scaffoling systems with a huge amount of resources,
cable-net and textile mould structures prove to be insanely difficult to work on as they deform under the non-uniform load conditions during construction and do not provide a stable working platform,
machines for the prefabrication of smaller elements are very difficult to simulate and control due to the complex behaviour of the elastic formwork material.

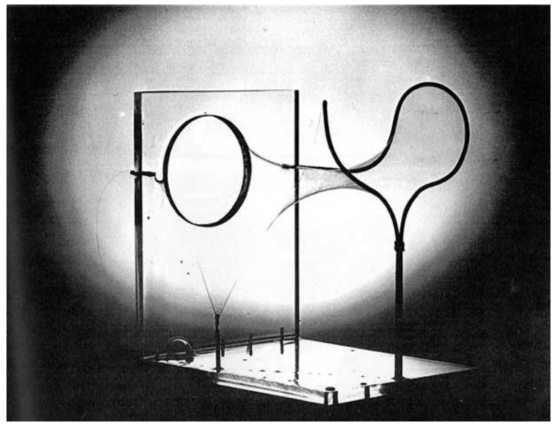
Amazingly, small scaled physical models work perfectly for formfinding - be it the suspended string structure of the sagrade familia of Antoni Gaudí, the soap film models for double curved tent structures of Frei Otto, or be it the infamous gypsum models cast on elastic membrane moulds from Heinz Isler.

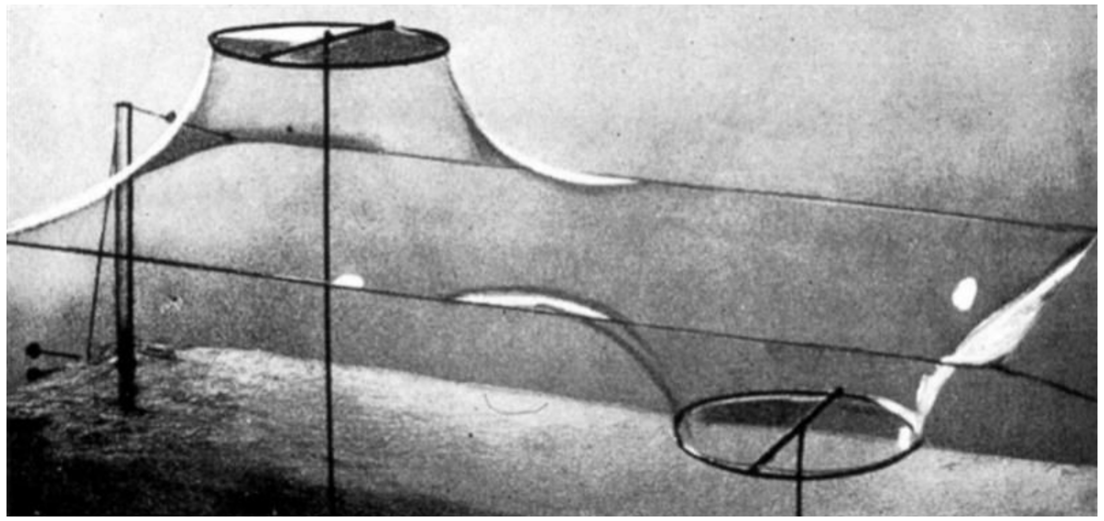
They all were the inspiration for the fabricational approach of this work.

fig 1

fig 2

fig 3





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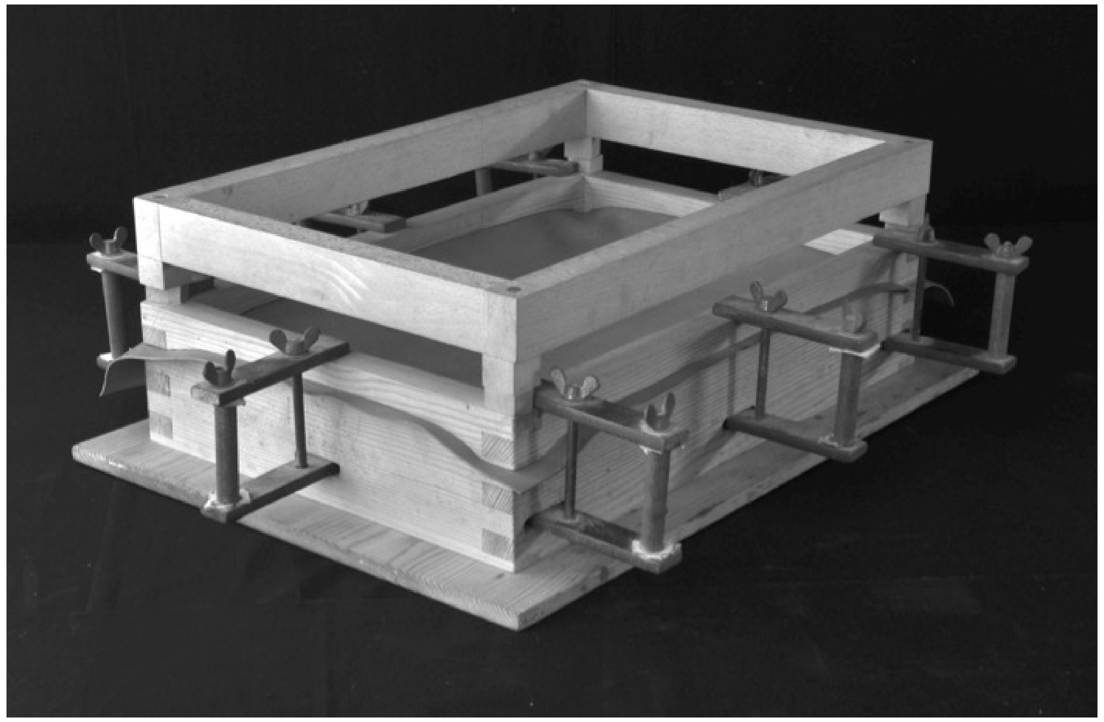
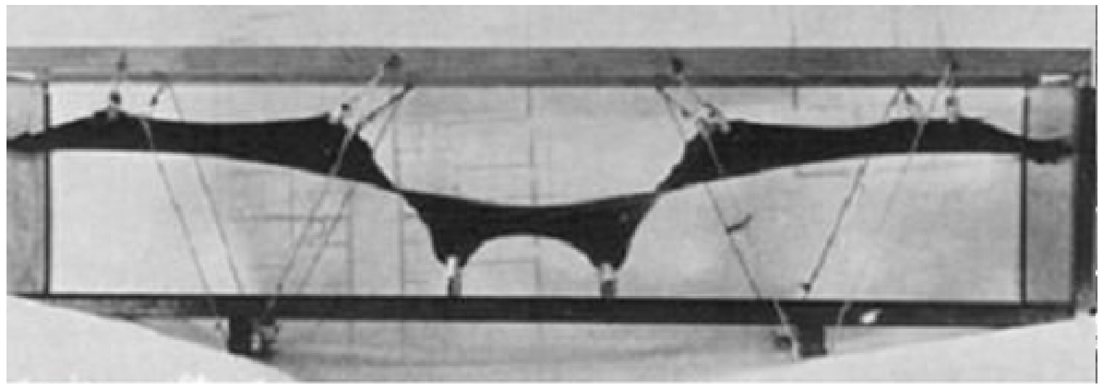


fig 6

fig 7

fig 8

fig 9



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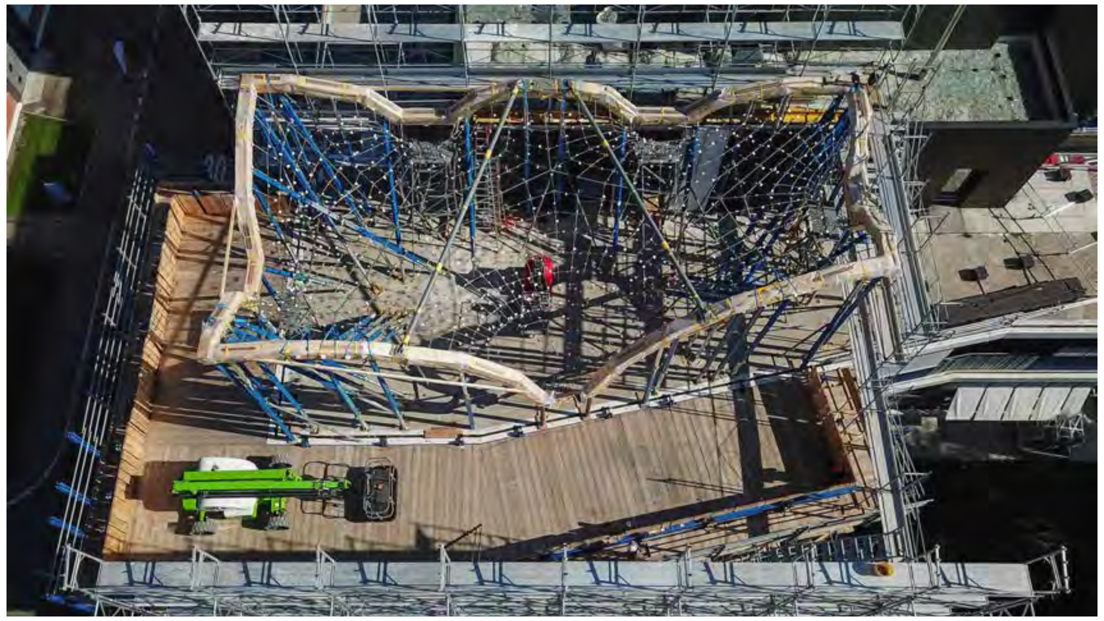

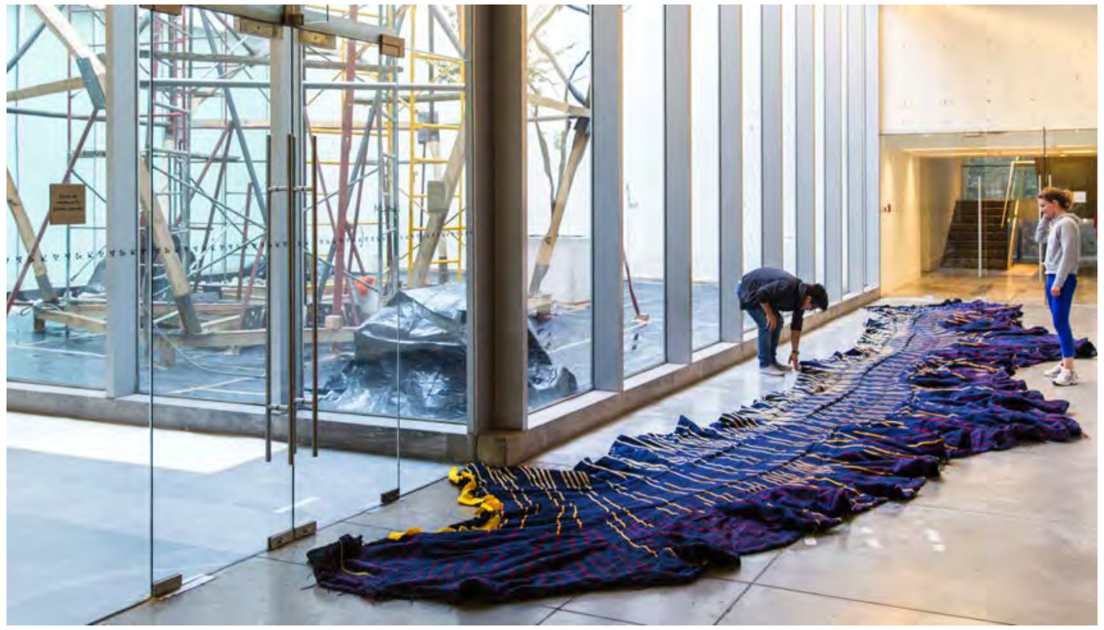

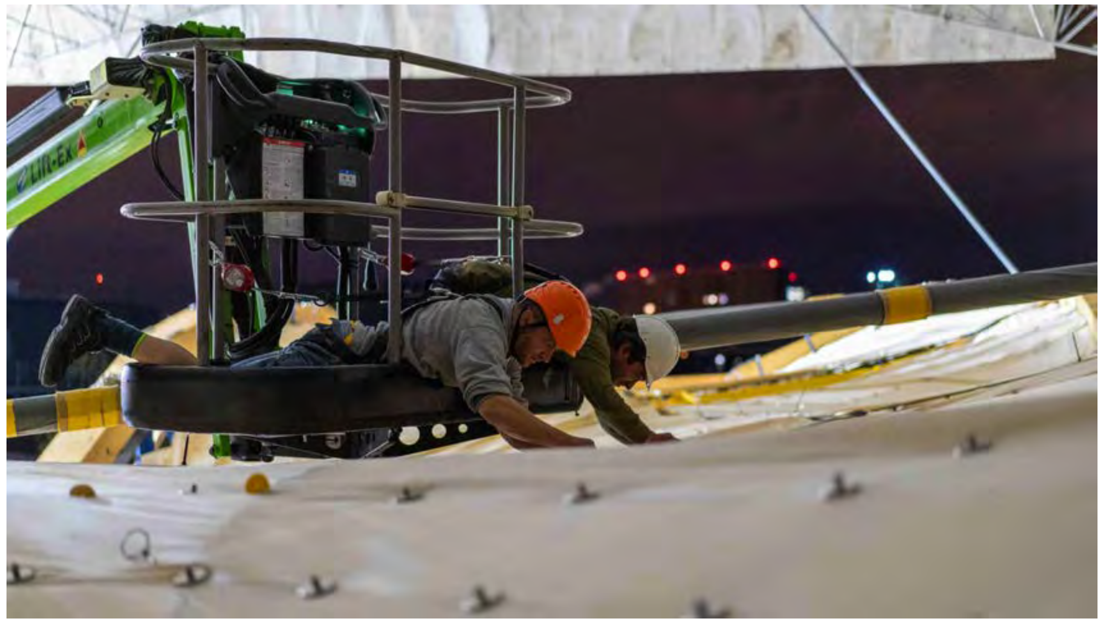

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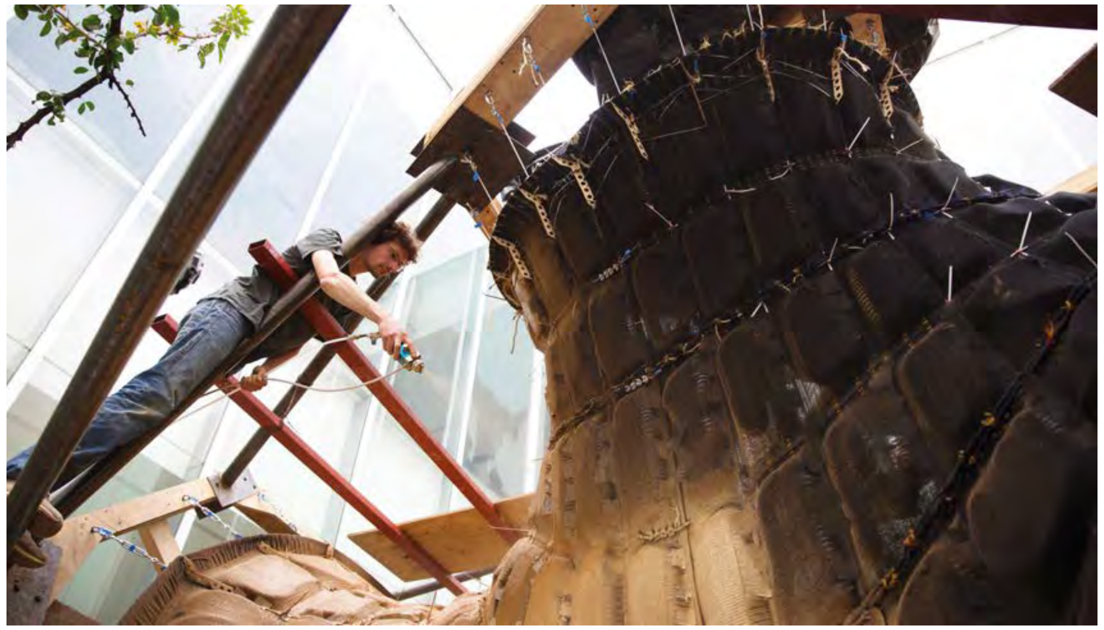

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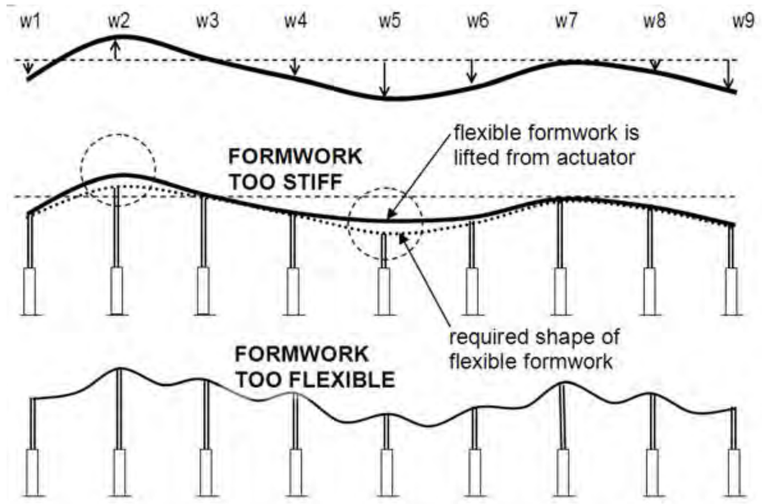
w1
w2
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FORMWORK
TOO STIFF
flexible formwork is
lifted from actuator
required shape of
flexible formwork
FORMWORK
TOO FLEXIBLE

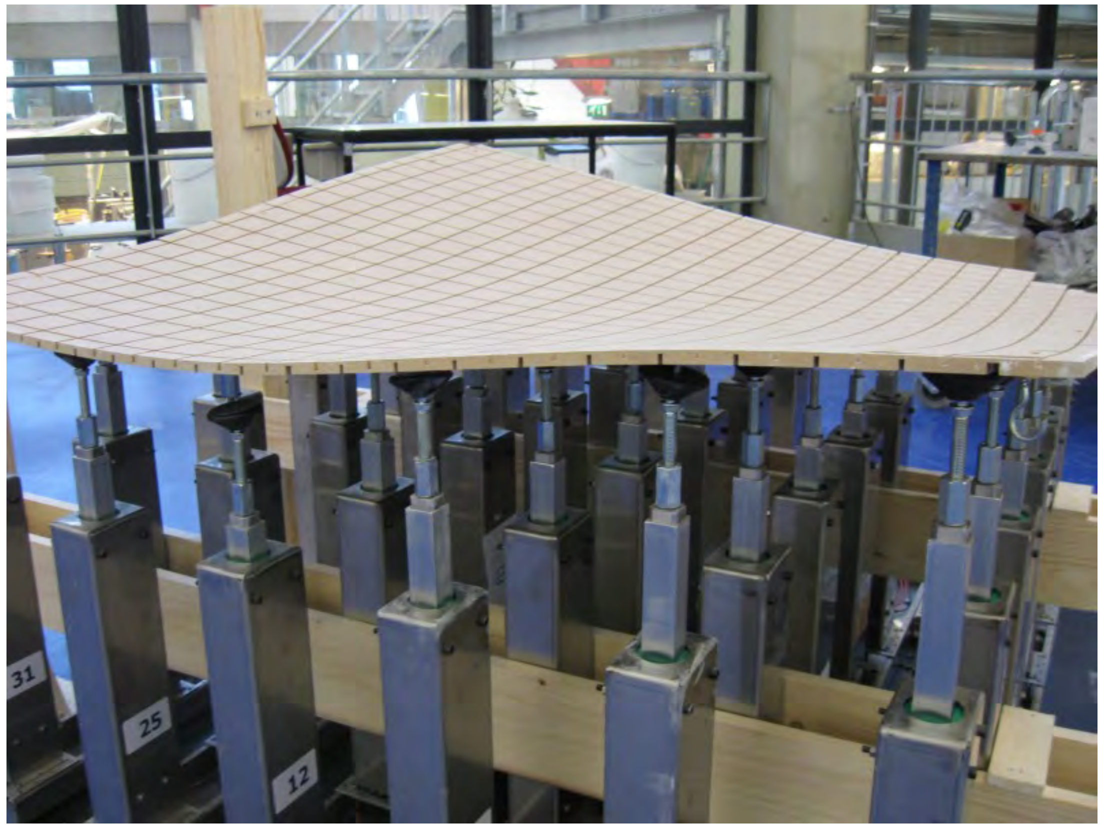
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fig 16-17

EXPERIMENTAL RESEARCH

EXPERIMENTAL RESEARCH // DOUBLE CURVED CAST PLASTER MODELS

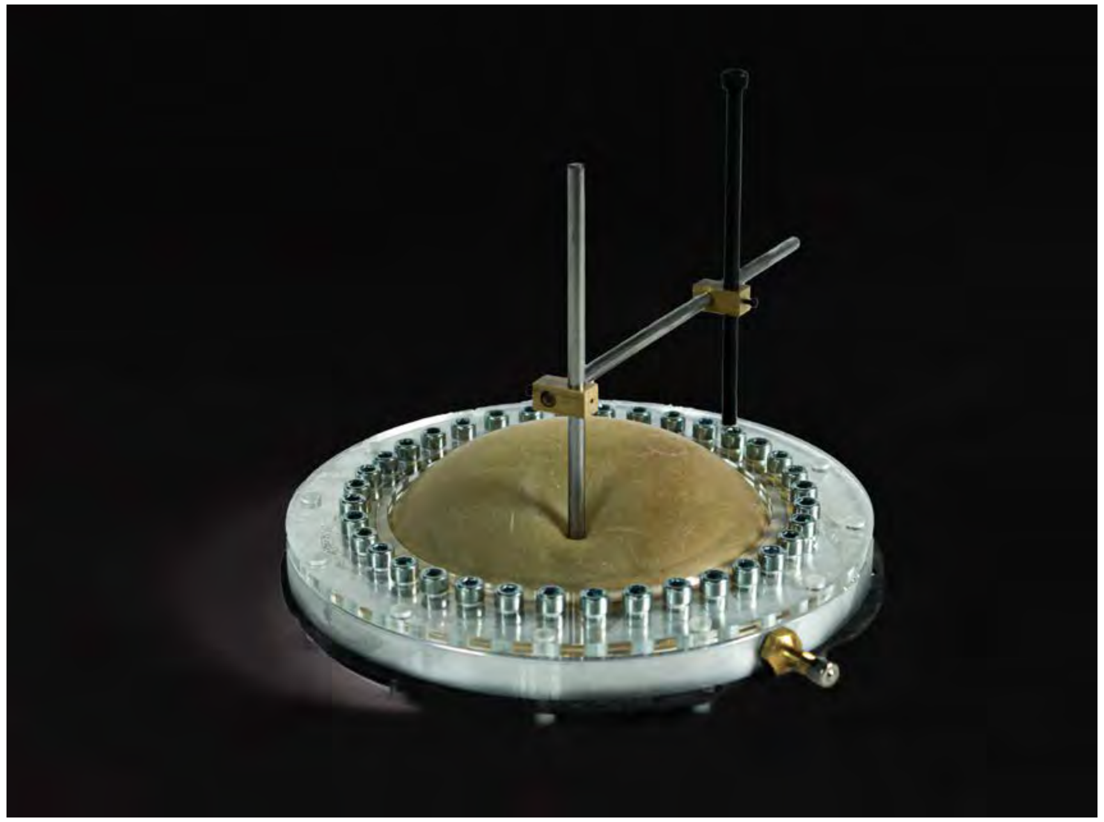
Having discovered new priciples for double curved cast elements before knowing the exact working methods of other researchers - I dived into finding new methods with elastic membranes instead.

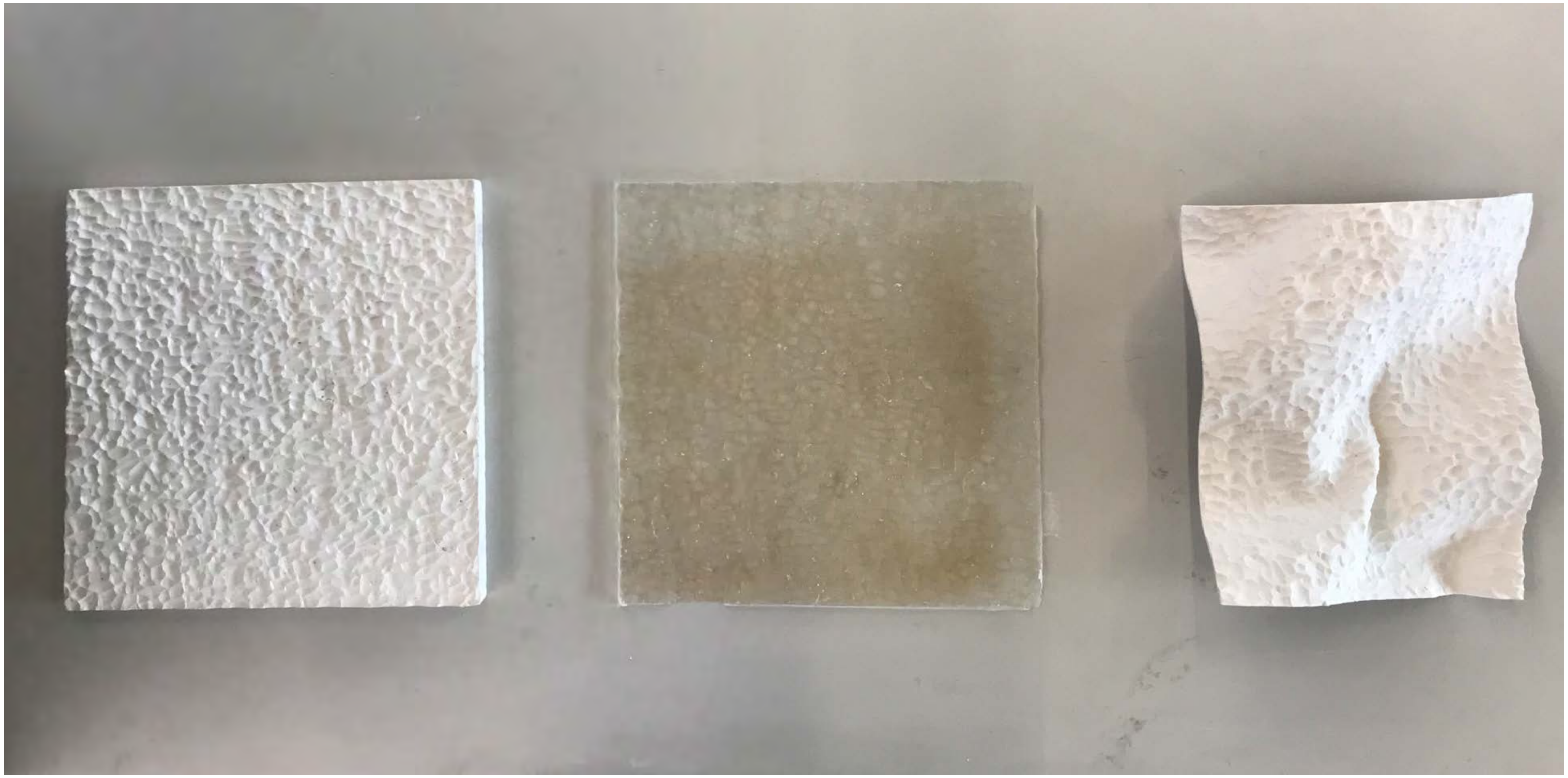
Elastic membranes as formwork offer many advances over other systems such as the reusability and thereby usage for various shapes, global tensile equilibrium of the membrane - resulting in the ‚ideal' shape between given boundary conditions.

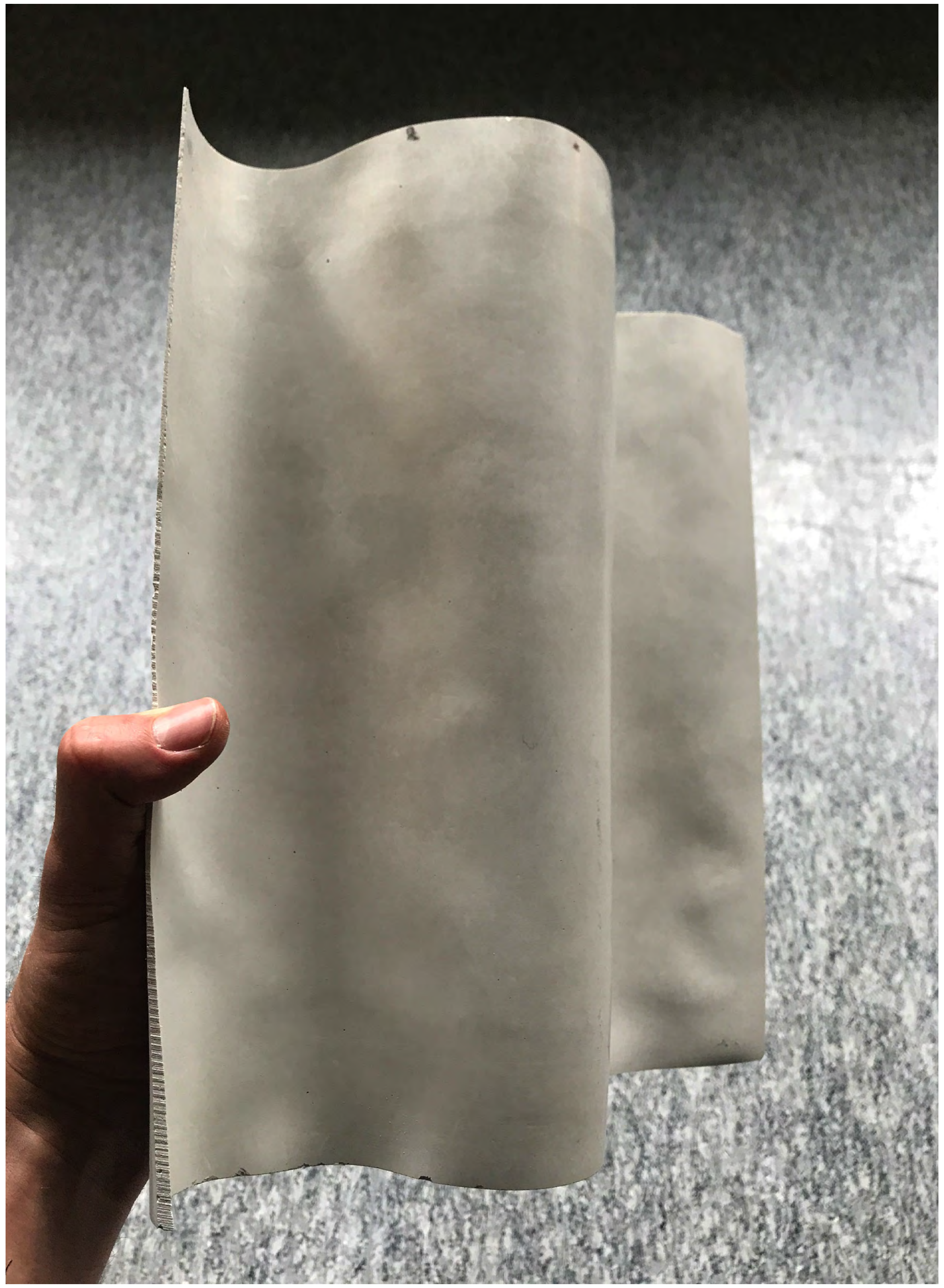
However they also come with some disadvantages such as a slightly non-uniform deformation curvature under a non-uniform stress distribution within a membrane system - stress applied on a point is always distributed into the membrane area, the closer to the applied force, the more deformation.

Another challange is the exact control and simulation of the physical membrane.

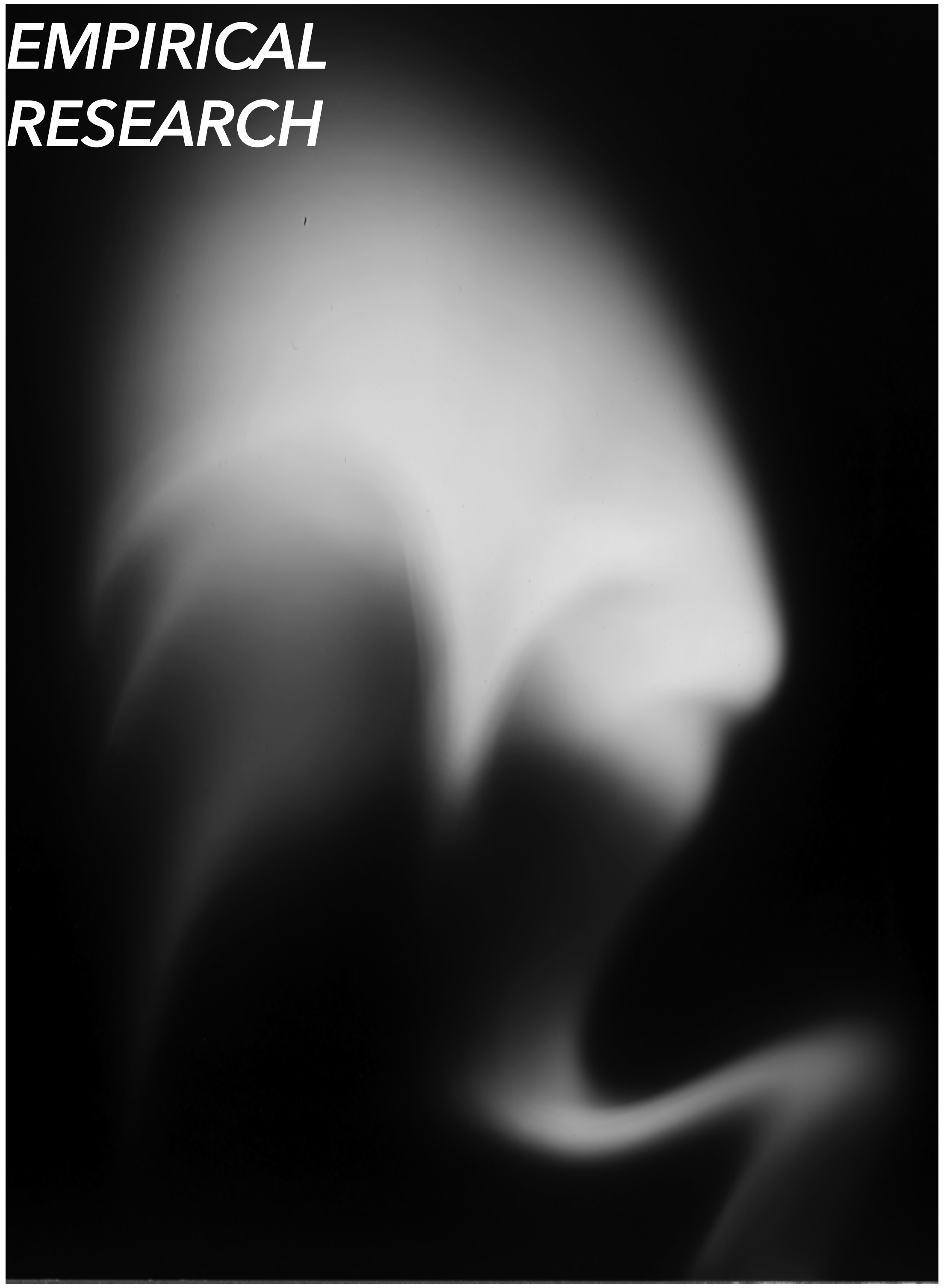
Following experiments in machinery set-ups and plaster models show the diverse possibilities of working with elastic membranes as formwork, be it in a global shape or a segment, with a textured membrane under pressure or suspended like a curtain, stretched by a machine or crumbled like paper.





EMPIRICAL RESEARCH



EMPIRICAL RESEARCH // COMPLEX CONCRETE BENDING MACHINE

The complex concrete casting machine is a new approach on a elastic membrane formwork.

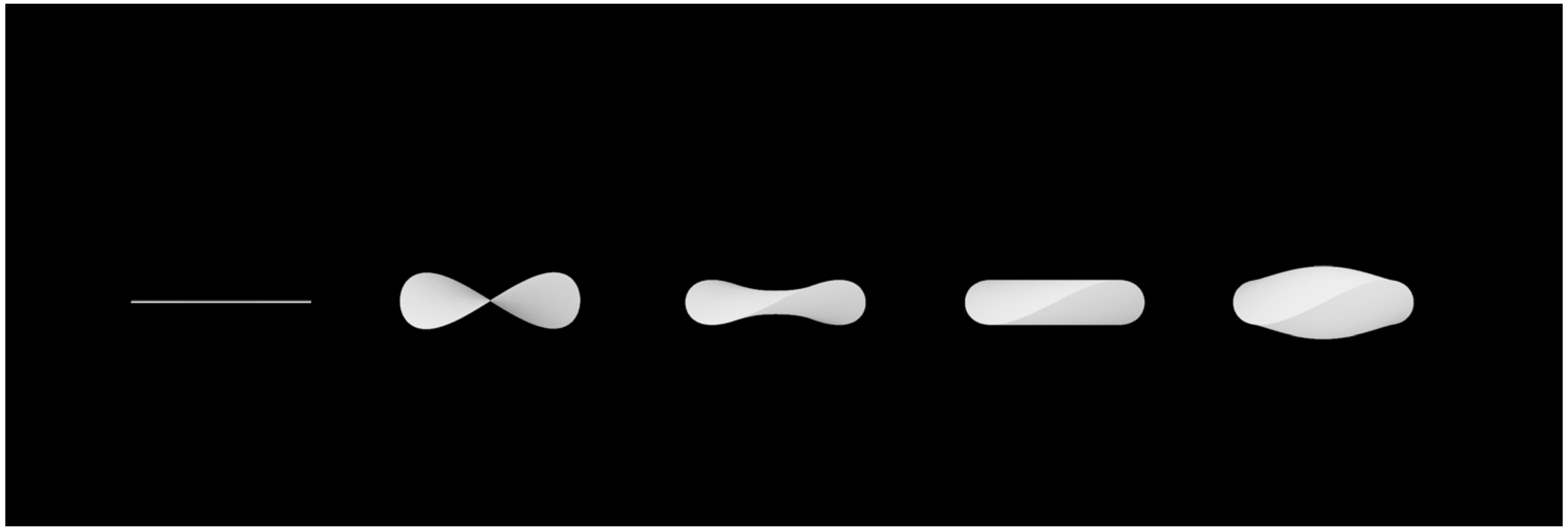
It features a circular inflatable elastic membrane, mounted on a circumferential suspension cable automatically adaptable in length.

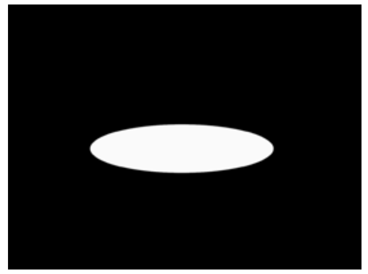
The suspension cable is then mounted to 8 z-axis actuators through a pulling cable adaptable in length.

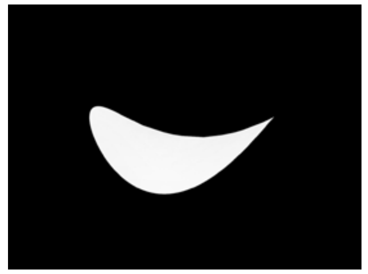
The 8 actuators sit between two circcumferential rails which are mounted on a rigid aluminium frame.

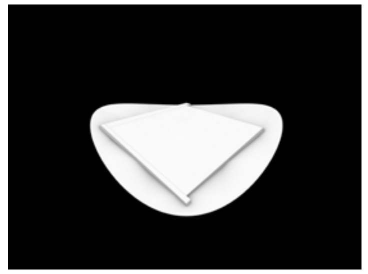
Among the bottom rail sits a flat casting plate to start the casting process with a rigid support.

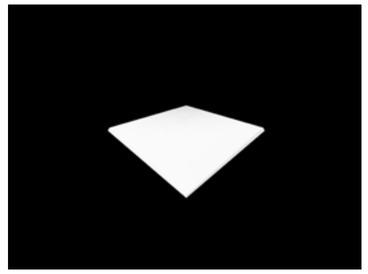
Line lasers project the boundary conditions of the cast element onto the deformed membrane, it's height in relation to the frame is measured with lasers and a 3D scanner.

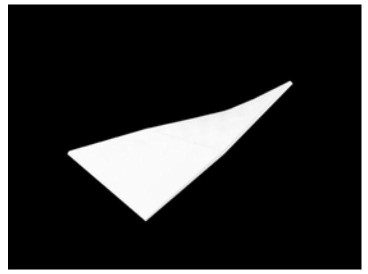


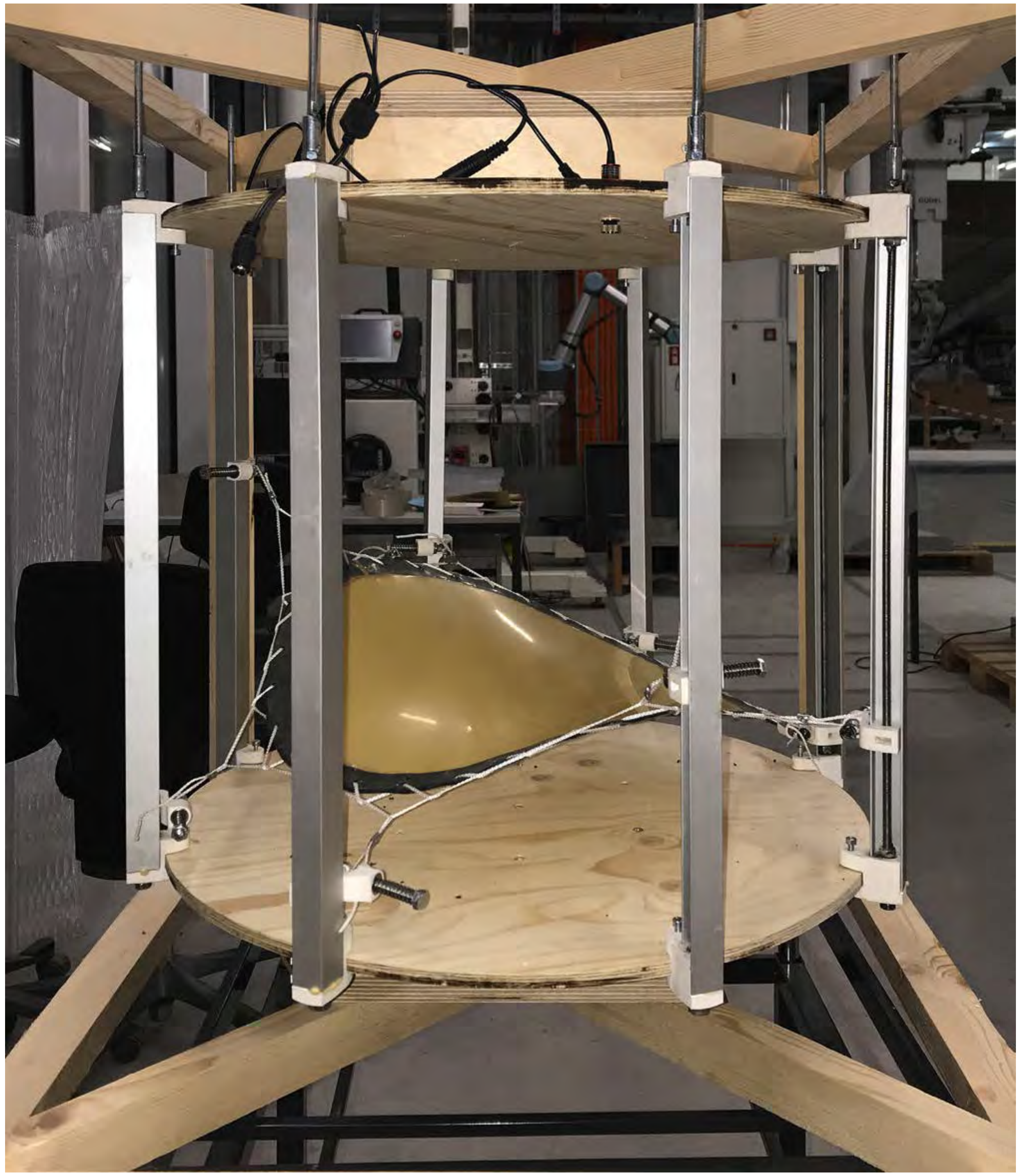


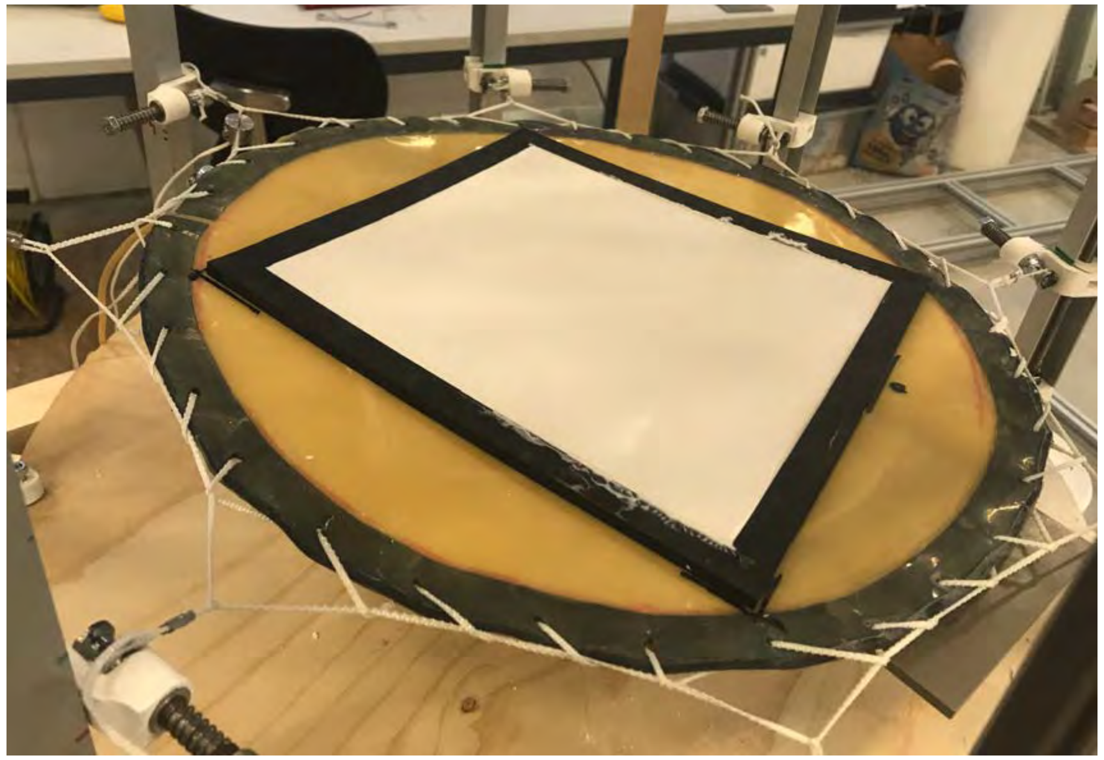


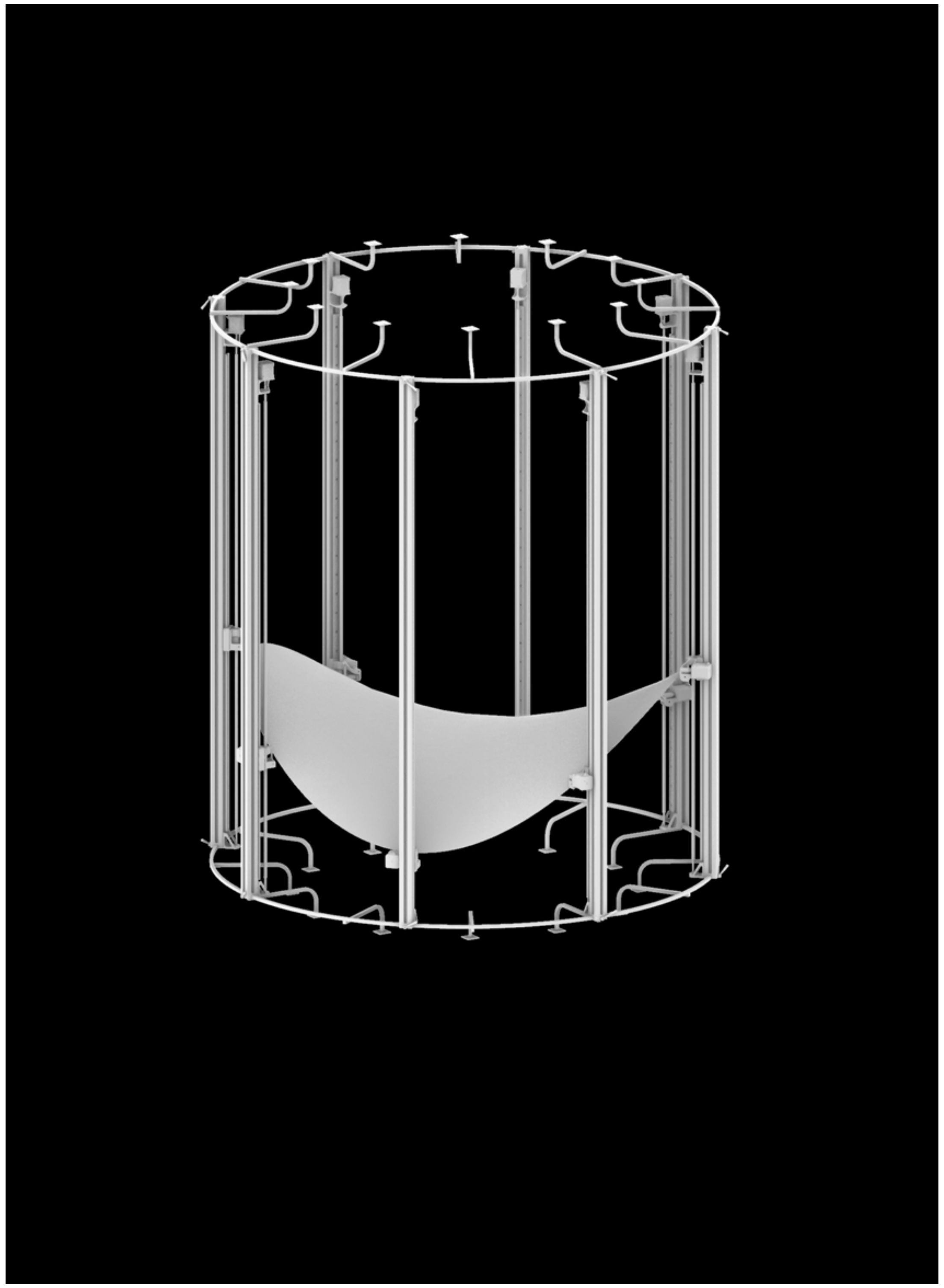


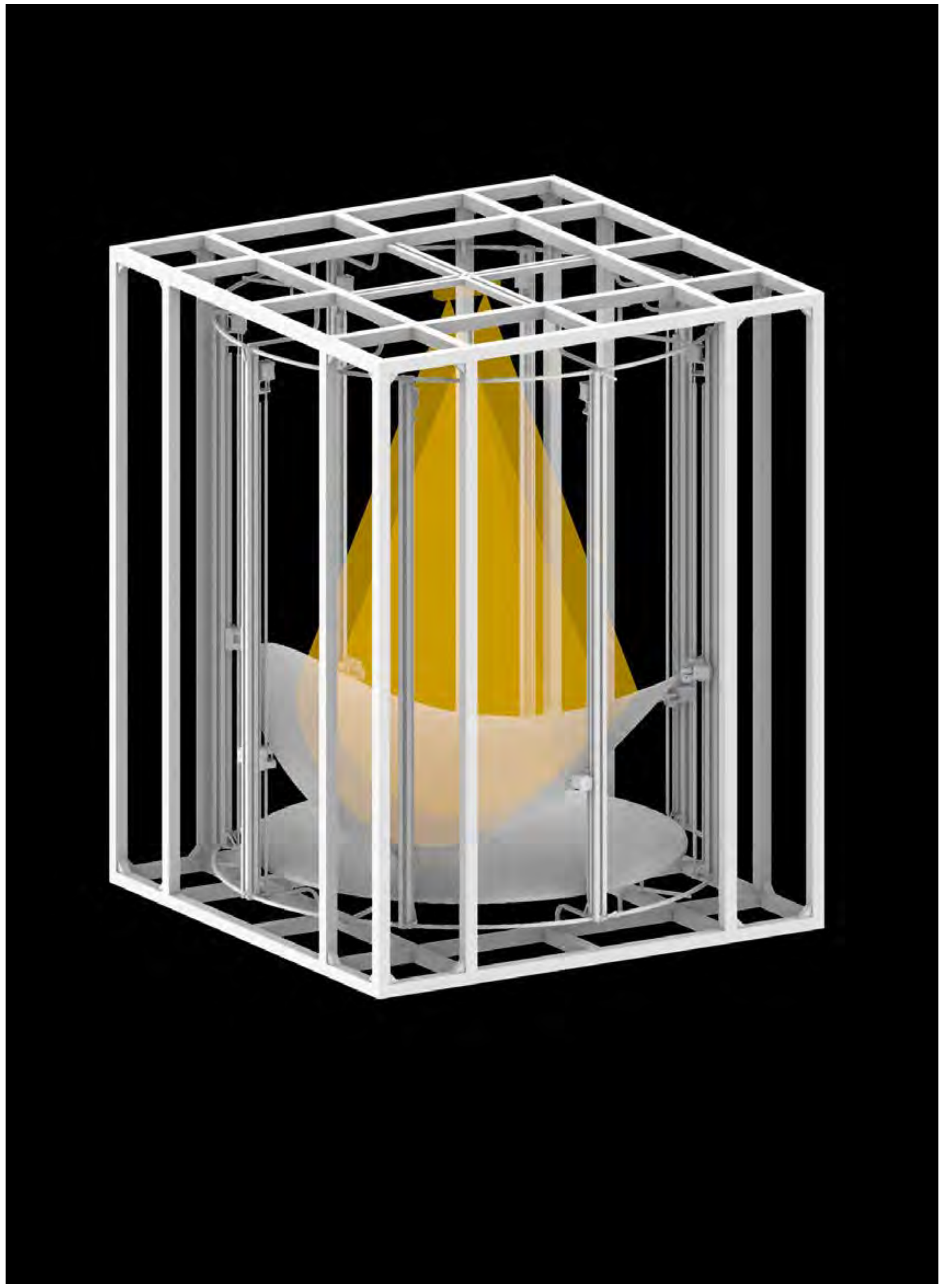


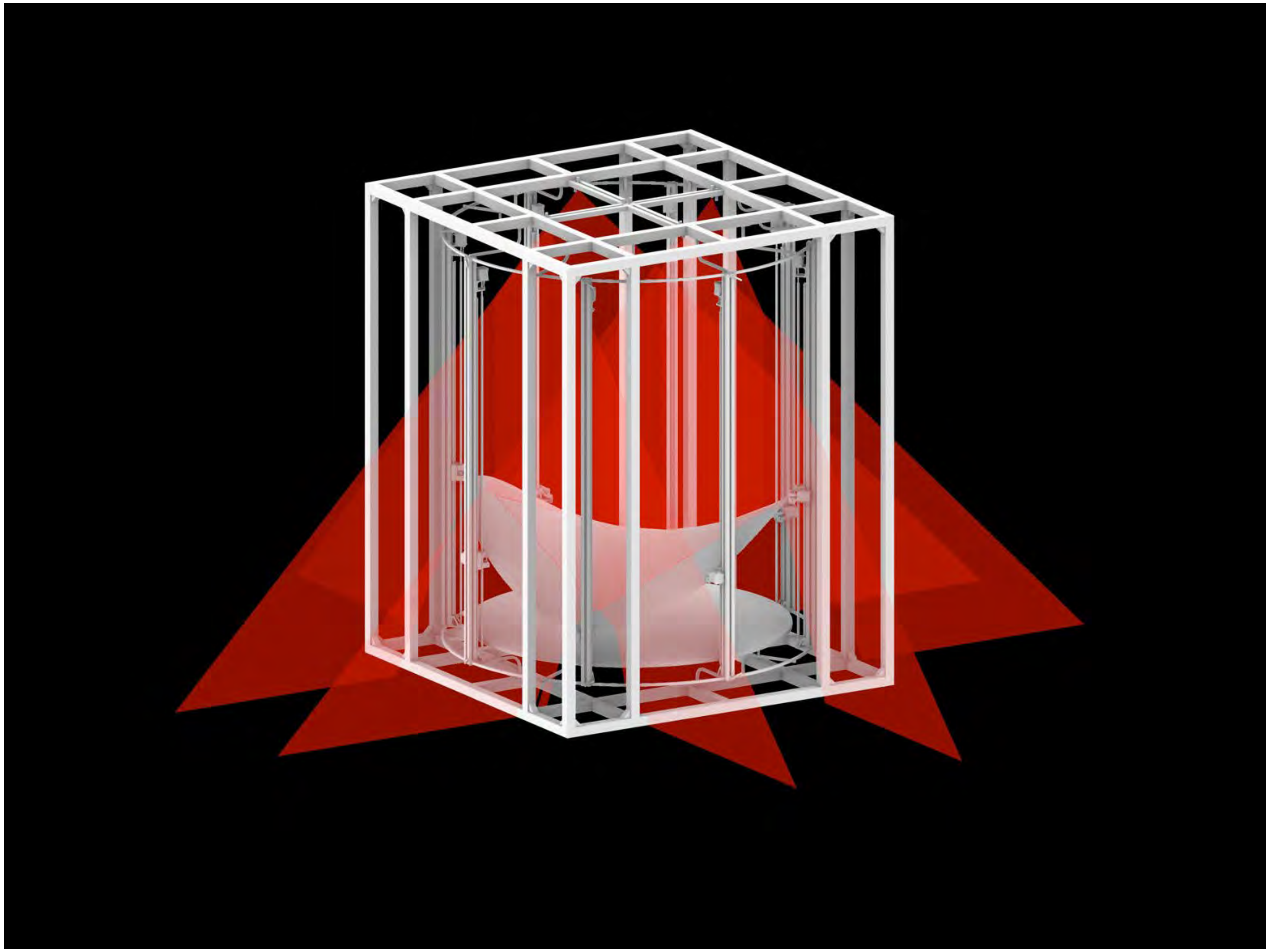


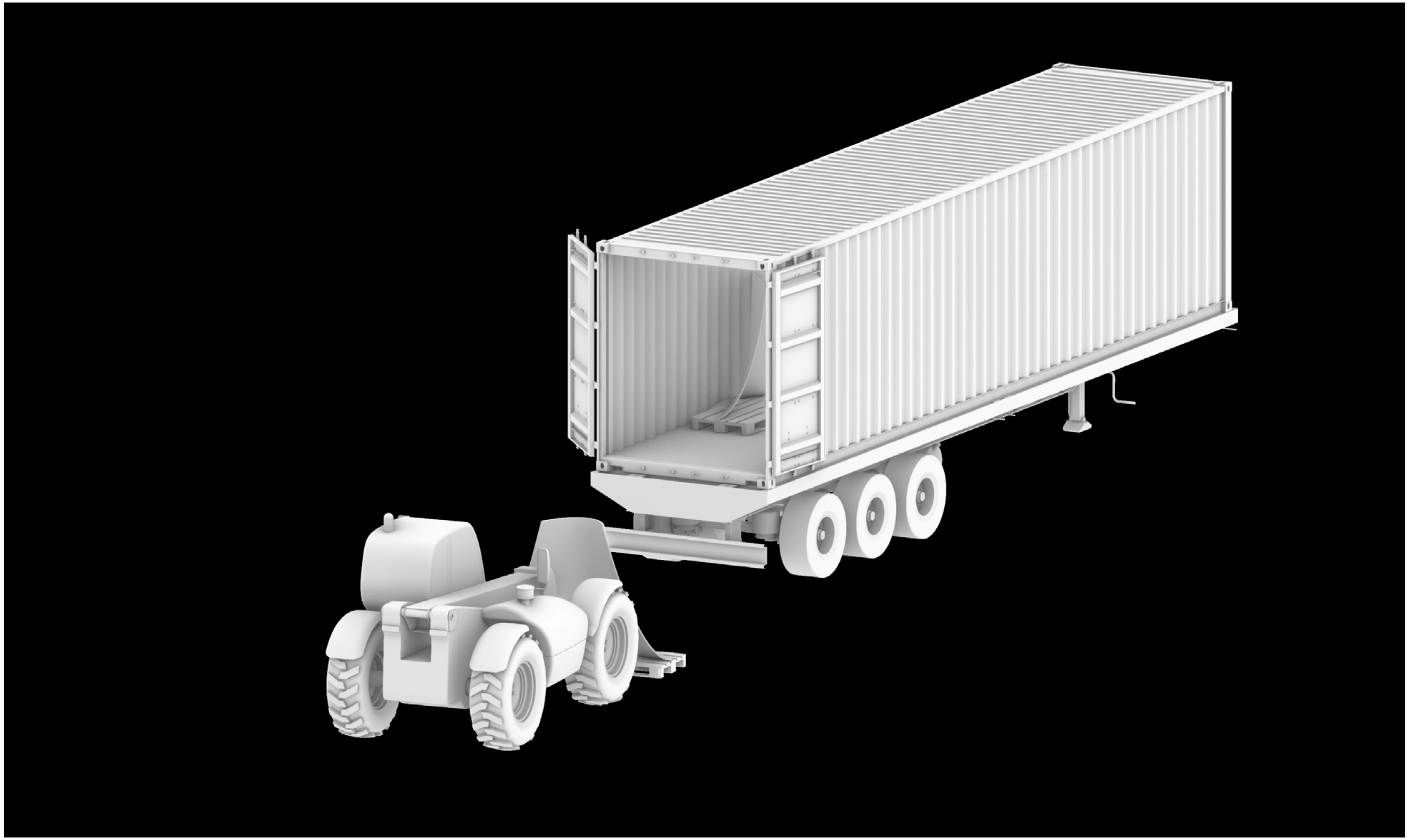




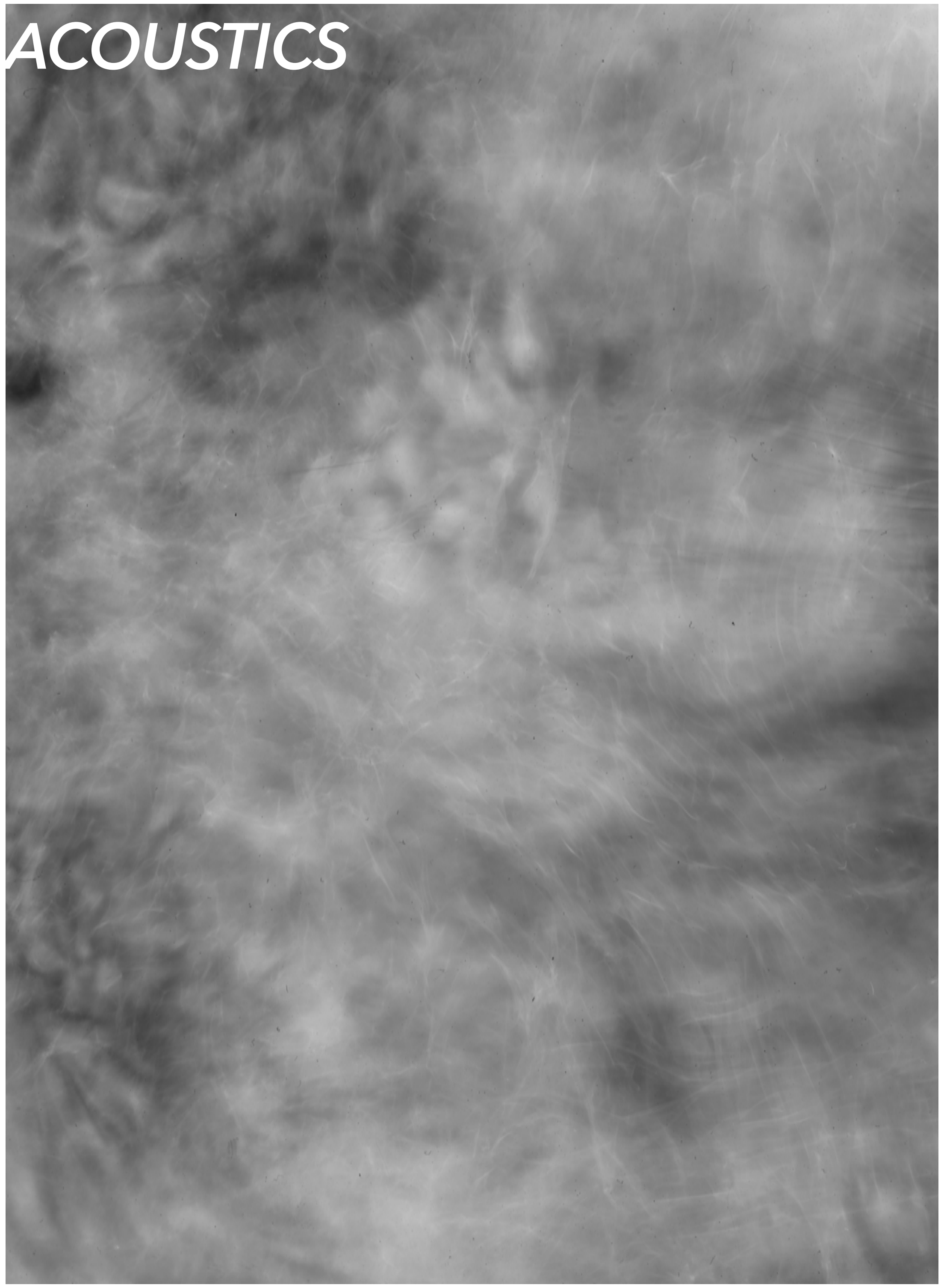








ACOUSTICS



ACOUSTICS
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INTRODUCTION

Acoustics - pragmatically divided into diffusion, absorption and perception, presents a field of research difficult to tackle without a profound expertise.

The following pages exemplify the projects intension.

Scientific literature supported by an expert and good online tools provided the foundation for this project together with the analysis of the feedback-recordings made in the space before the installation.

They describe the parameters set to design a new interpretation of a small concert space for a ‚Stubenkonzert'.

It would be a bit far stretched to introduce the needs for good acoustical properties throughout history and its different settings like sacrilegious spaces, spaces for the display of power, entertainment or musical production -
simplified, they all share two common characteristics:

- The need for something or someone to be heard or understood loud and clearly.

- The act of listening as a social gathering.

For now ignoring the scenography and speaking only about spatial acoustics:

Amplification and homogenity of sound - thus a good audibility, can be accomplished through a good balance between the directivity of the sound source, its diffusion through reflectors and the right amount of absorpotion.

By doing so, we relate the volume and aspect ratio of the space directly to the absorption coefficients of its materials and the resulting reverberation time.

Of whatever nature an assembly might be, to understand, hear or proclaim the same thing is a unifying act.

In this sense, the living room concerts in the aristocratic system e.g. by Joseph Hayden and Wolfgang Amadeus Mozart, as well as the „gathering among family and friends" by Beethoven, the Mendelssohns, Franz Schubert or the Schumanns, can be understood as entertaining and intimate events of music and discussions to establish a ‚community'.

ACOUSTICS // REFERENCES AND VISION

Comparing the projects space volumetry of 200m^3 with other concert spaces, it relates to the historic term of chamber-music.

This music was explicitly written as a ‚secular' counterpart to church music for a small group of instruments to perform in a larger room.

The most famous formations being the piano trio or the string quartet.

With the further development of new musical styles and the invention of the pianoforte, the formations grew and the former „living room" concerts transformed from „home to hall".

Nowadays, a distant remainder of the former chamber music spaces can often be found in „band rooms".

My intention is to reclaim the intimate and experimental classical concert athmosphere through architectural design, music and performances for an audience of 30 people.

fig 18

fig 19

ACOUSTICS
//
ACOUSTICAL QUALITIES OF CONCERT SPACES

Every space has variable acoustic characteristic in different frequencies due to its volumetry and aspect ratio. The spaces different materials with their properties in reverberation shape the acoustic impression.

Example:

As an ‚ideal' diffusive space we hear the same reverberation time and sound volume at any listening position.

If this is often not the case, it's important to tune the characteristics of diffusion and absorption to the musical and aural demands.

The requirements depend much on the chosen instrument and the played music - it might be captious, but every musical repertoire demands other acoustic arrangements of the space to perfectly highlight its character.

Concert halls with outstanding acoustical properties often contain more than 1000m^3 - enough to provide a good reverberation time even throughout the lowest frequencies without creating room modes.

fig 20

fig 21

fig 22

fig 23


ACOUSTICAL
RESEARCH

ACOUSTICAL RESEARCH // SOUNDWAVE

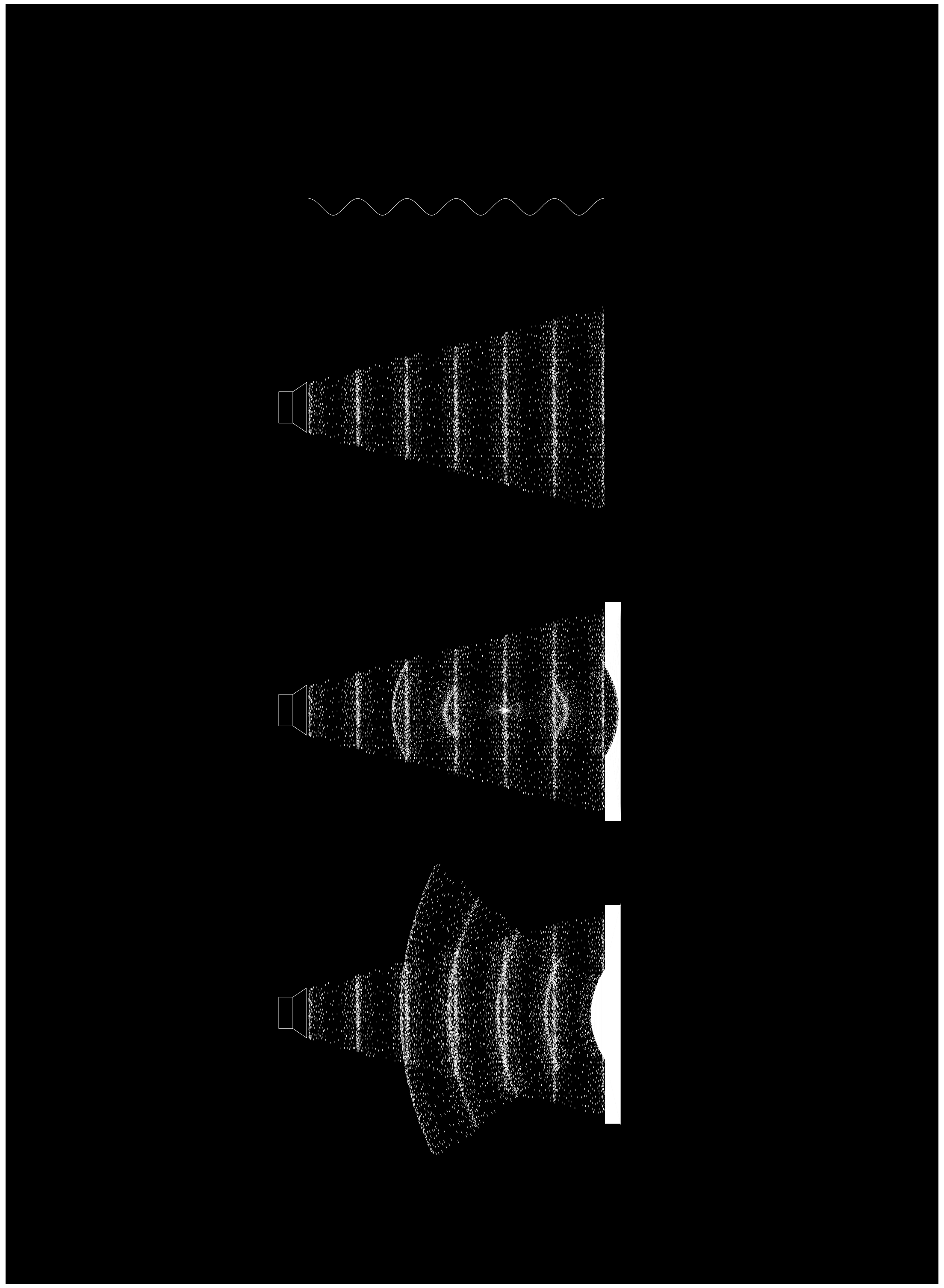
SOUNDWAVE
Visualised - yet simplified in a sinewave, the soundwave is characterised by a oscillation of density and pressure.

The characteristics of the soundwave will be shown as follows:

HIGH DENSITIY & PRESSURE
LOW DENSITY & PRESSURE
REFLECTORS//DIFFUSORS

PERCEPTION
The process of hearing is wondrous:
frequency, sound volume, masking effect, directivity, direction of the sound and level difference form the main differentiations our ear and brain makes to process sound and its qualities. This, along the visual impression and our mood, form the auditive perception.

REFLECTORS
The focal of curved surfaces sets the absolute minimal distance for the audience to be seated away from.



ACOUSTICAL RESEARCH
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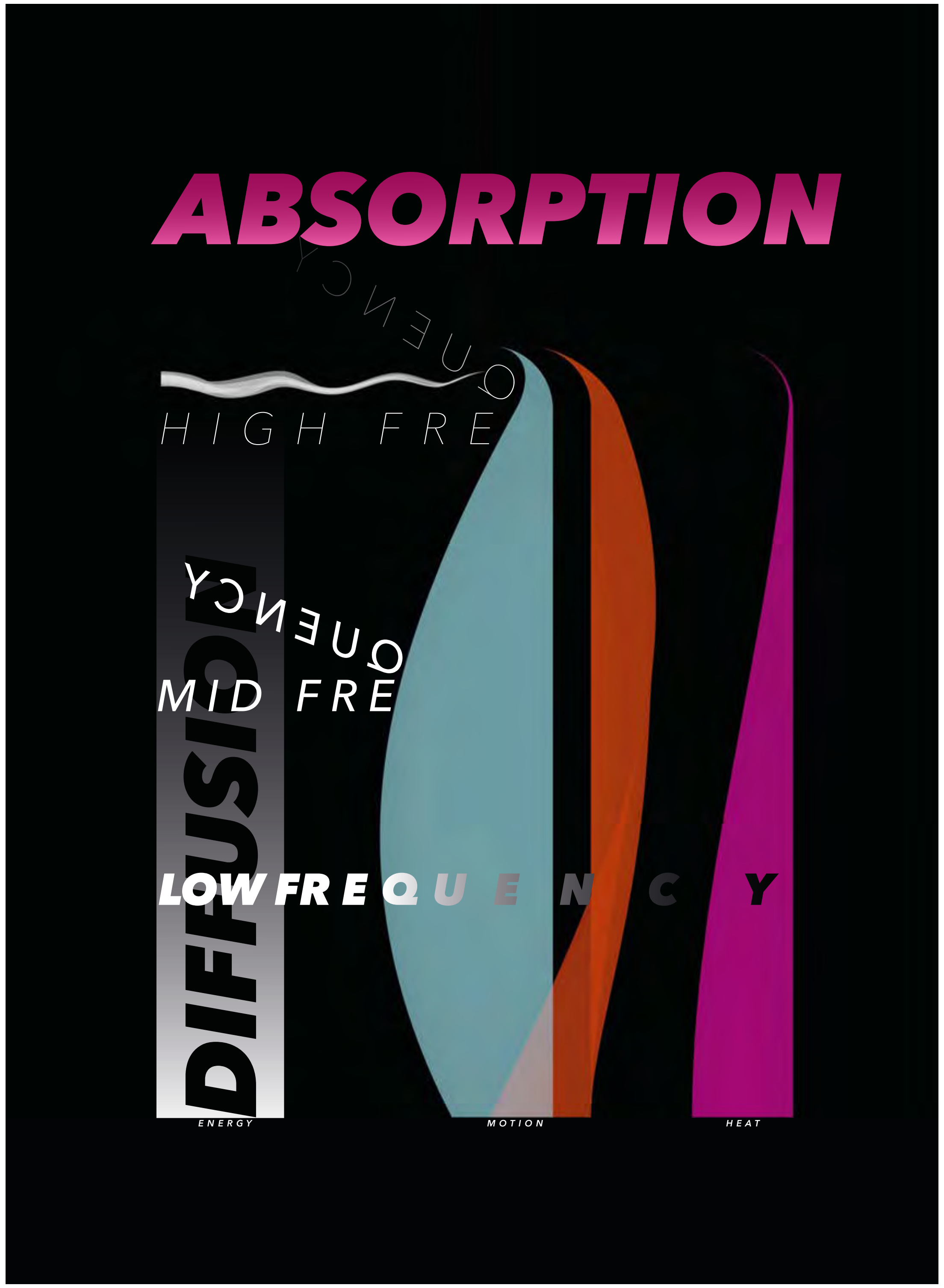
DIFFUSION ABSORPTION

DIFFUSION
Energy-free procedure of spreading the sound energy evenly in a given environment.

ABSORPTION
Transformation of sound energy into heat in the absorbent material - yet a part of the energy is transmitted through or reflected by the body.

MATERIALITY
The density and rigidity of a material define absorbent or diffusive characteristics as well as its total weight in relation to the sound energy .



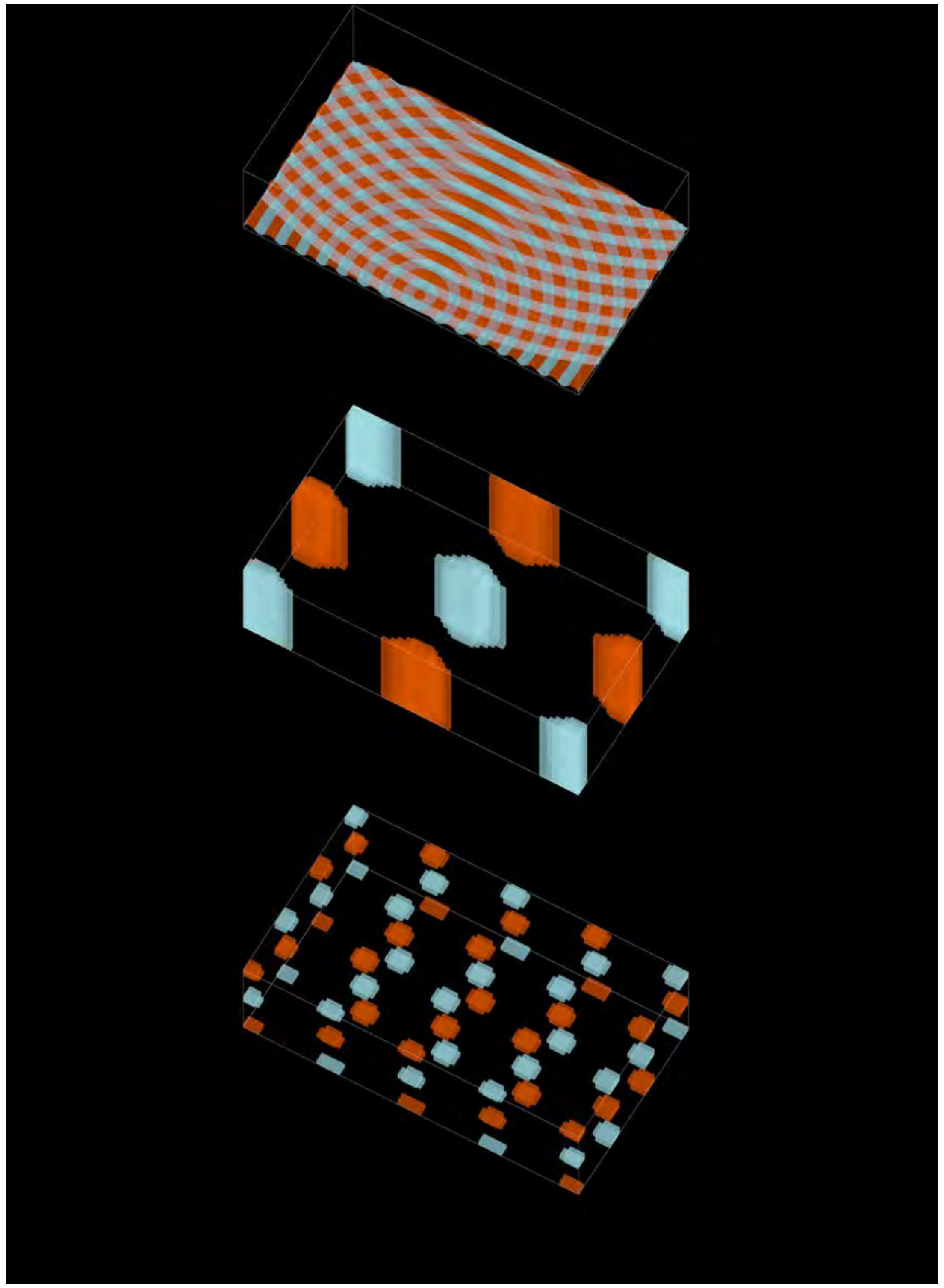
ACOUSTICAL RESEARCH // ROOM MODES

To operate with 1/5th of the minimum of an ‚ideal' volume for a concert space presents a physical barrier not to overcome: The acoustic qualities will always be those of a small room and not a hall.

Since floor, walls and ceiling are perpendicular to each other, standing waves with phase addition and phase cancellation of low frequencies (modes) occur.

The waves overlapping ‚in phase' (orange [sin] OR blue [cos]) present peaks and add up in sound volume, the waves ‚out of phase' (orange [sin] AND blue [cos]) create noise cancellation.

The higher the frequency, the more homogenous the distribution of the sound level appears to our ears.



ROOM
MODES
SIMULATION
HPT B71

HIGH
AND
LOW
PRESSURE
AREAS

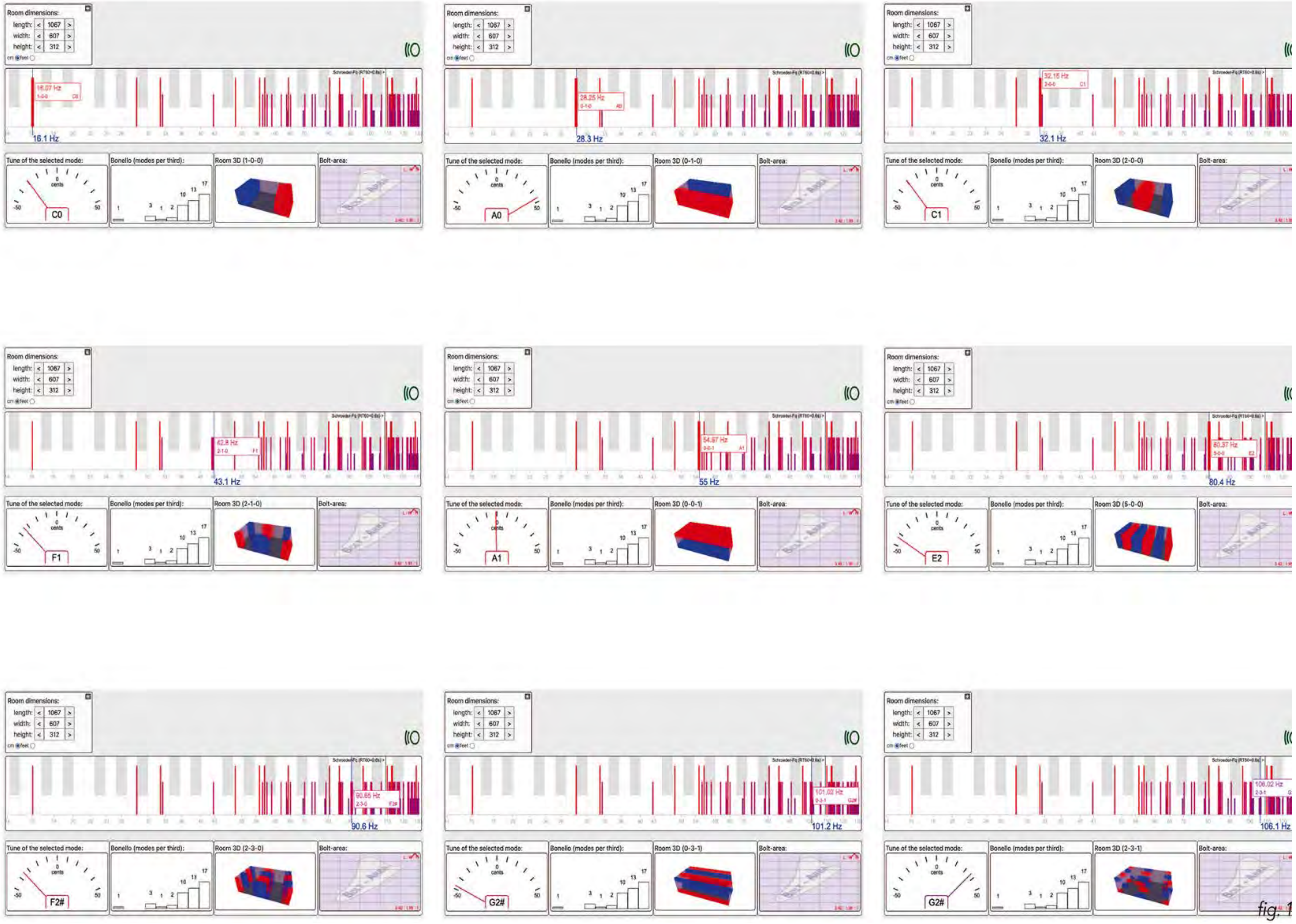


fig. 1

fig 24

ACOUSTICAL RESEARCH
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TONE

Instruments each have their own charakteristics in sound which make them distinguishable from each other.

Each played note is a motion of waves with changing numbers of oscillations and their intensity over time.

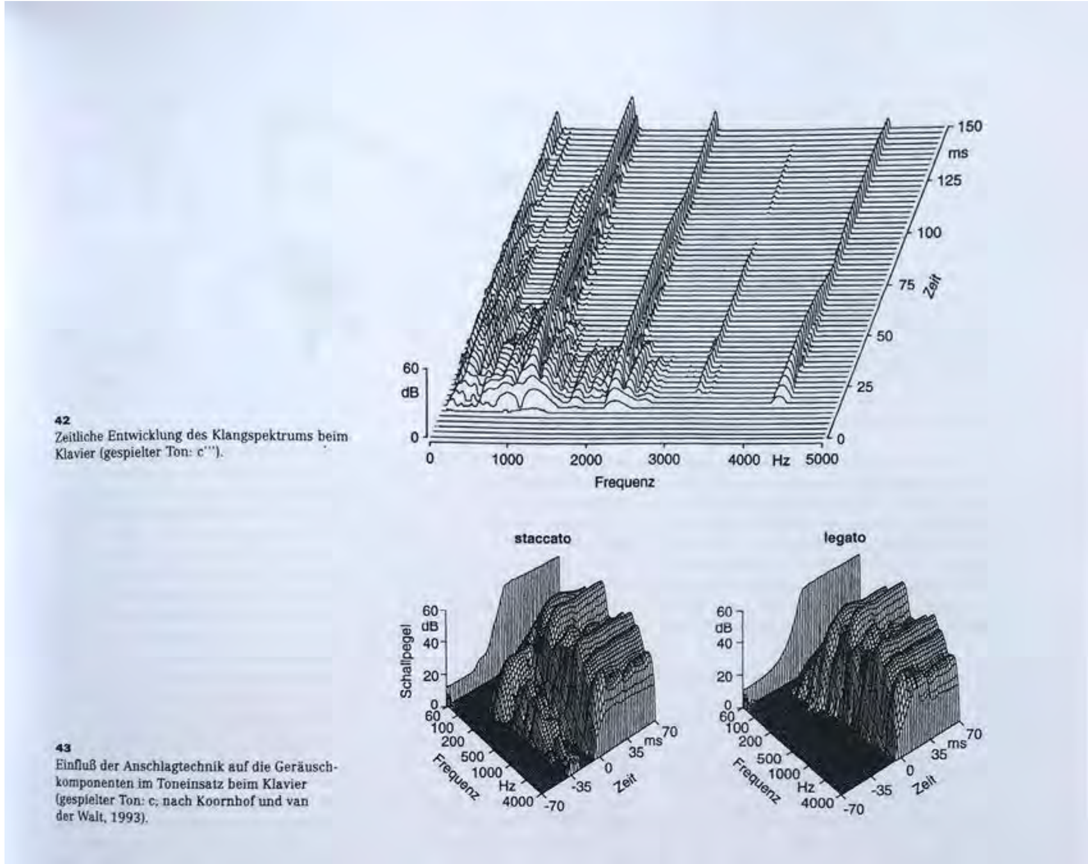
In this model, the wave motions are understood as a coexistance of different partial oscillations, called overtones.

To characterise a tone, it can be divided into three parts:

1. The transient effect: The time it takes for a tone to develop its full characteristics.

2. The static condition: The time, in which a tone doesn't change its characteristics (almost) at all.

3. The fading time: The time it takes for a tone after the halt of stimuli to decay to complete quietness.



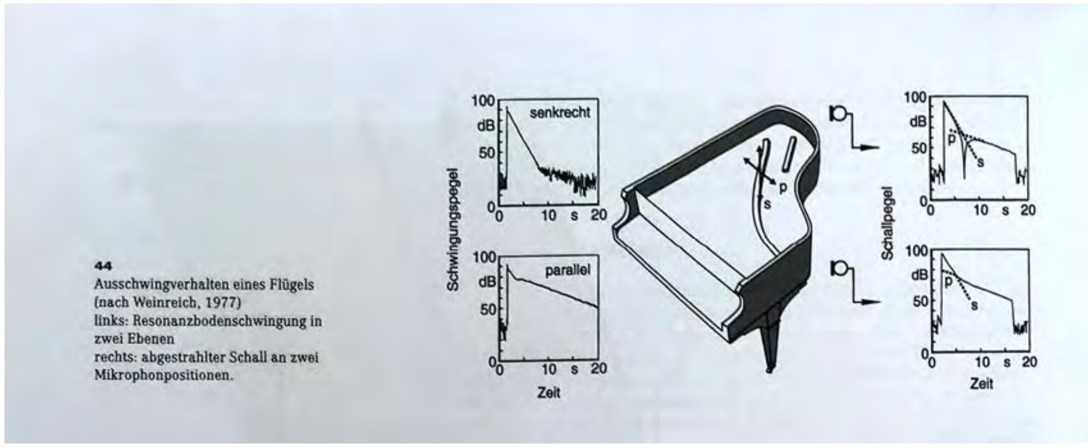


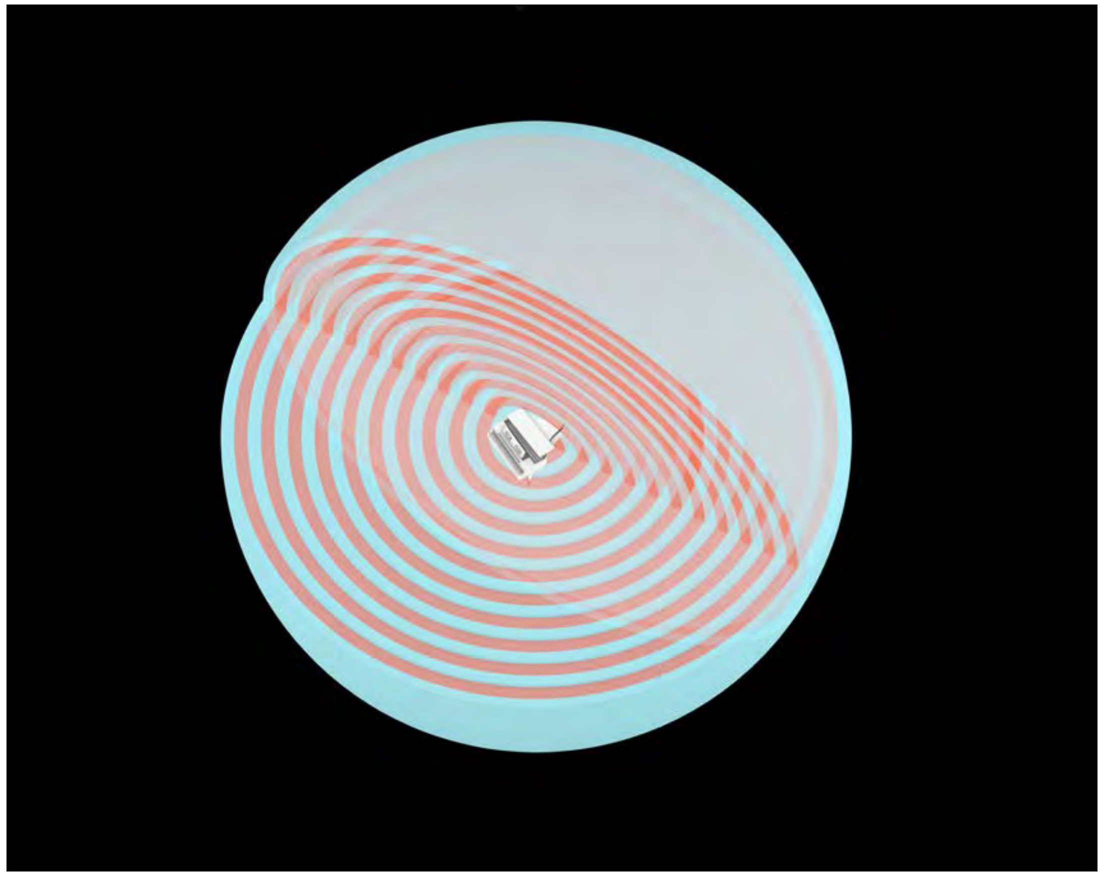
fig 25 -26

ACOUSTICAL RESEARCH
//
THE PIANO

The transient effect contains much of the sound characteristics to distinguish different instruments from each other, often through components not included in the later sound impression - e.g. the sound of the hammers hitting the strings on a piano.

This is one of the main characteristics to identify the sound of a piano:

Besides the distribution of sound throughout the body of the instrument and enlongated fading time withouut the dampers, it is the noise of the hammers hitting the strings can not be covered/masked by the overtones, especially in the middle to high frequencies.



ACOUSTICAL RESEARCH

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DIRECTIVITY

The directivity, i.e. the dependency of the radiated sound pressure to its direction moving away from the body of the instrument defines the way we percieve the sound in a given space.

It is dependent on the frequency, the materiality and the shape of the instrument.

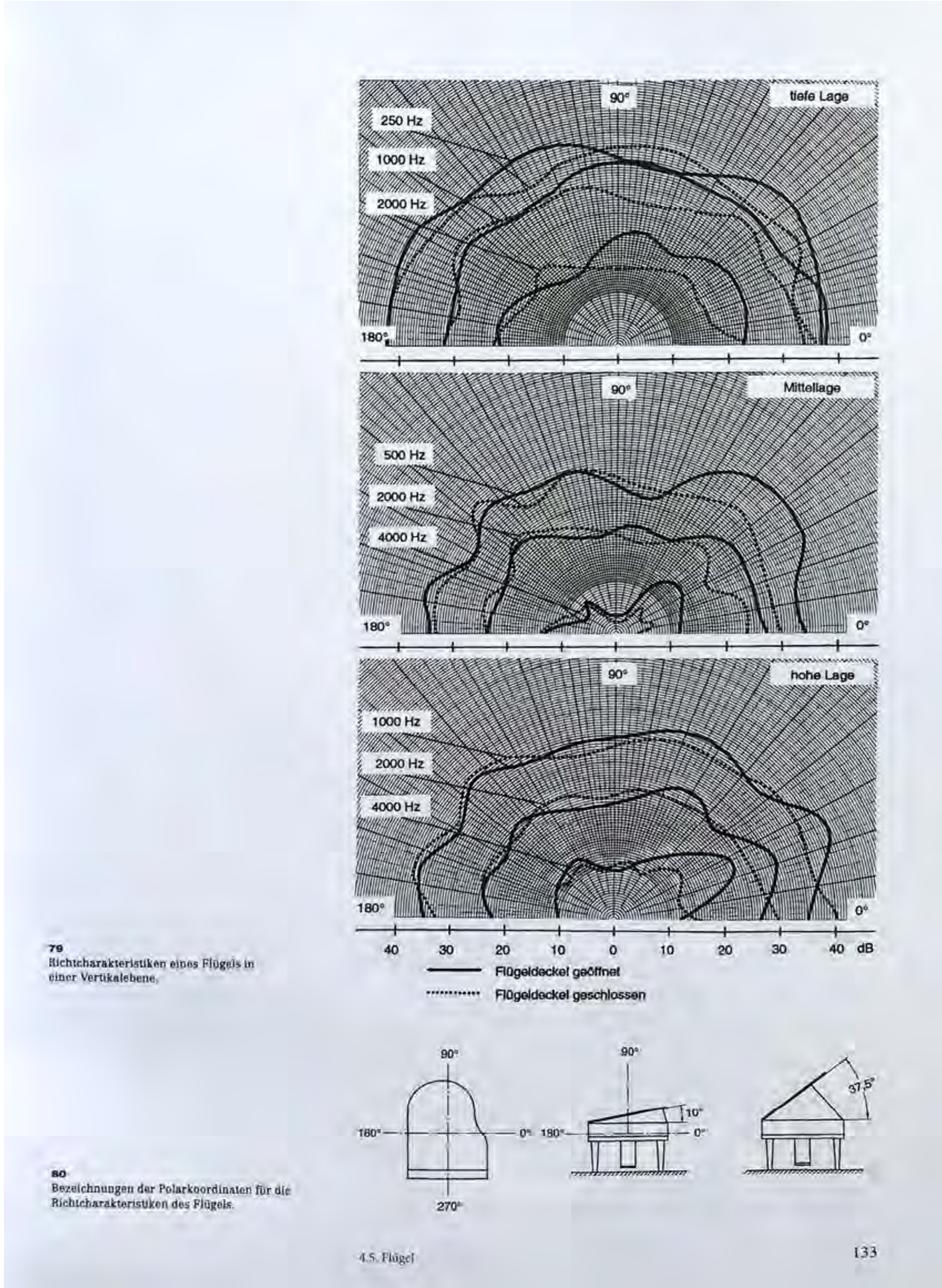

fig 27

ACOUSTICAL RESEARCH
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REVERBERATION RECORDINGS

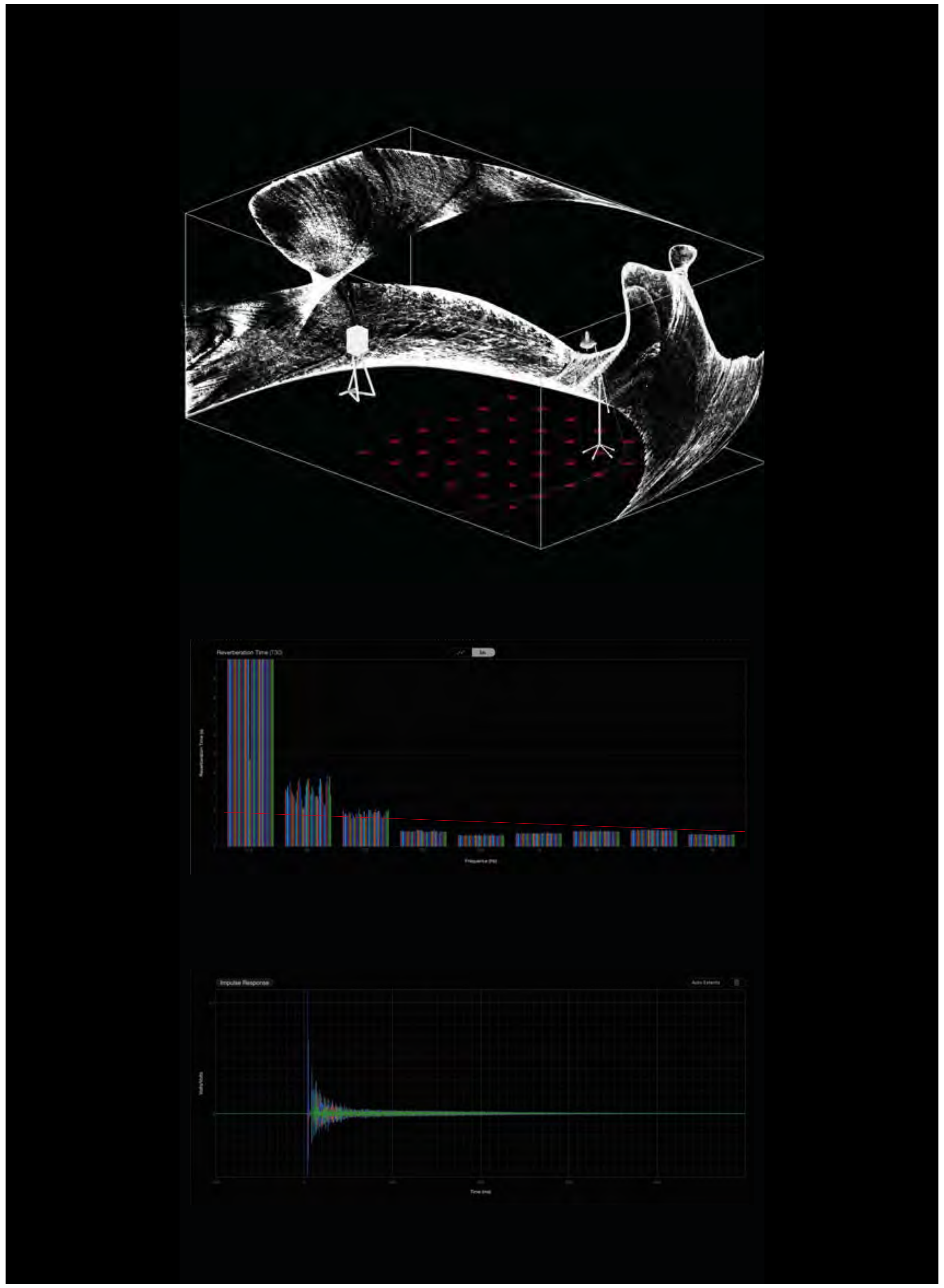
Reverberation recordings are used to identify the acoustic behaviour of reverberation in different frequencies with measurements taken from different locations in the room.

To visualise the detected low and high sound-volume areas in all the different frequencies sets the first constraints on where to place absorption and diffusion elements.

The diagrams show the reverberation time RT and the impuls response of the project space HPT B71:

HPT B71 ‚suffers' from low frequency room modes and a poor RT in the mid and high frequency range.

The impulse response graph shows an exponential decay of sound instead of amore linear decay which is better for concert rooms.



ACOUSTICAL RESEARCH

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REVERBERATION TIME CALCULATION

$RT_{60} = 0.16V/A$

$V(B71) = 202m^3$
$A(B71) = 256m^2$

The sabine calculation shows reverberation time as the volumetric absorption coefficient of the material per area.

As classical music with piano and strings has an optimal reverberation time (RT60) from 1.2 to 1.6 seconds as an average, its maxima and minima shouldn't differ more than 1 second. To achieve this in the given space, we find that an equivalent absorption area of 20-30m² is needed troughout all frequencies.

As only middle to high frequencies are absorbed too well in HPT B71, this absorption area is mostly needed for frequencies below 150Hz.

The middle and higher frequencies require more diffusion elements to evenly distribute the sound energy.

Lenght L: 10.62 m	Width B: 6.07 m	Total floor area: 64.46 m²
Height 1: 3.12 m	Volume: 201.13 m³	Total wall area: 89.15 m²
Door area: 6 m²	Window area: 9 m²	Total ceiling area: 64.46 m²

Calculation

Floor	64.46 m²	Linoleum on concrete	125hz: 0.04 |250hz: 0.04 |500hz: 0.05 |1000hz: 0.05 |2000hz: 0.03 |4000hz: 0.02
Wall	89.15 m²	Concrete, painted	125hz: 0.01 |250hz: 0.01 |500hz: 0.01 |1000hz: 0.02 |2000hz: 0.02 |4000hz: 0.02
Door	6 m²	Door, heavy	125hz: 0.14 |250hz: 0.1 |500hz: 0.06 |1000hz: 0.08 |2000hz: 0.1 |4000hz: 0.1
Window	9 m²	Window (3+12+3 mm)	125hz: 0.25 |250hz: 0.2 |500hz: 0.1 |1000hz: 0.05 |2000hz: 0.04 |4000hz: 0.05
Ceiling	64.46 m²	Troldtekt PLUS 25+18 mm / Cavity 22 mm / 18 mm mineral wool (C)	125hz: 0.1 |250hz: 0.3 |500hz: 0.75 |1000hz: 1 |2000hz: 0.85 |4000hz: 0.95

Calculation 1

	Frequency						Average	
Reverberation time T [sec]	**125hz**	**250hz**	**500hz**	**1000hz**	**2000hz**	**4000hz**	**From 125hz**	**From 250hz**
Calculation 1 Without absorber	2.47	1.28	0.60	0.46	0.54	0.49	0.97	0.67

fig 28


DESIGN

DESIGN
//
MODELLING

My method of design works reciprocal from physical modelling back to 3D CAD drawing, sketching new fabrication methods and back again into physical modelling, where the ideas can quickly be tested spatially.

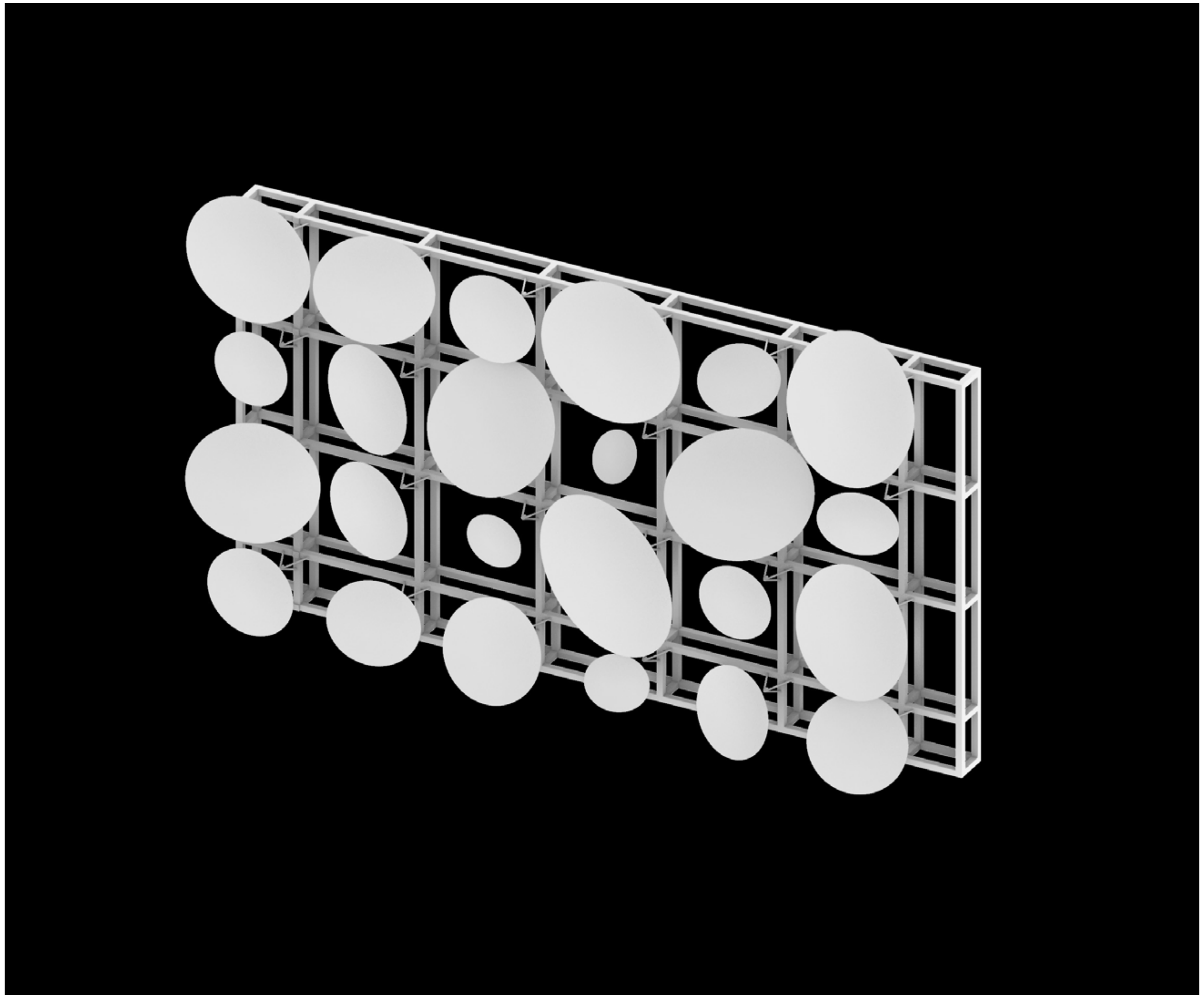
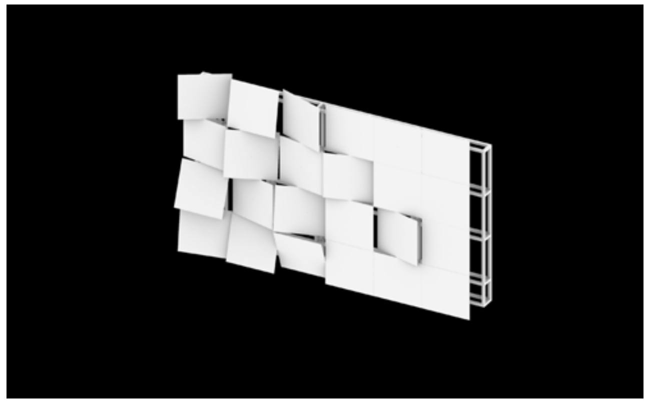
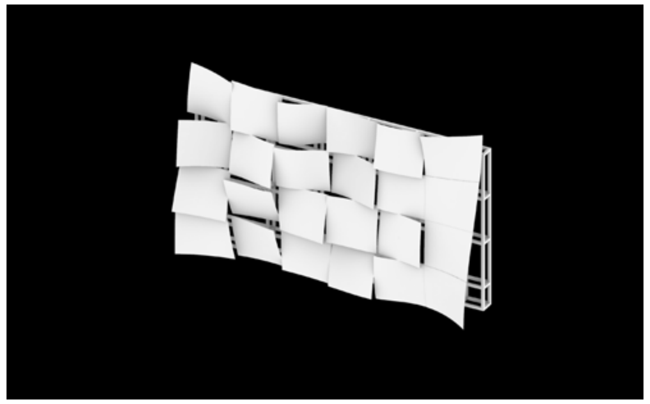
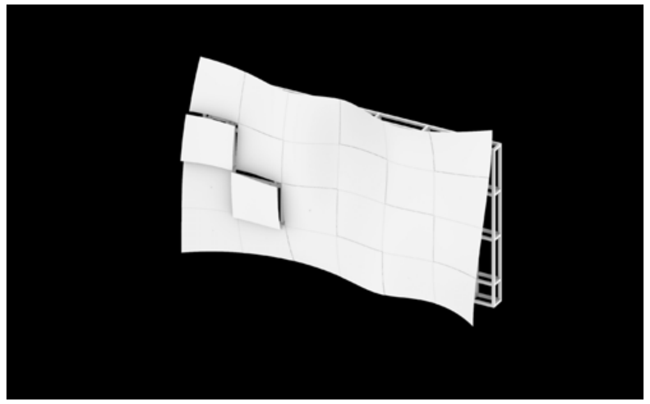
The intention was to apply the acoustical findings with regard to the new fabrication technology and set the design conctraints as follows:

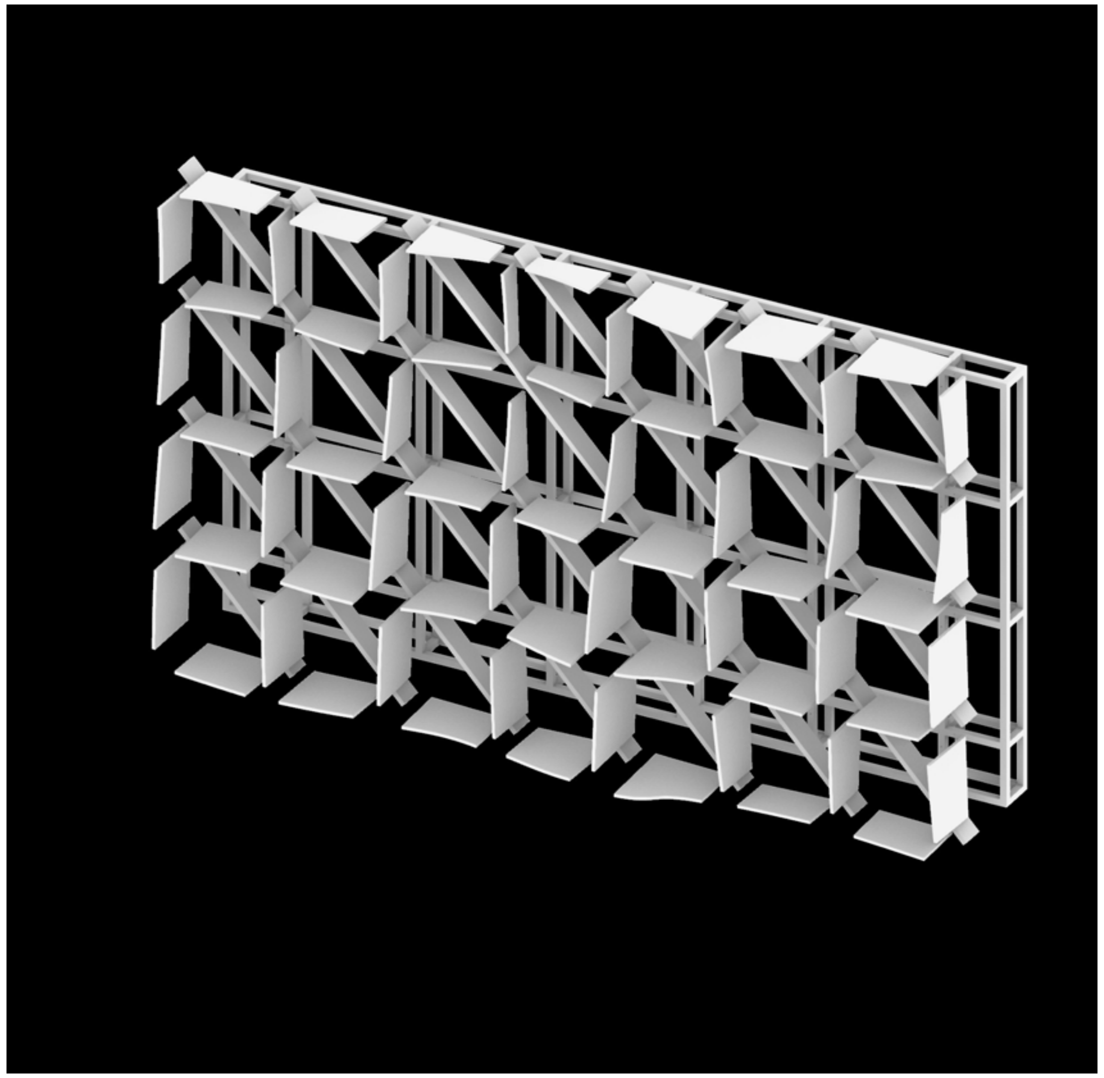
Acoustics:
The ceiling panels should work as reflectors for mid to high frequencies, the wall panels as reflectors for low to mid frequencies and absorbers for the lowest frequencies.

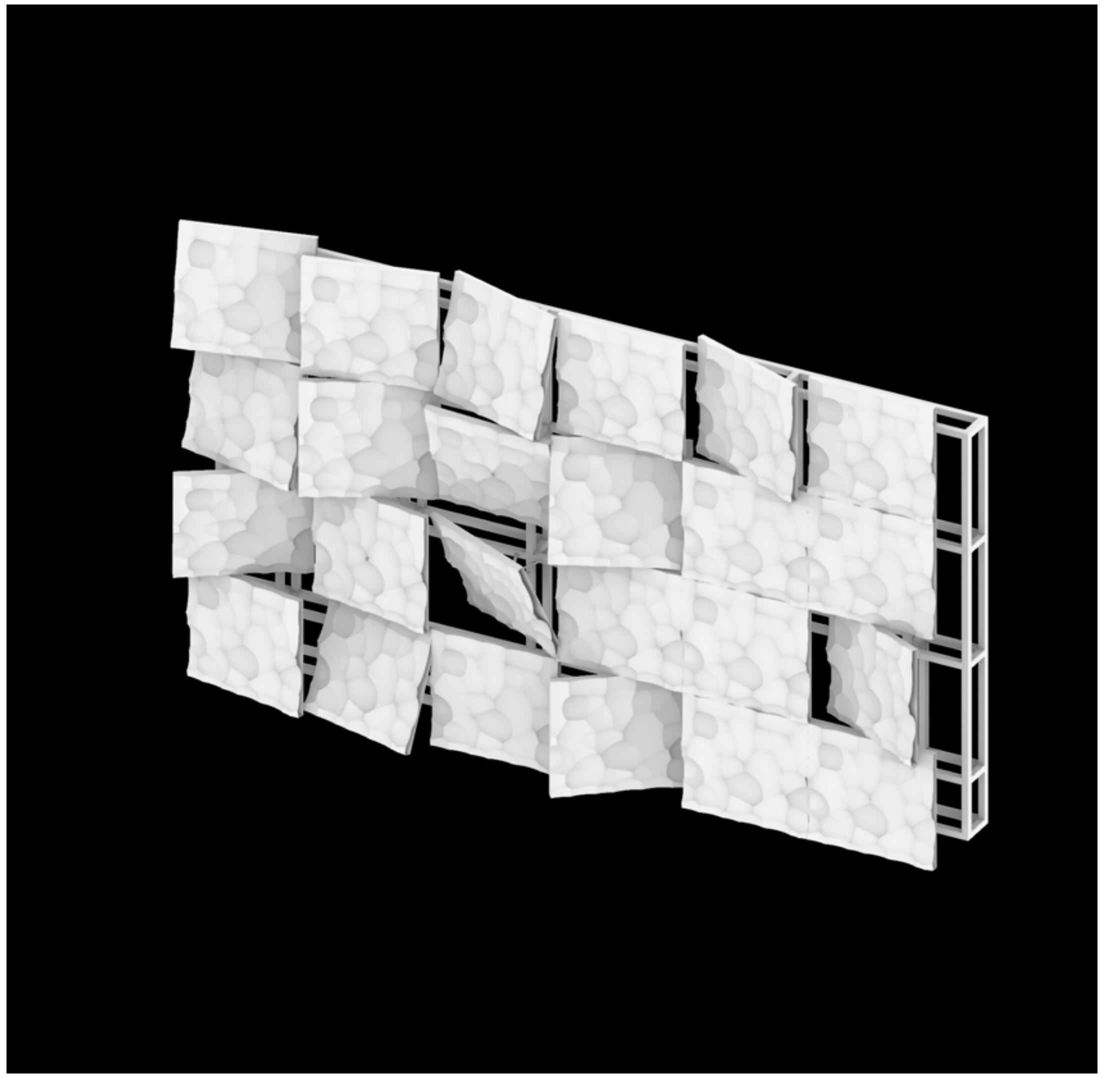
Continuity of form:
All variations of a type of panel should match seamlesslly both in the edges as well as the surface curvature.

Fabrication:
All panels should be fabricated by me with my new design and built machine set-ups.

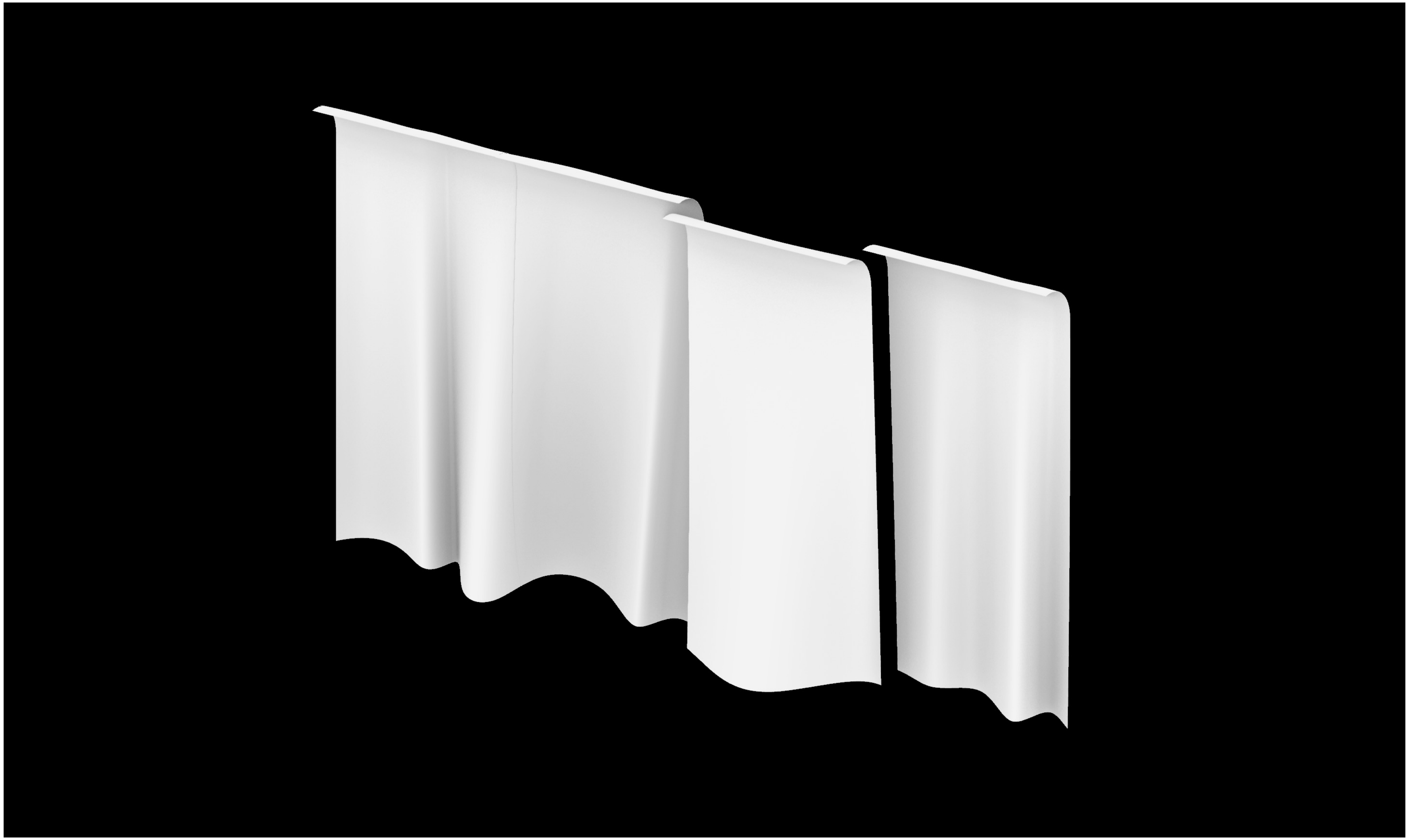
Time:
None of the new fabrication techniques had ever been tested in this scale - still the whole project should be build before deadline.

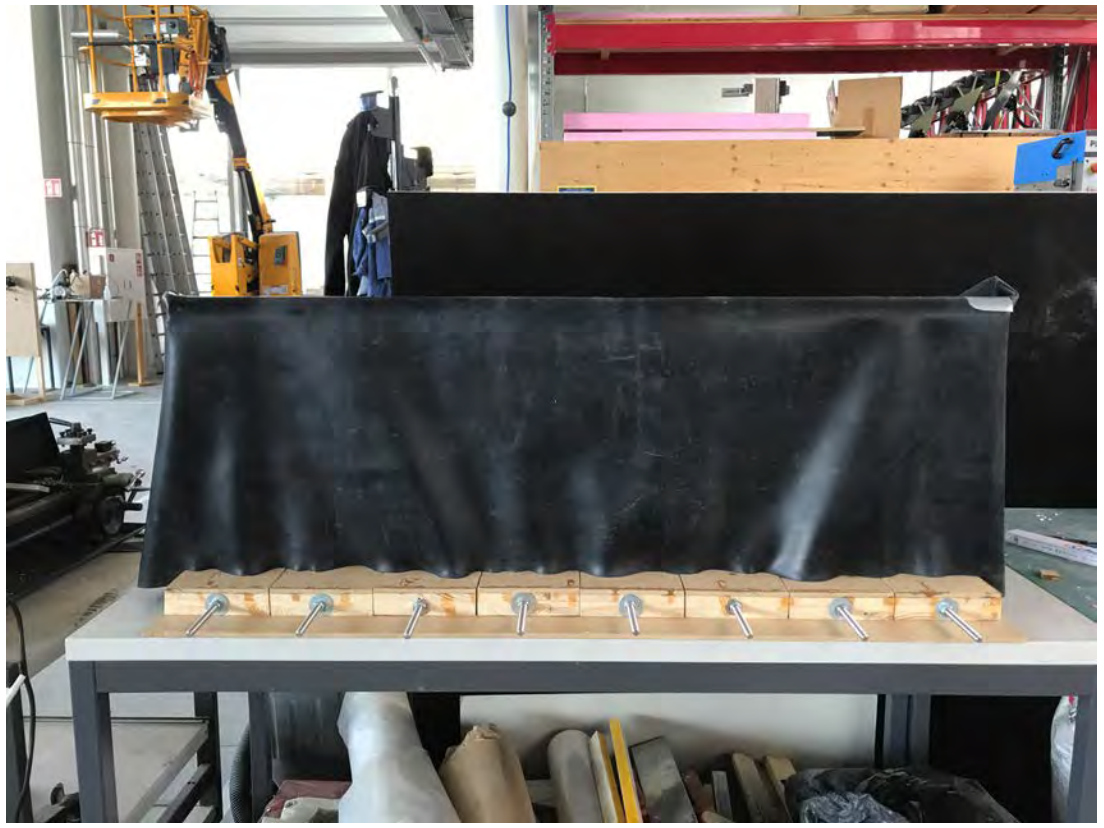













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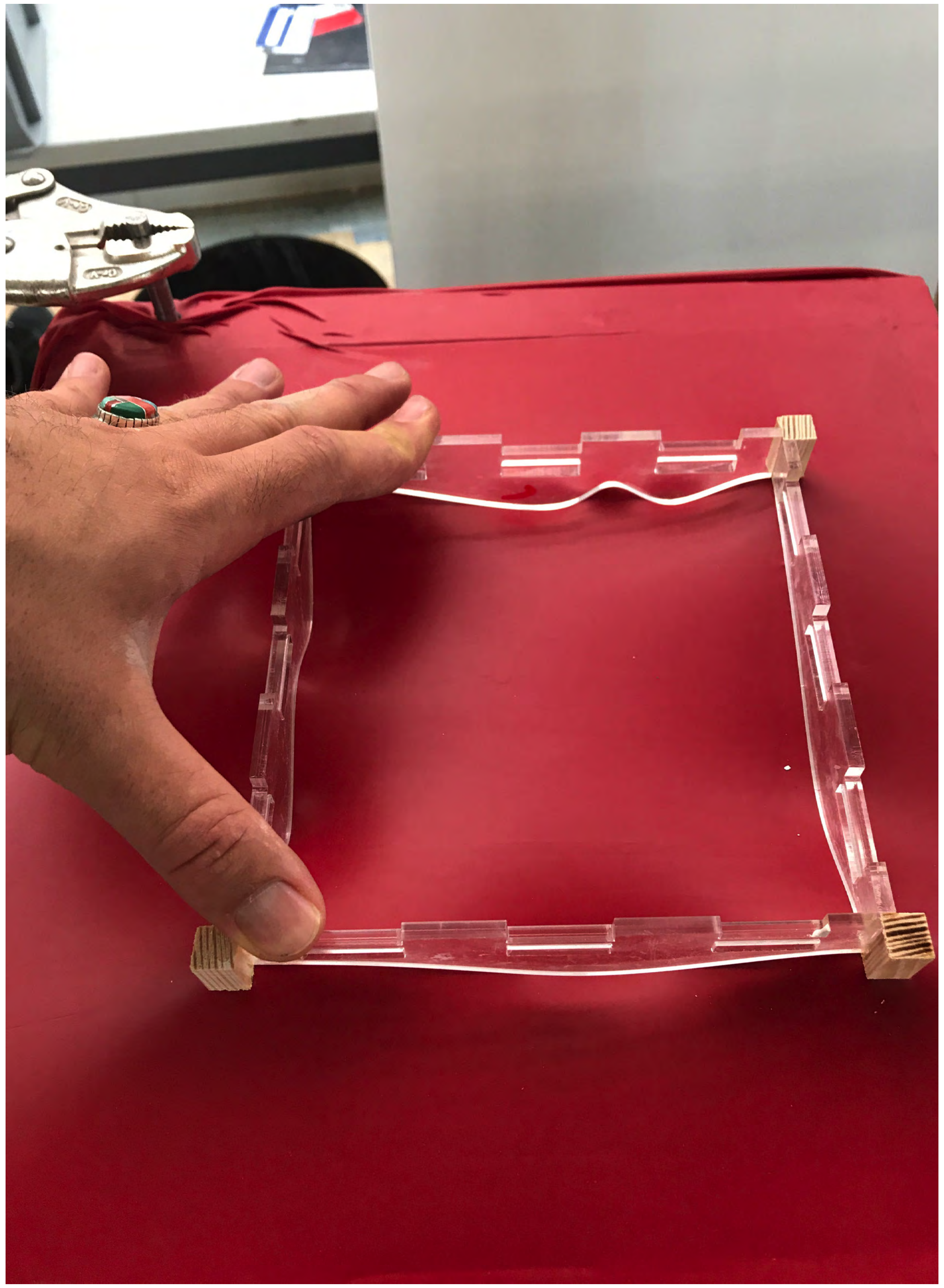
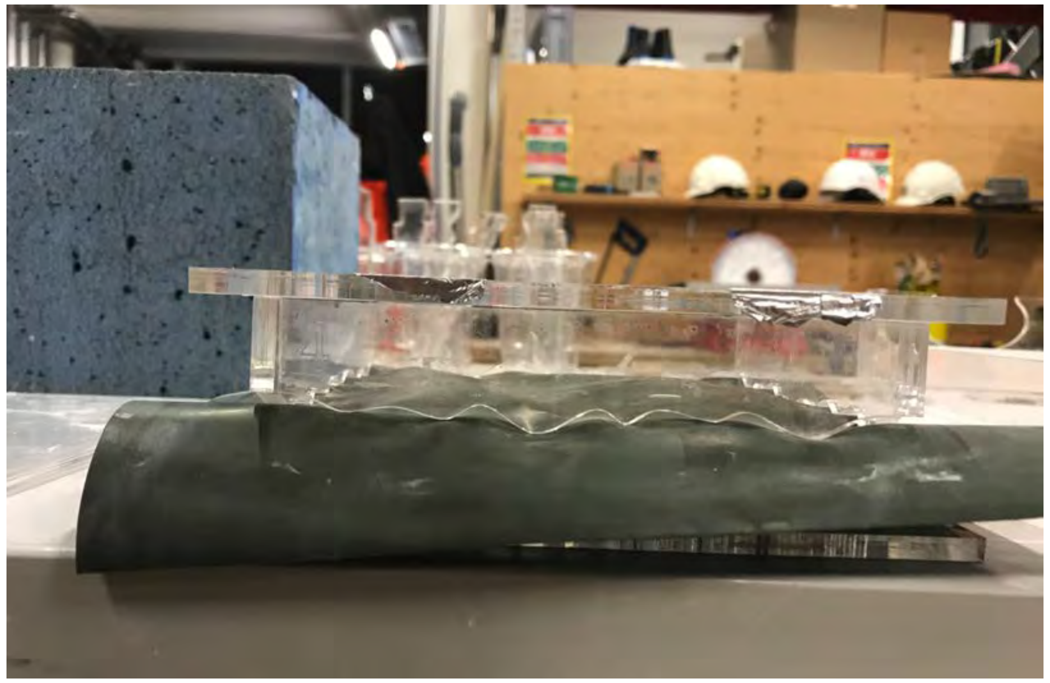
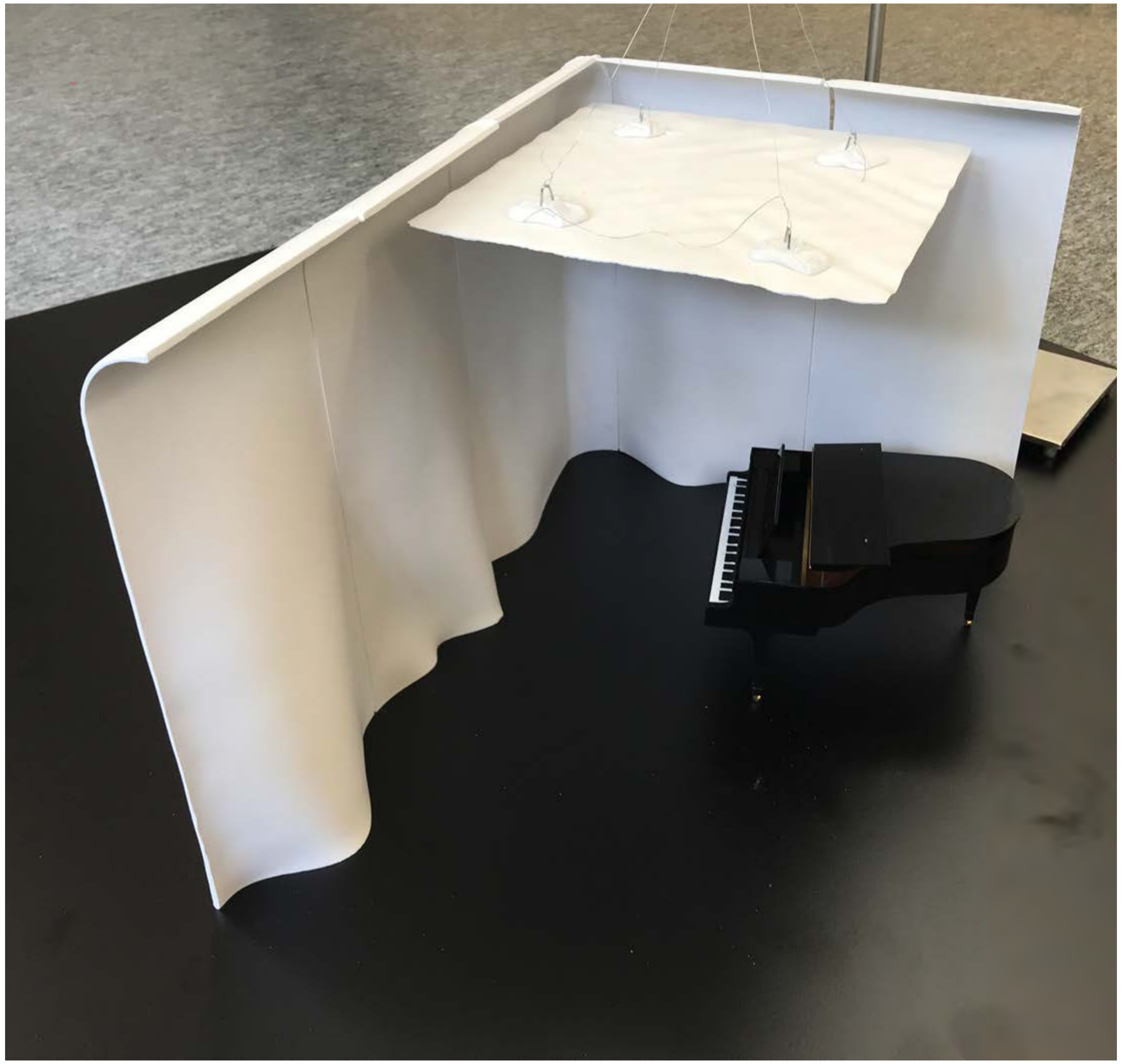
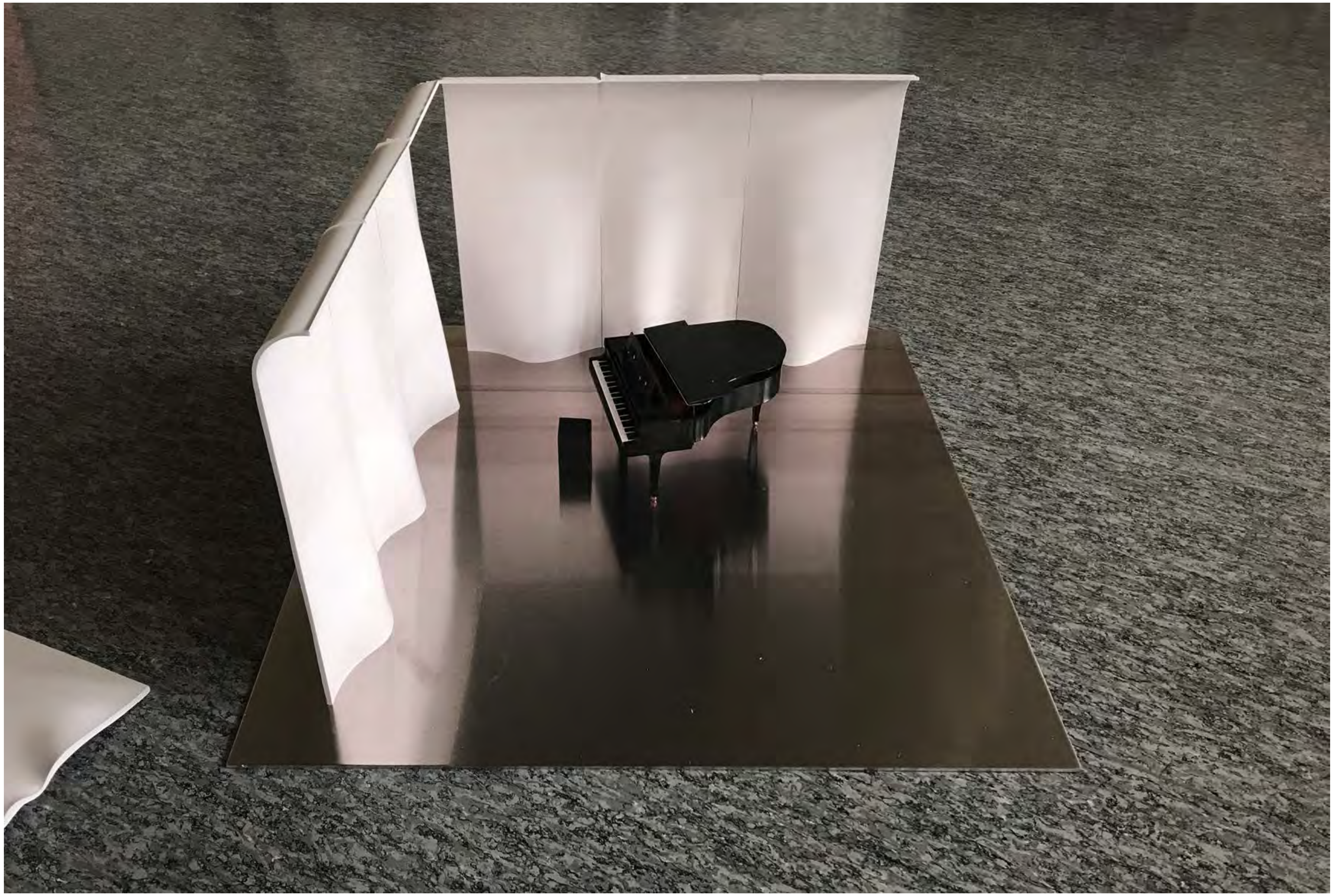






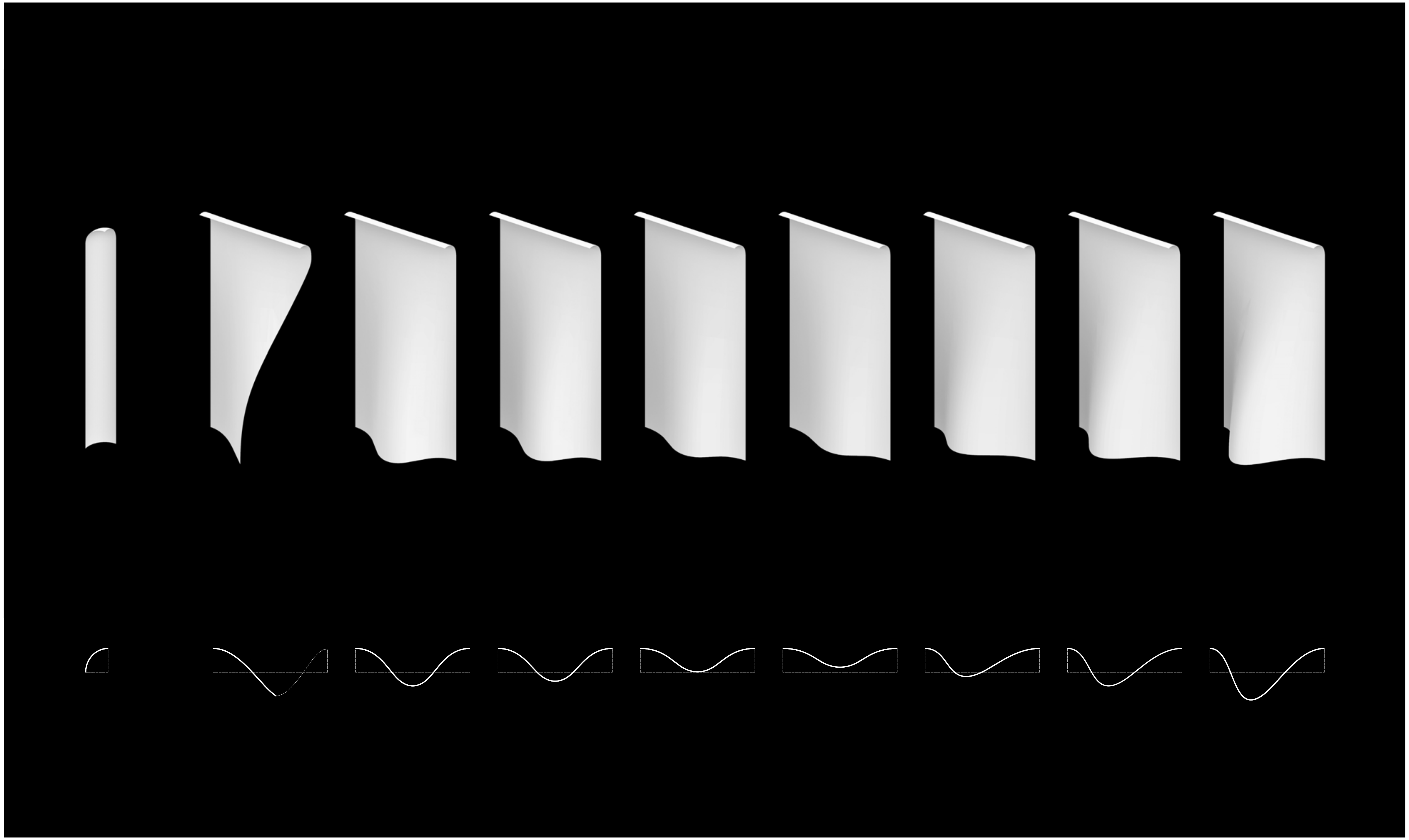


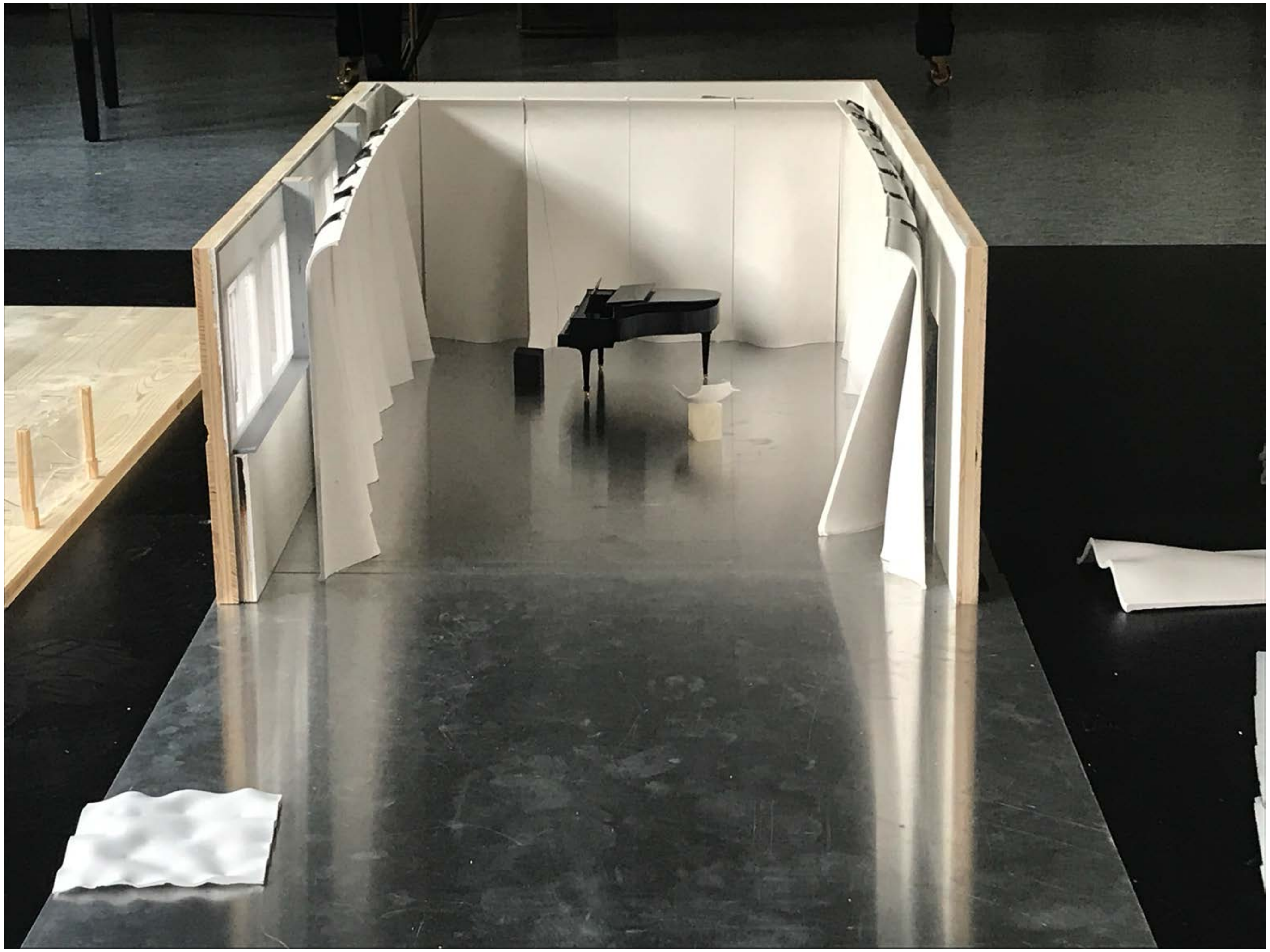
DESIGN // *APPLIED ACOUSTICS*

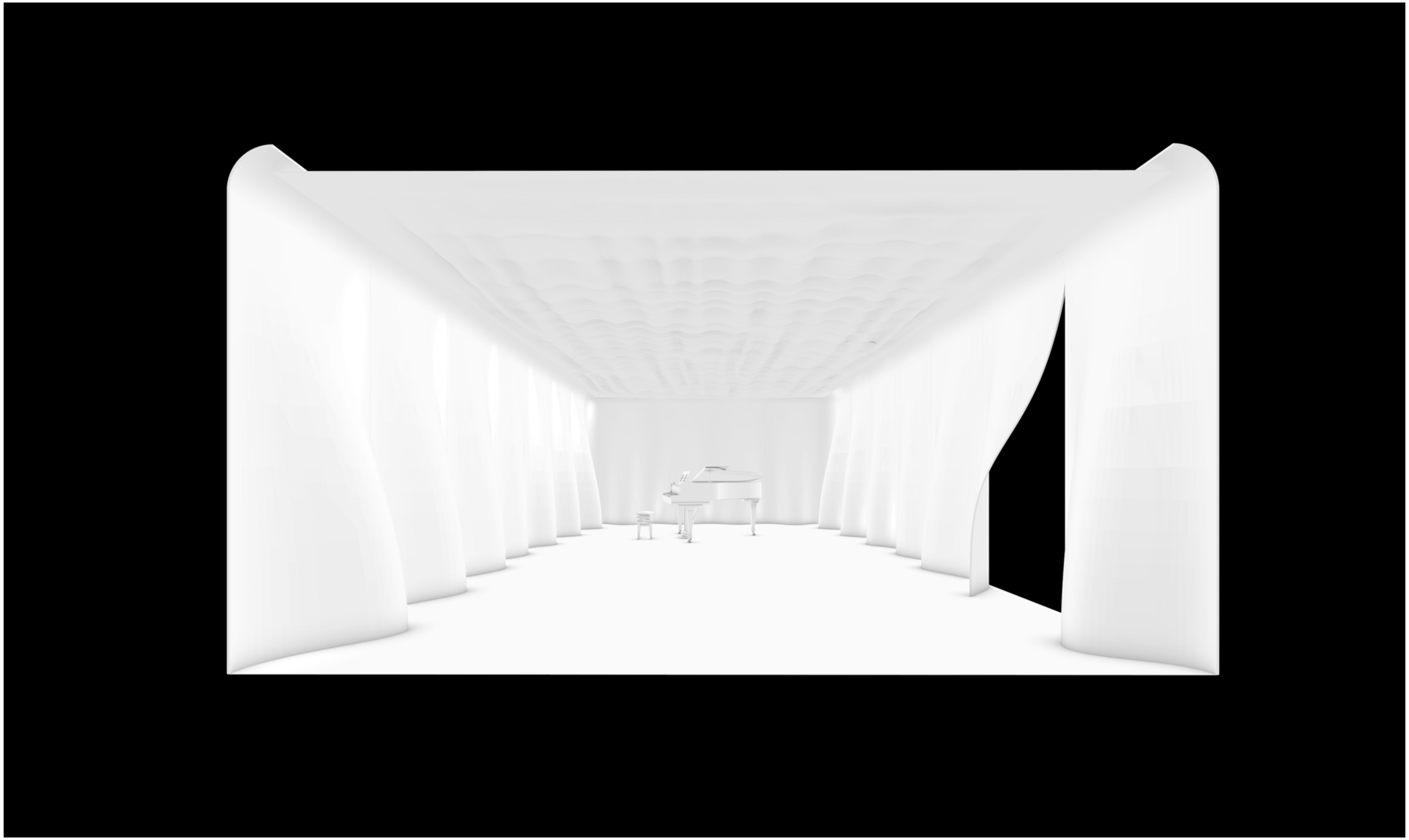
Following the described acoustical design constraints, the principle of the final design for the wall and ceiling panels :

WALL PANELS
Wall panels efficiently diffuse all frequencies but the lowest - they are being absorbed by the soft infill inside the absorption box behind the panels.

CEILING PANELS
Ceiling Panels efficiently diffuse mid to high frequencies - the equivalent absorption area for mid to high frequencies is mounted to the ceiling as wooden fibre plates with an insulation infill.







DESIGN
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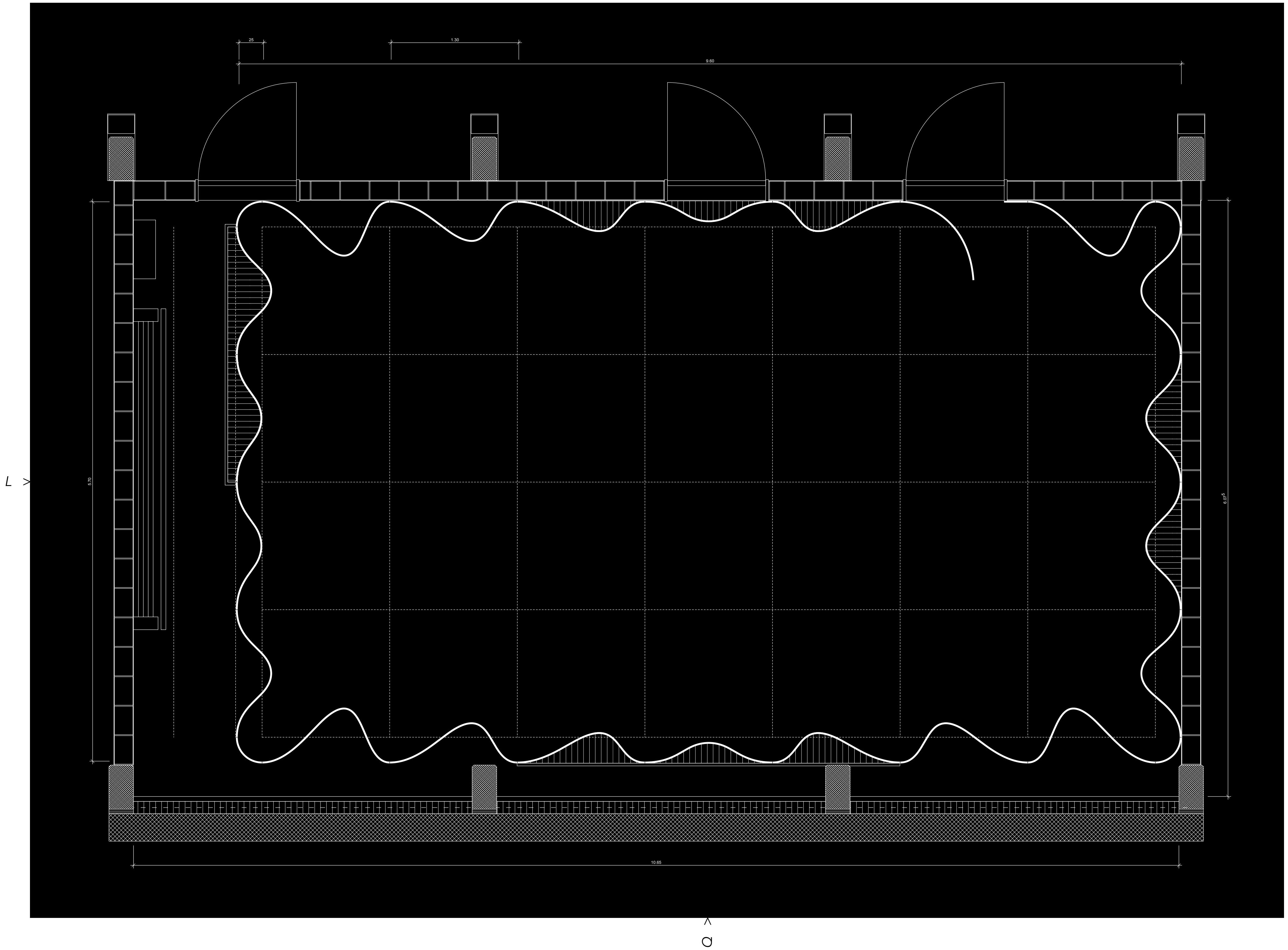
GROUND PLAN



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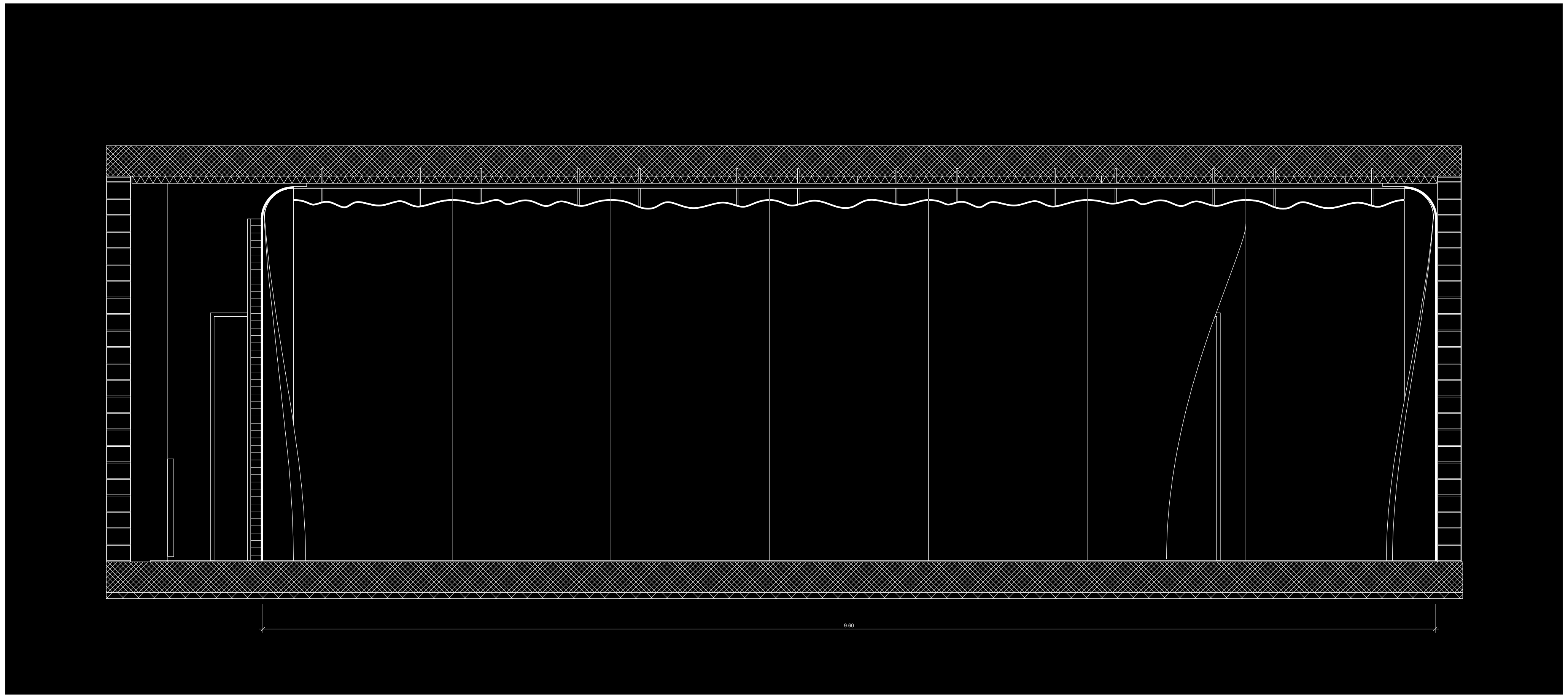

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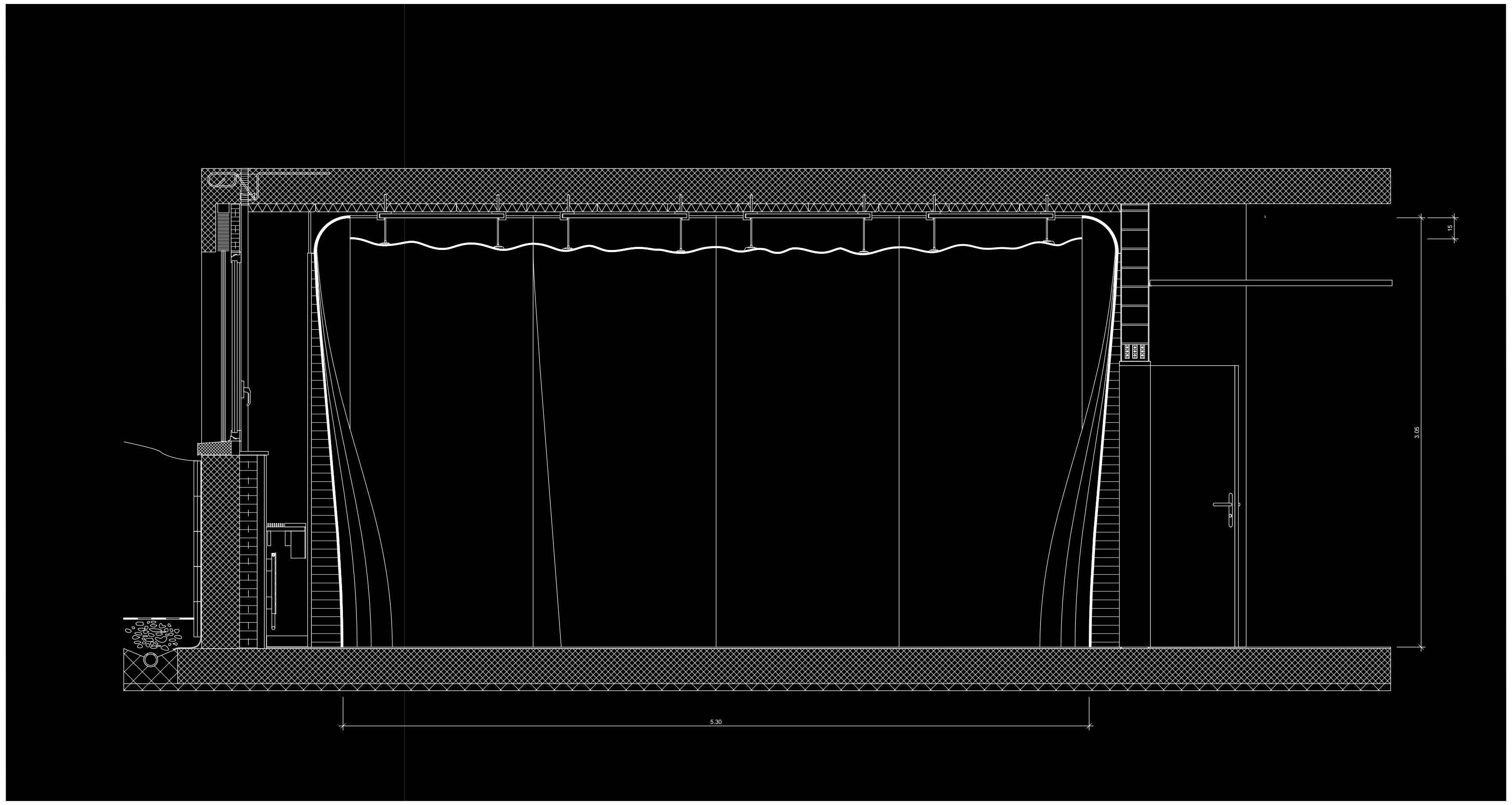
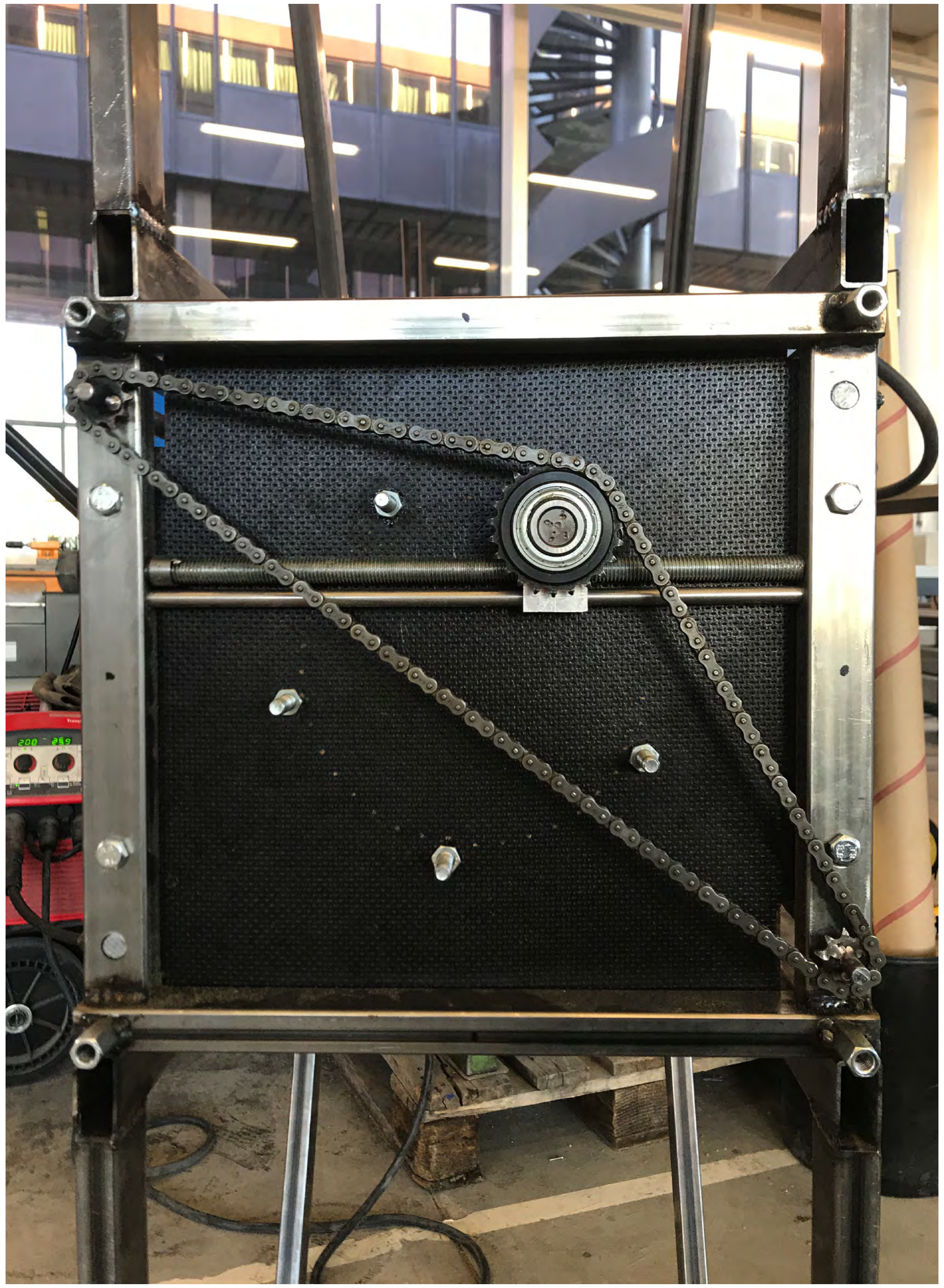


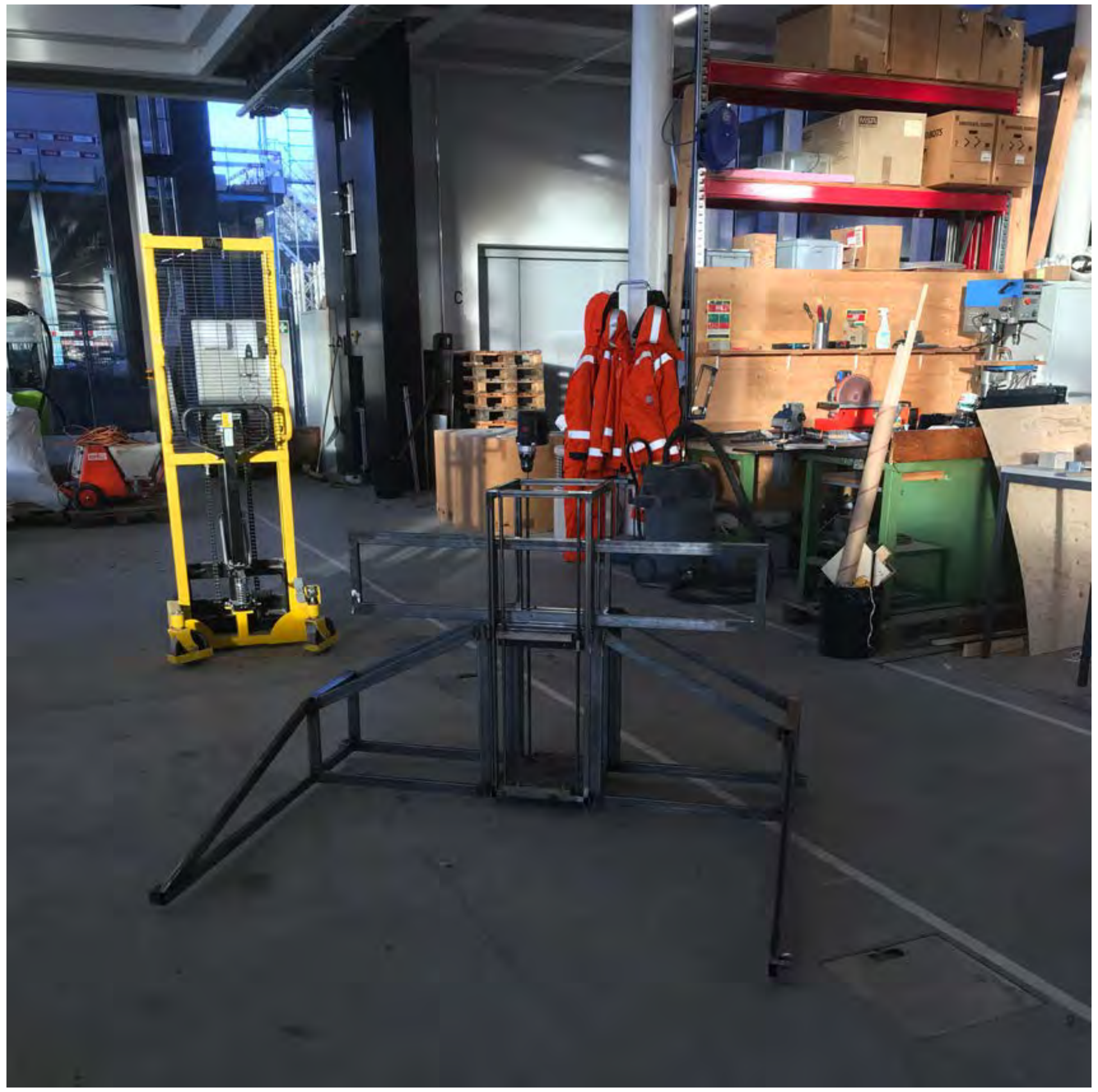

FABRICATION

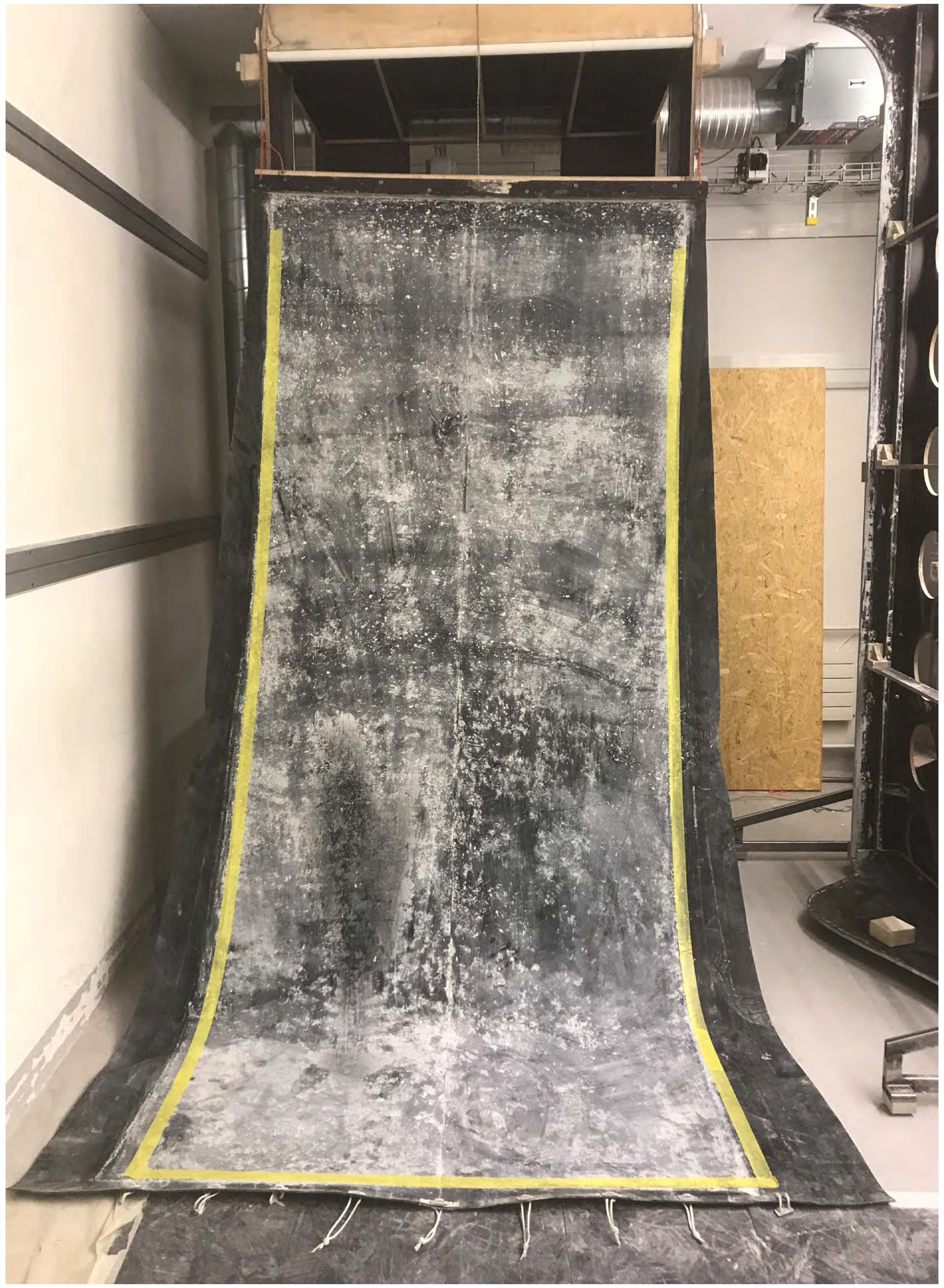
FABRICATION
//
WALL
PANEL

The following images show the proces off building the wall panel machine and their fabrication process and installation.

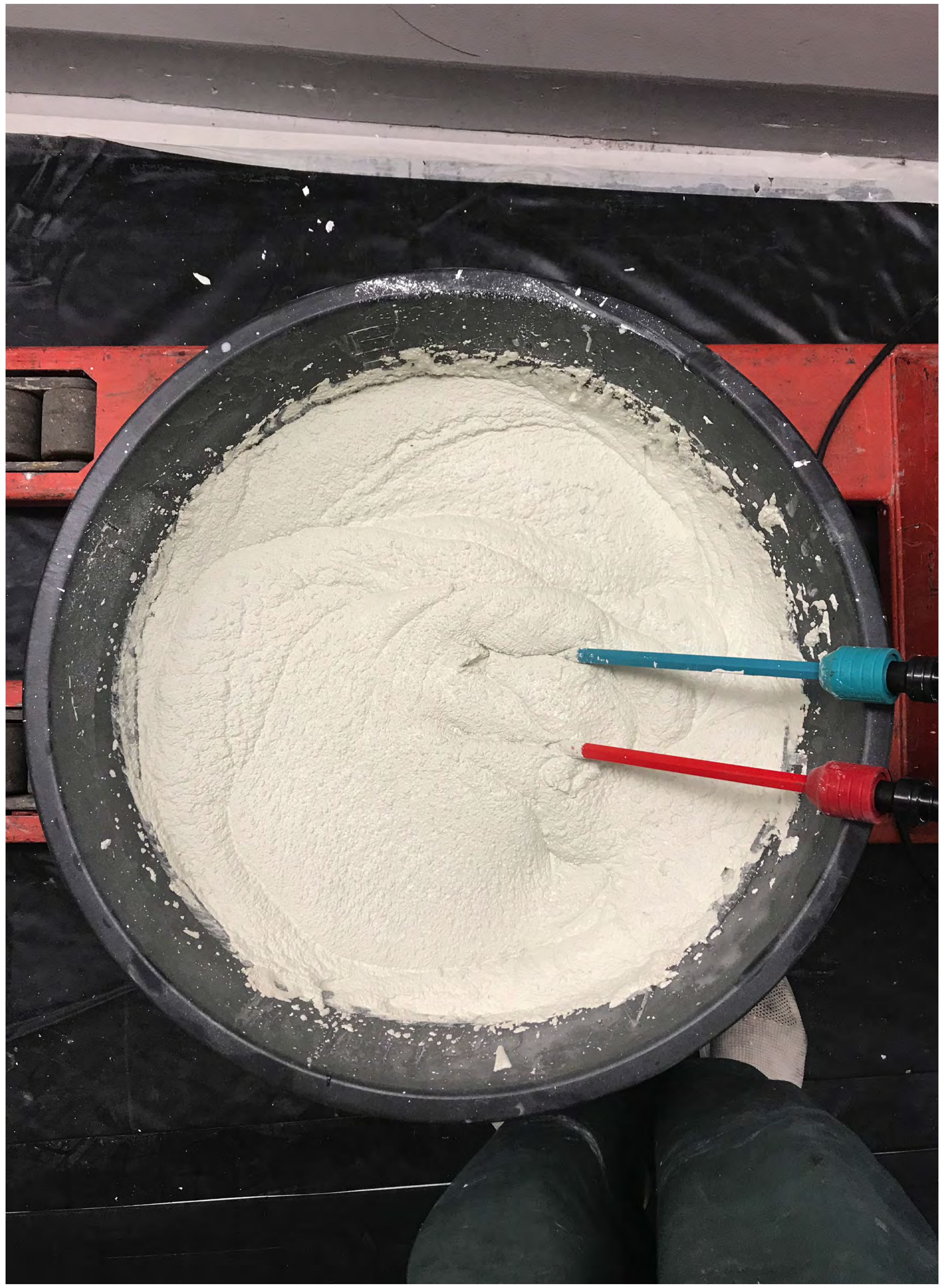

Hzürich

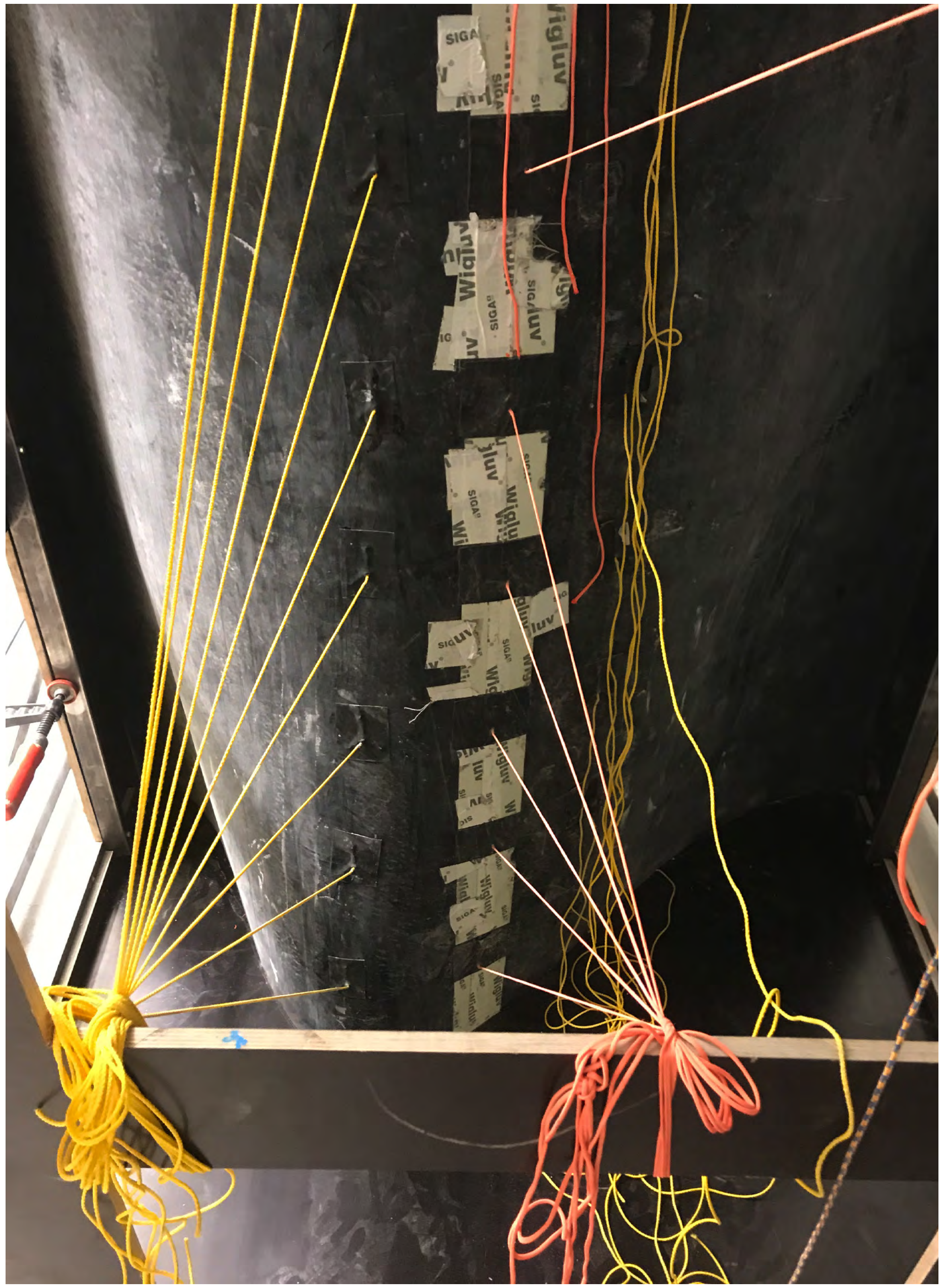







Collomix
Collomix




SIGA
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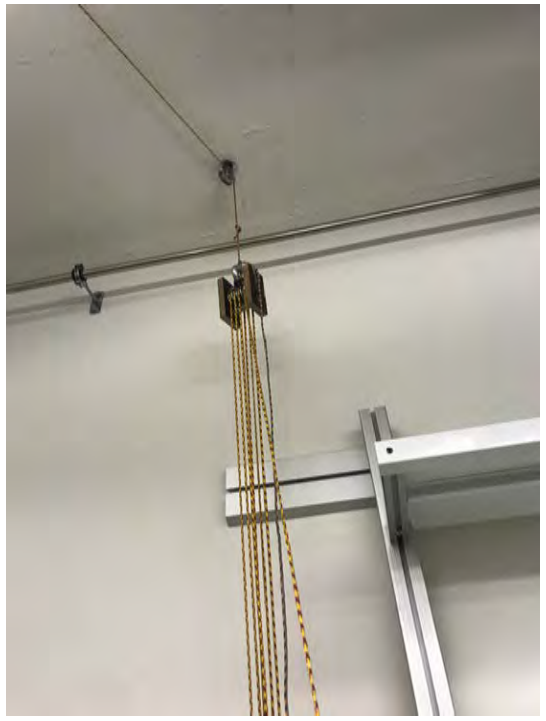
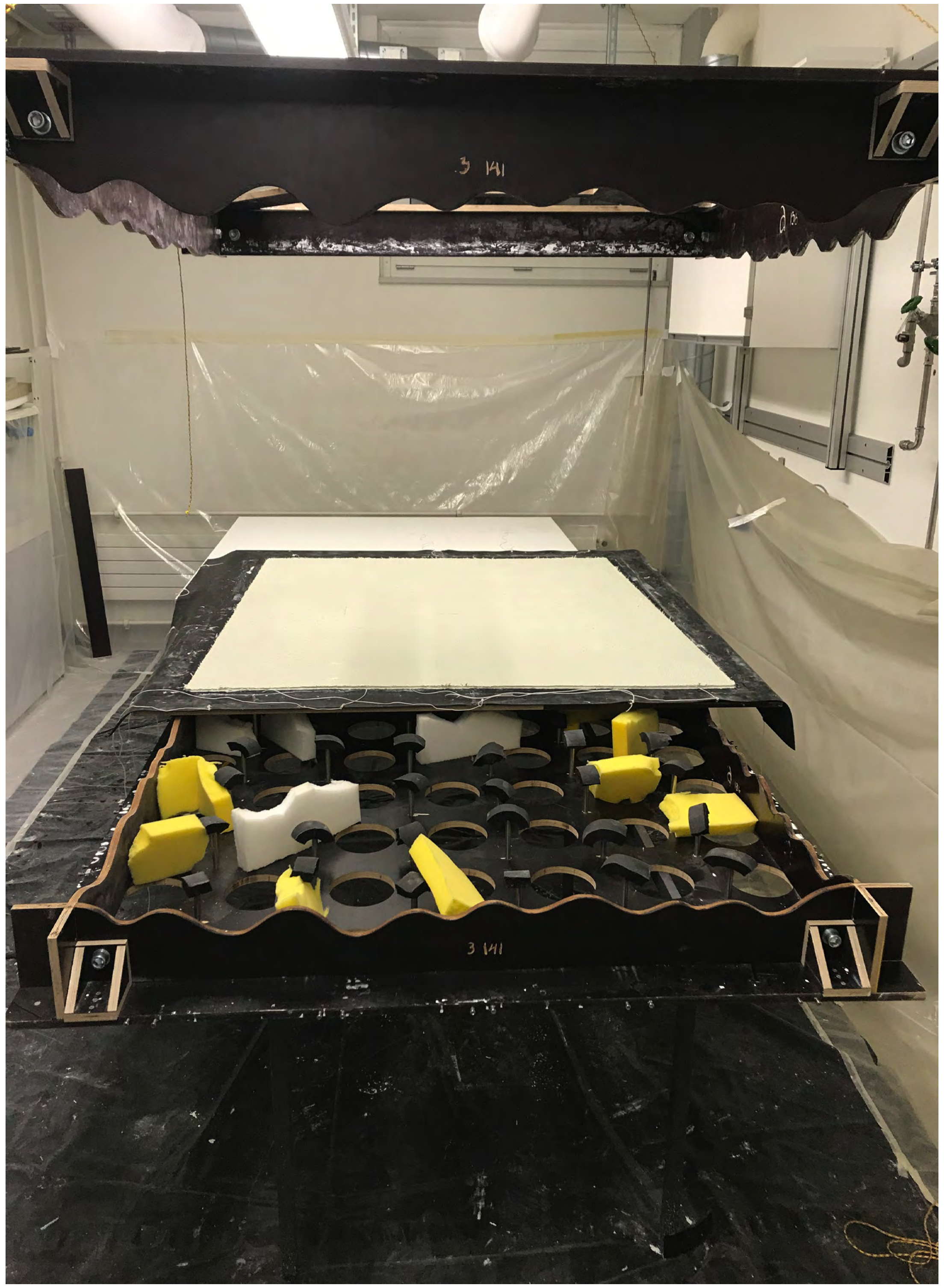
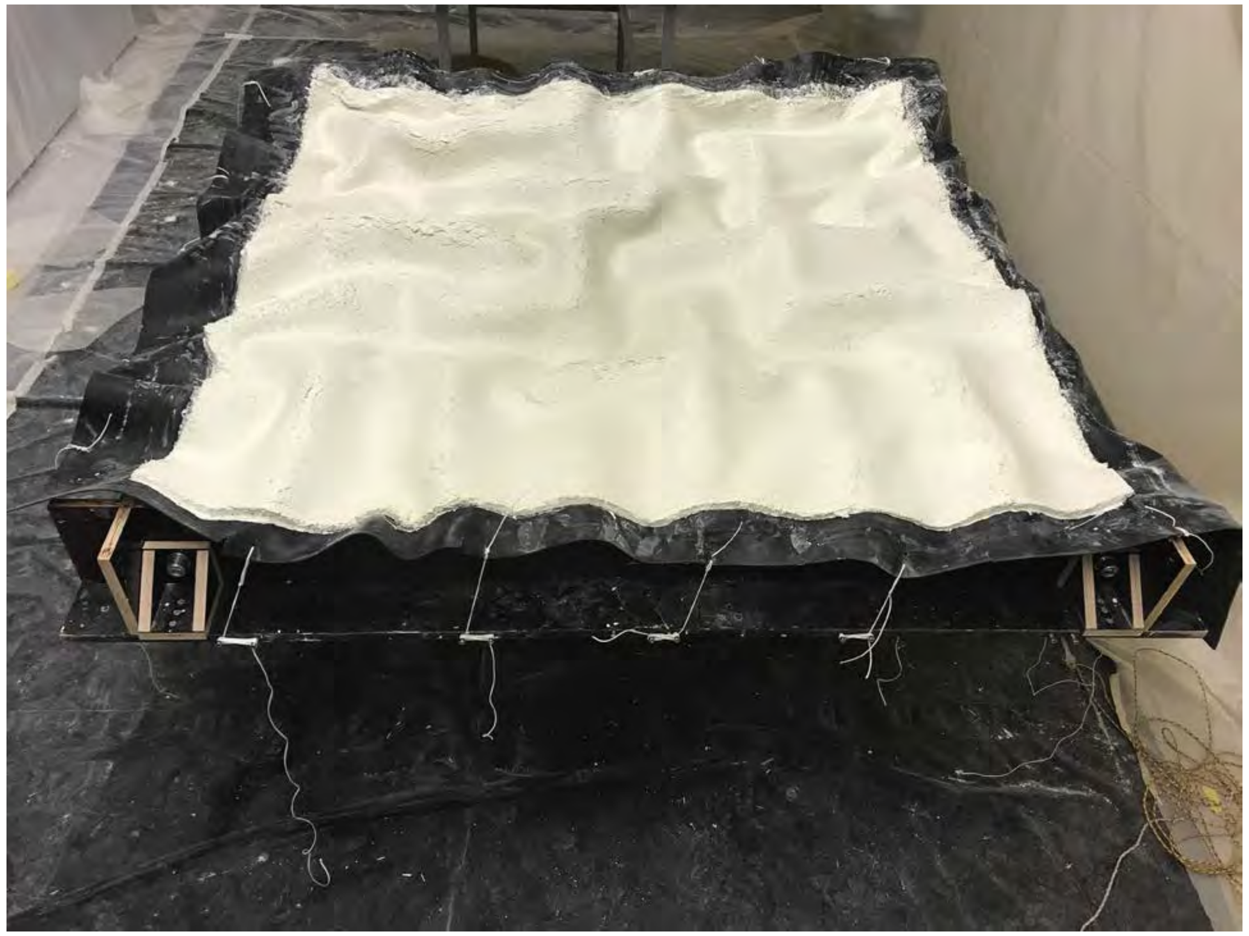
B 71

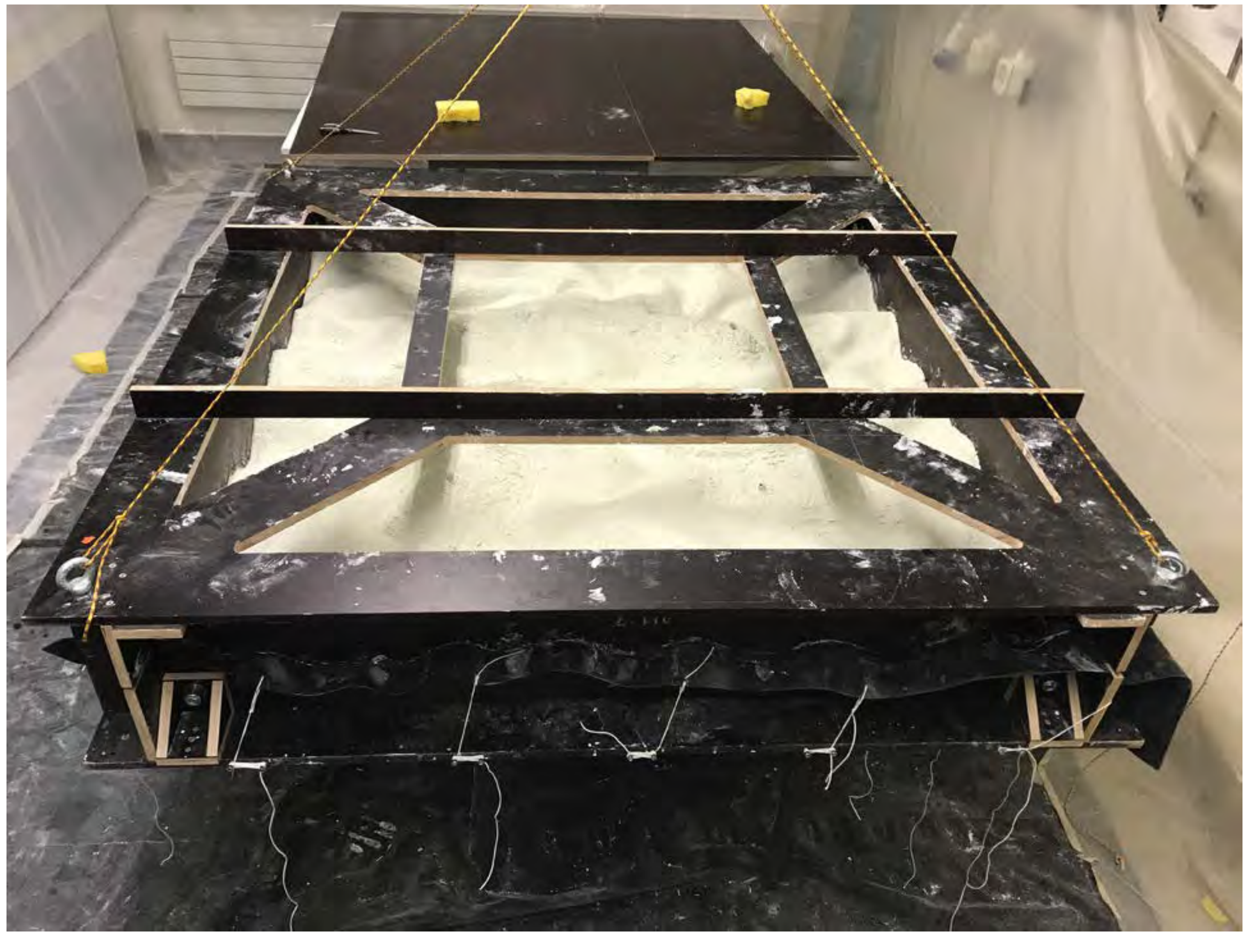
FABRICATION // CEILING PANEL

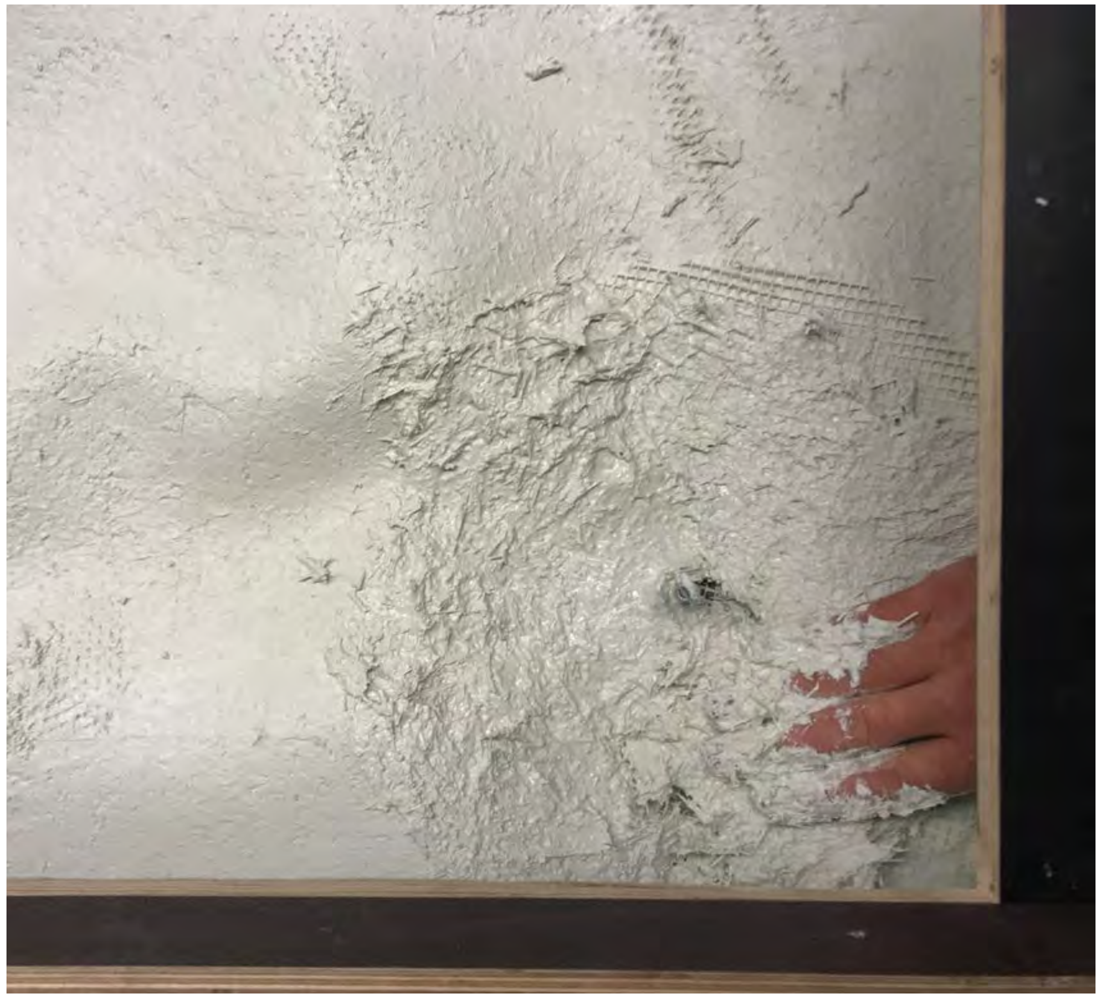
The following images show the fabrication process and installation of the ceiling panels.

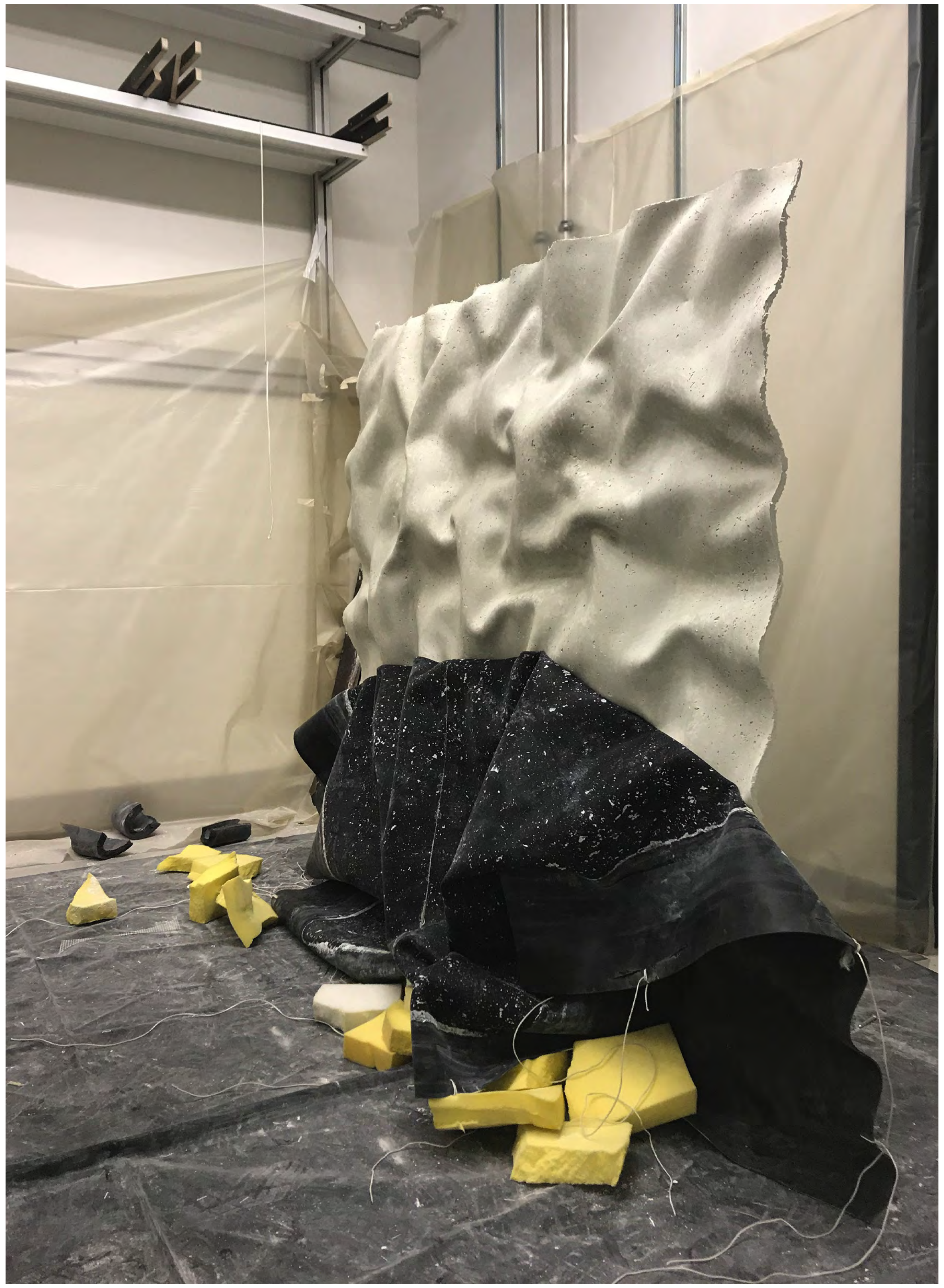









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FABRICATION
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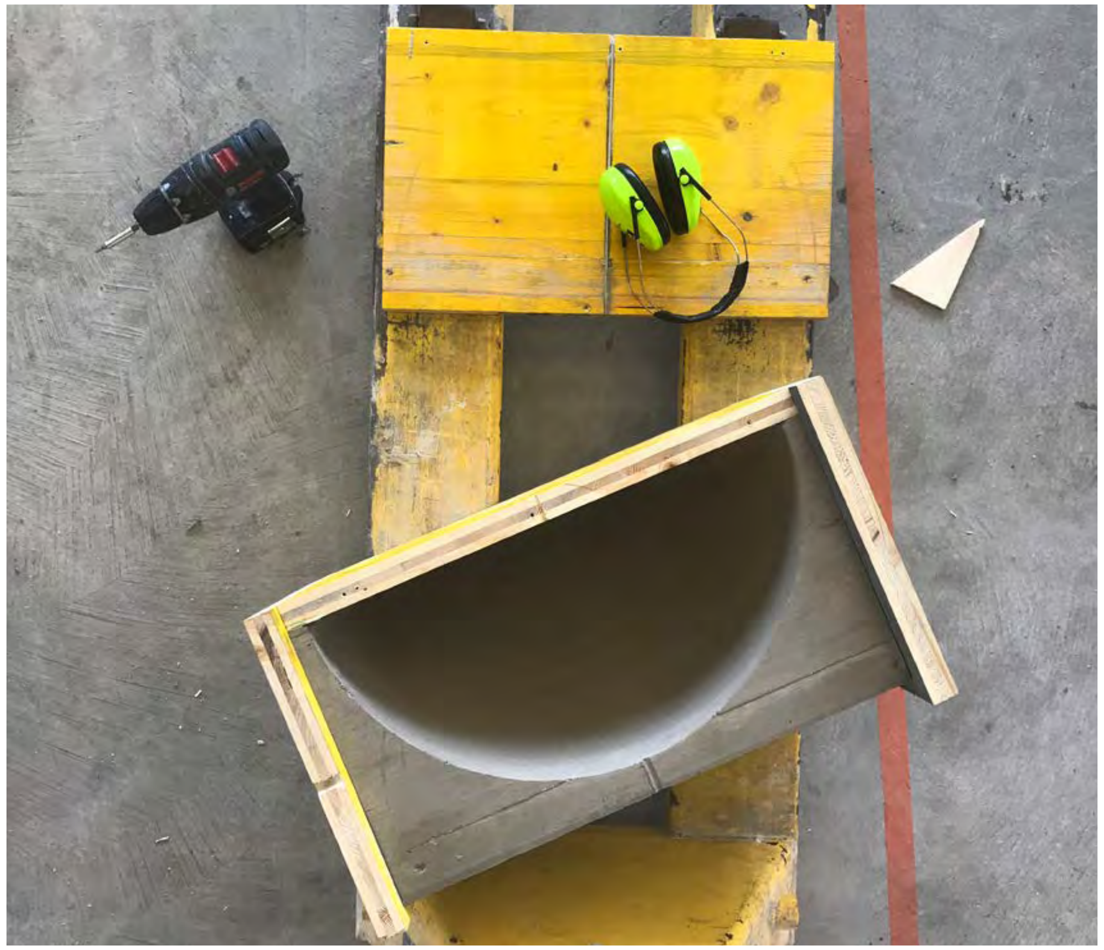
CORNER PANEL

The following images display the process of building the corner panel machine and their fabrication process.


HA12CJ

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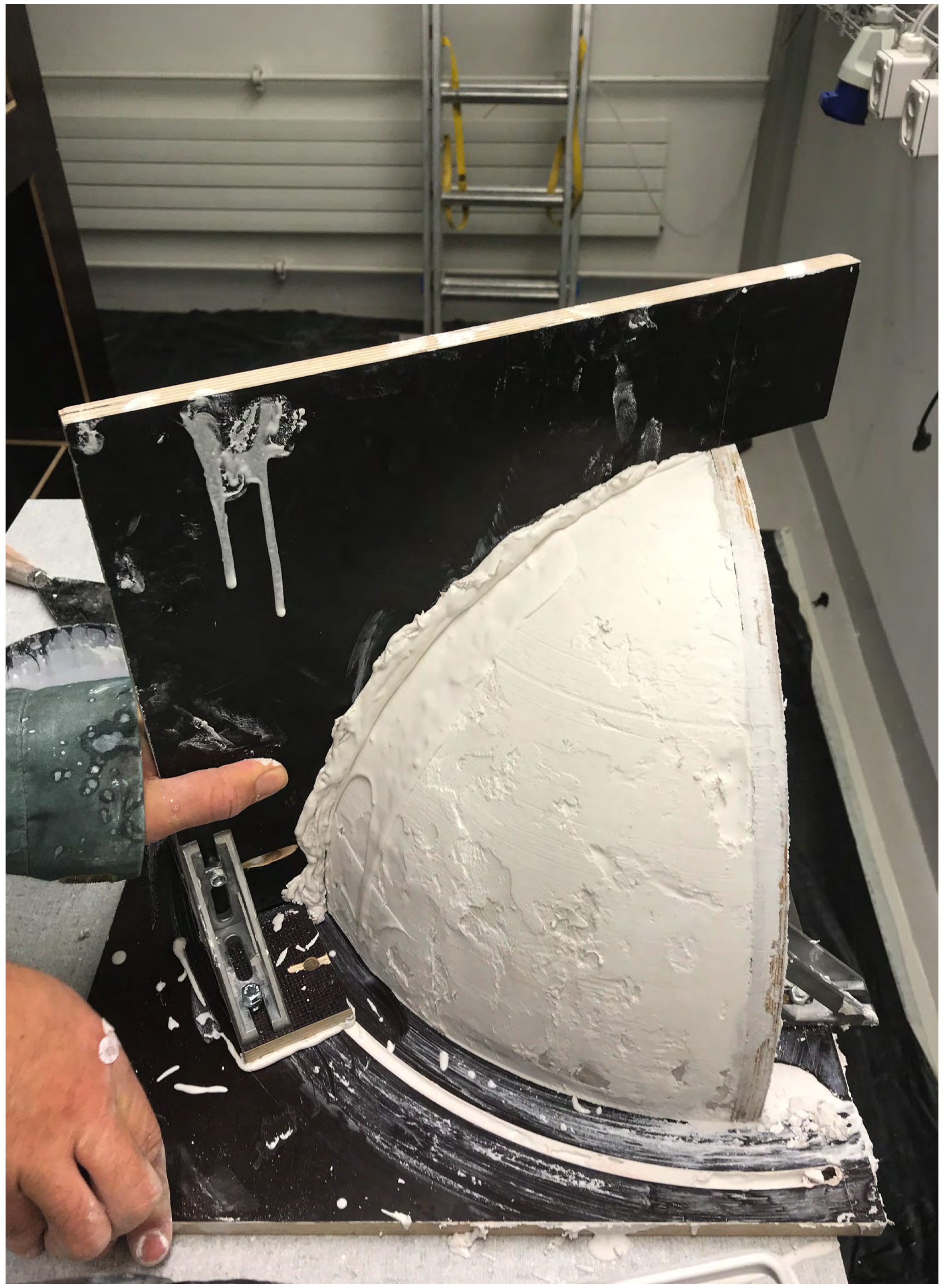

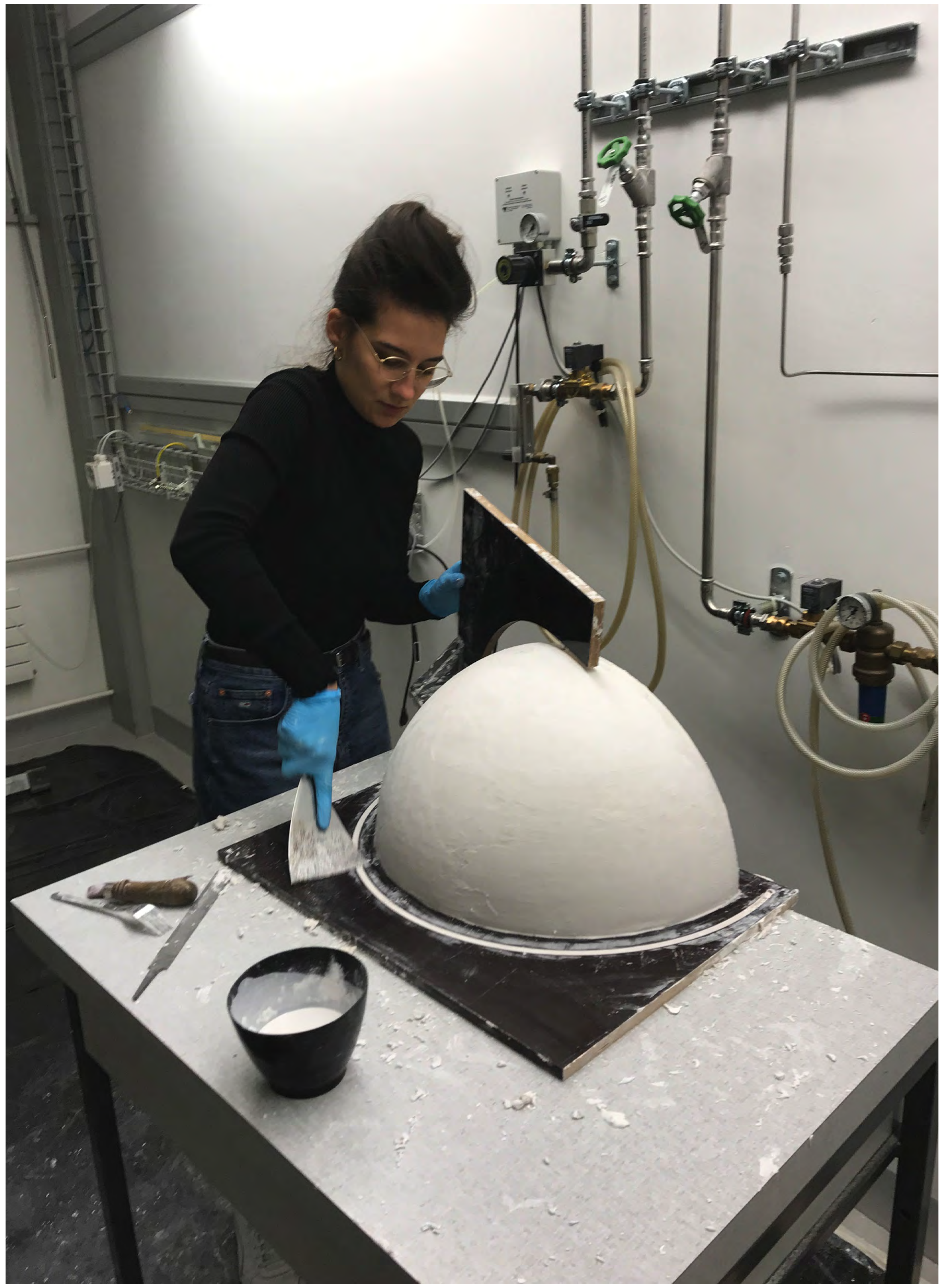


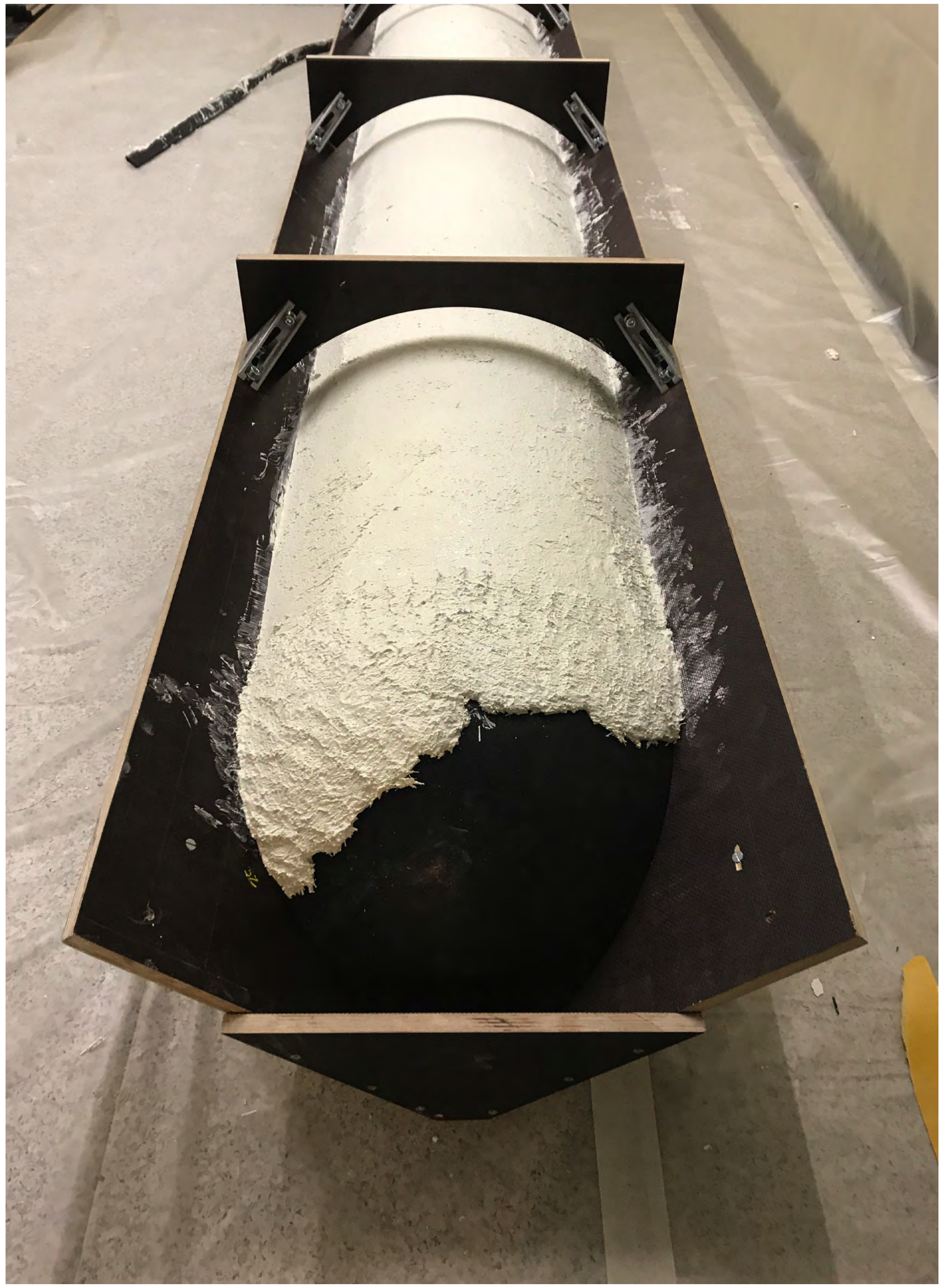

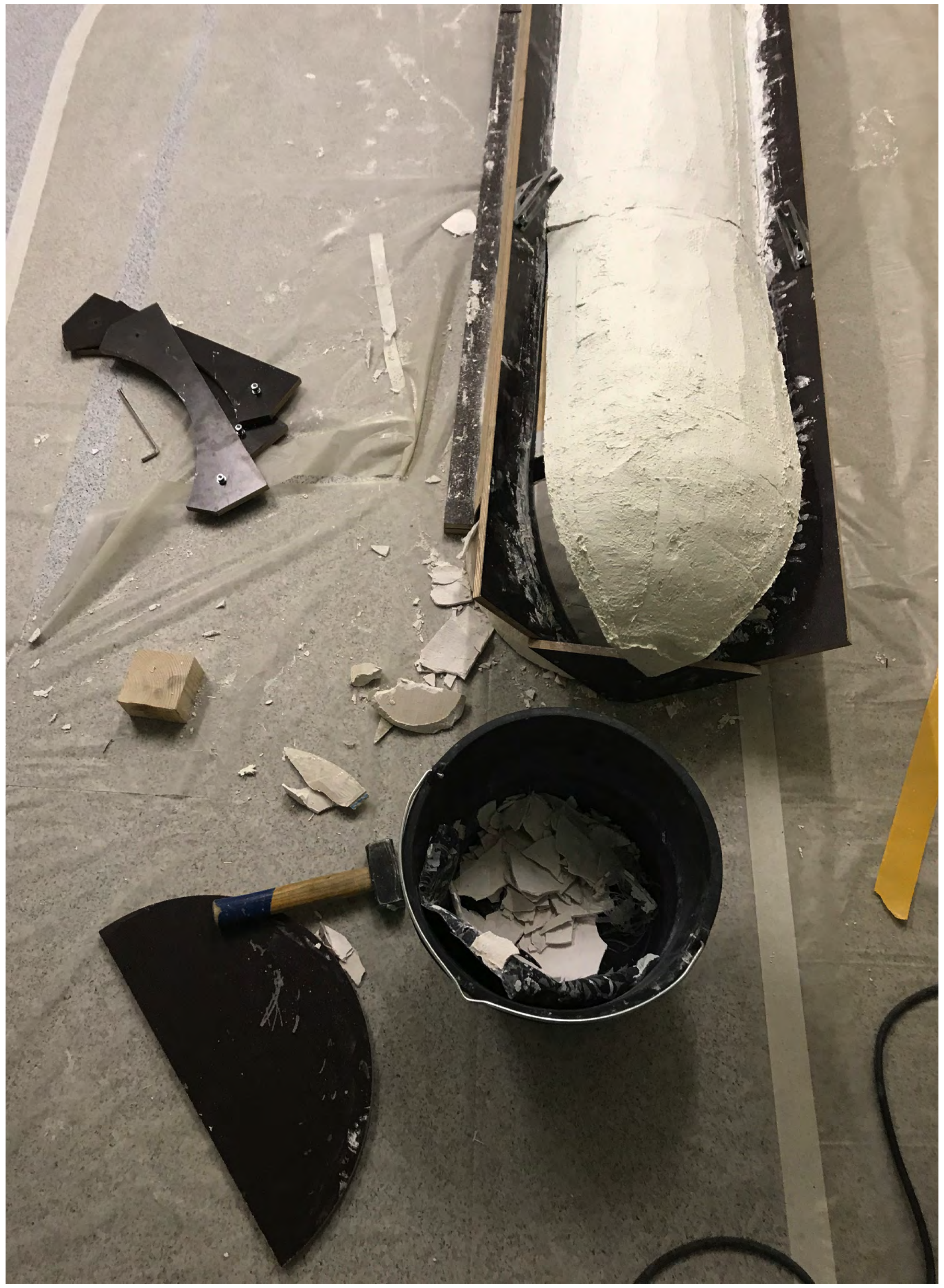
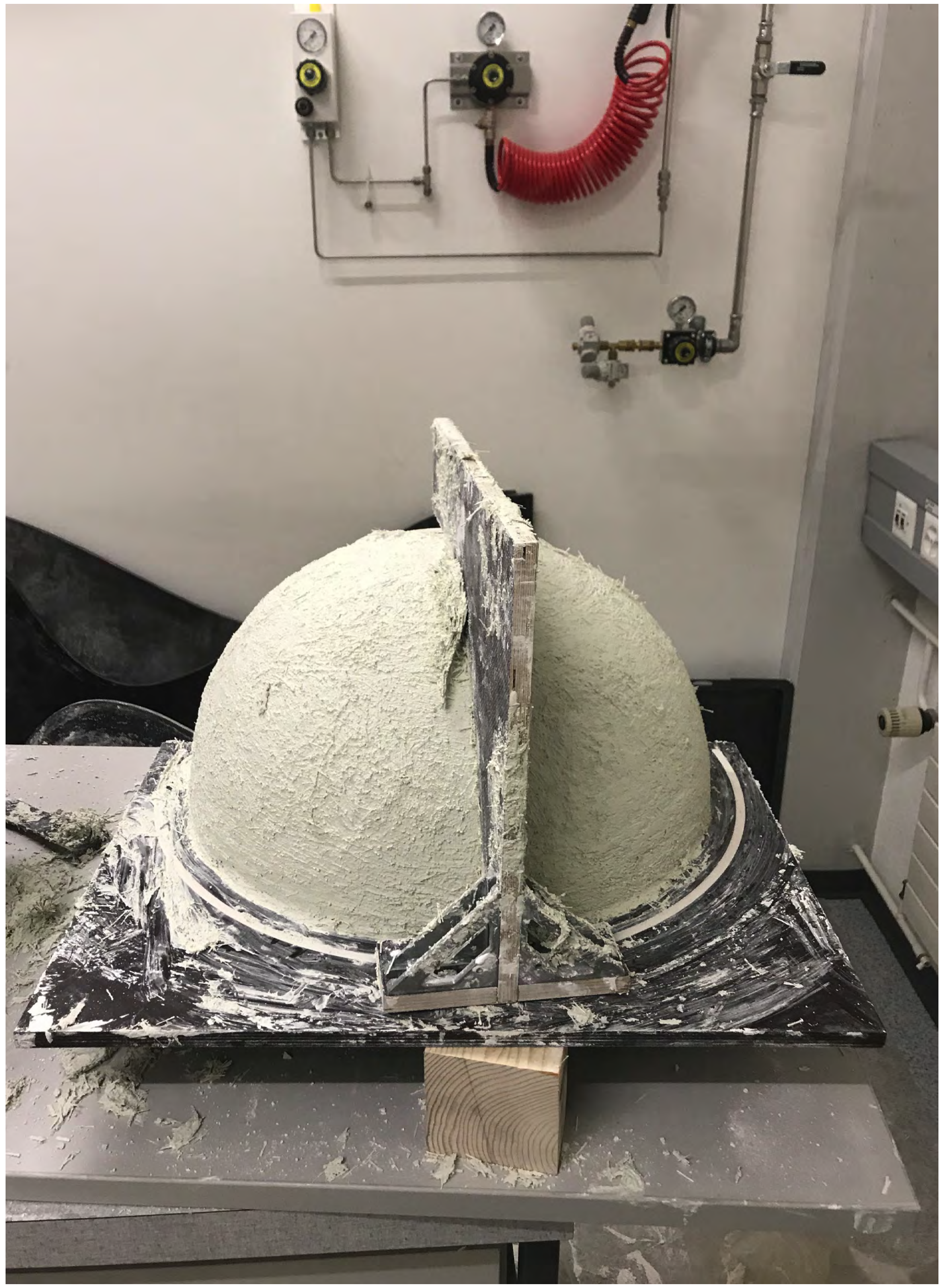

FABRICATION
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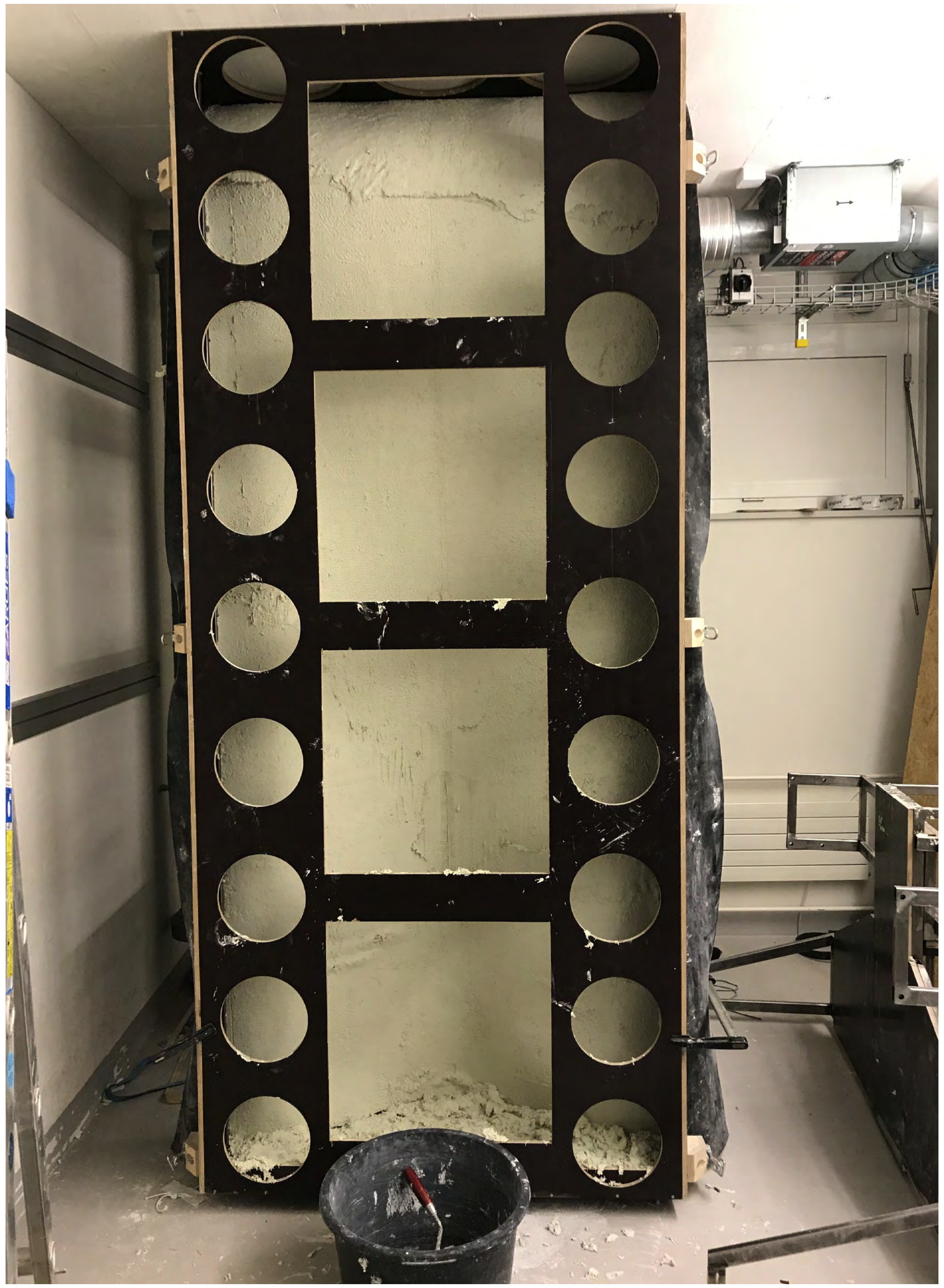
LEARNING FROM LAS FAILAS

Learning and adapting quickly in process was key to the success of the project - the following chapter shows some excerpts from failures.

The challenges were e.g. the delamination of concrete layers caused by a strong non-linear deformation of the membrane to then tear out the reinforcement net, the decay of the membrane and weak concrete mix formulas followed by a new design applied on the wall panel machine to create an elementy for the entry situation which put an asymmetric load to the machine - the final element could only be achieved without an inlayed reinforcement net.

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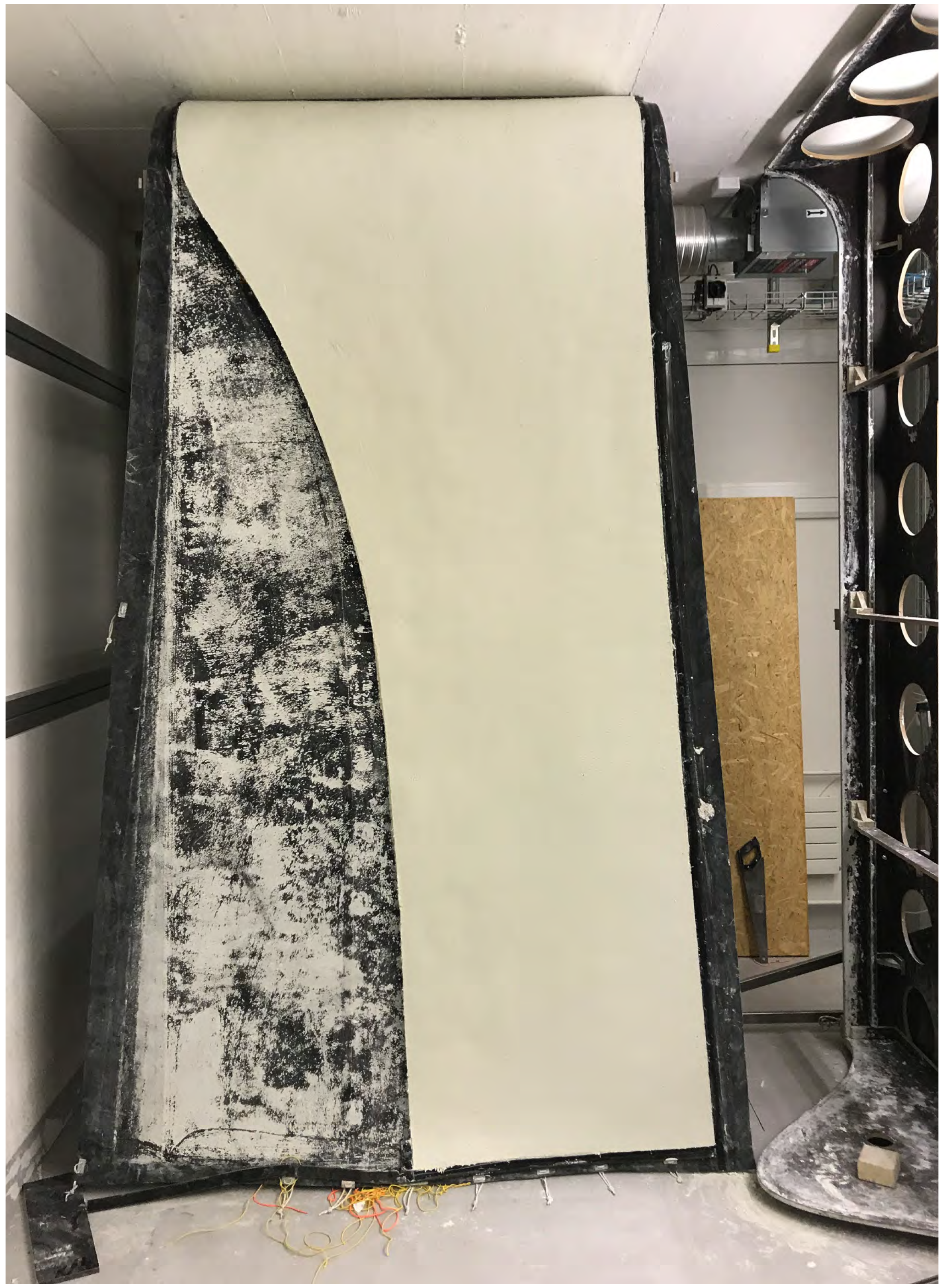

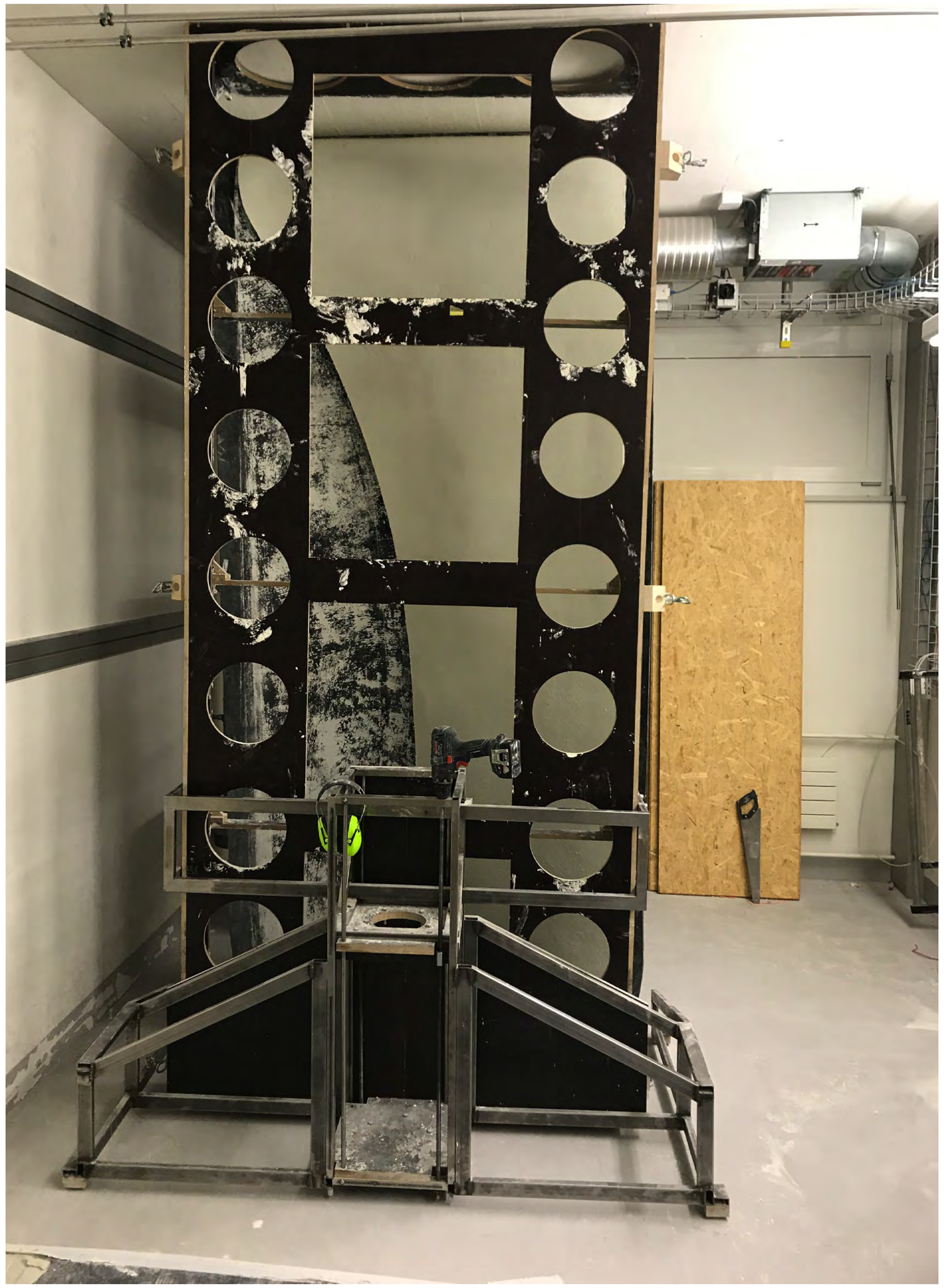

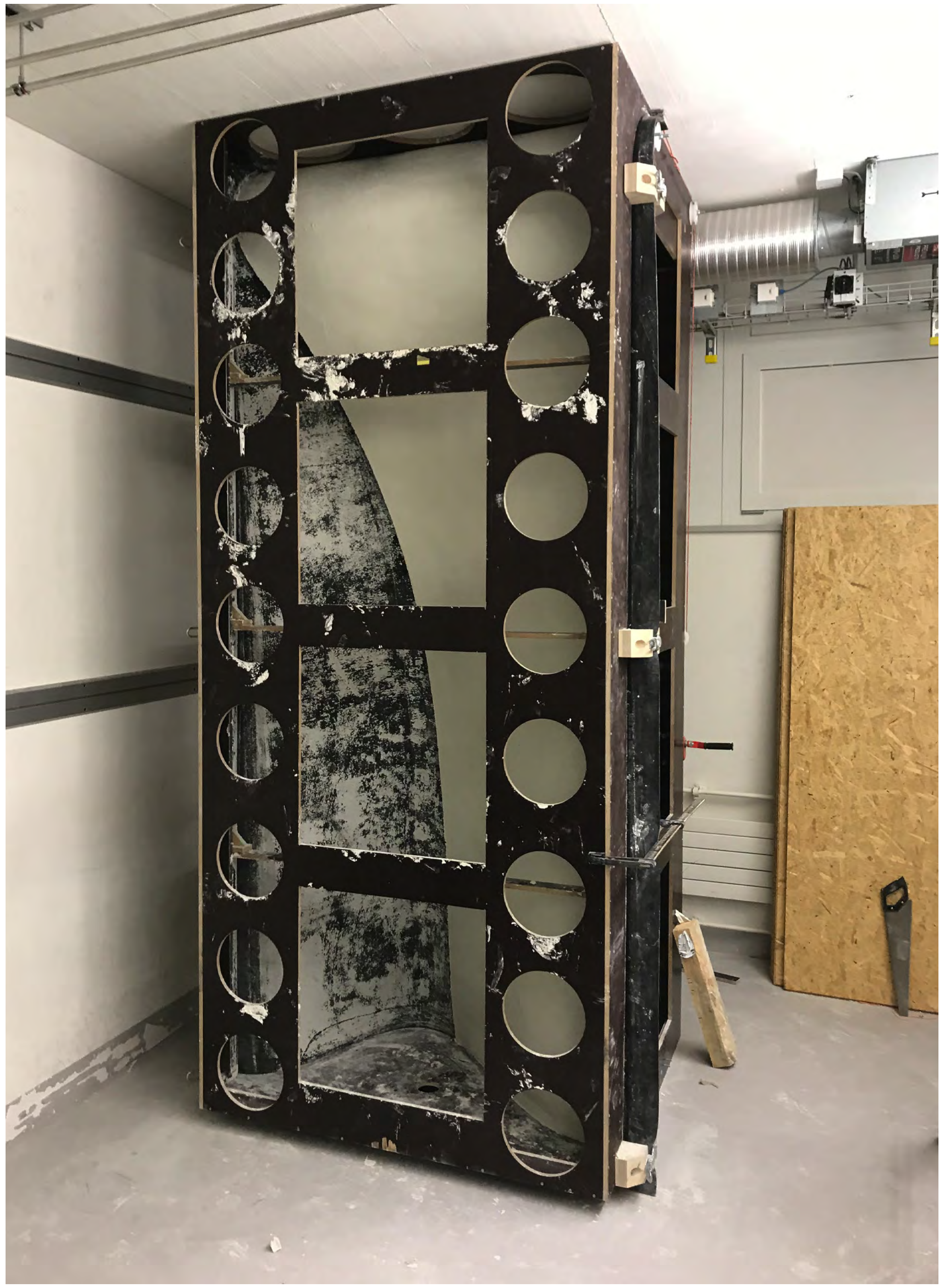

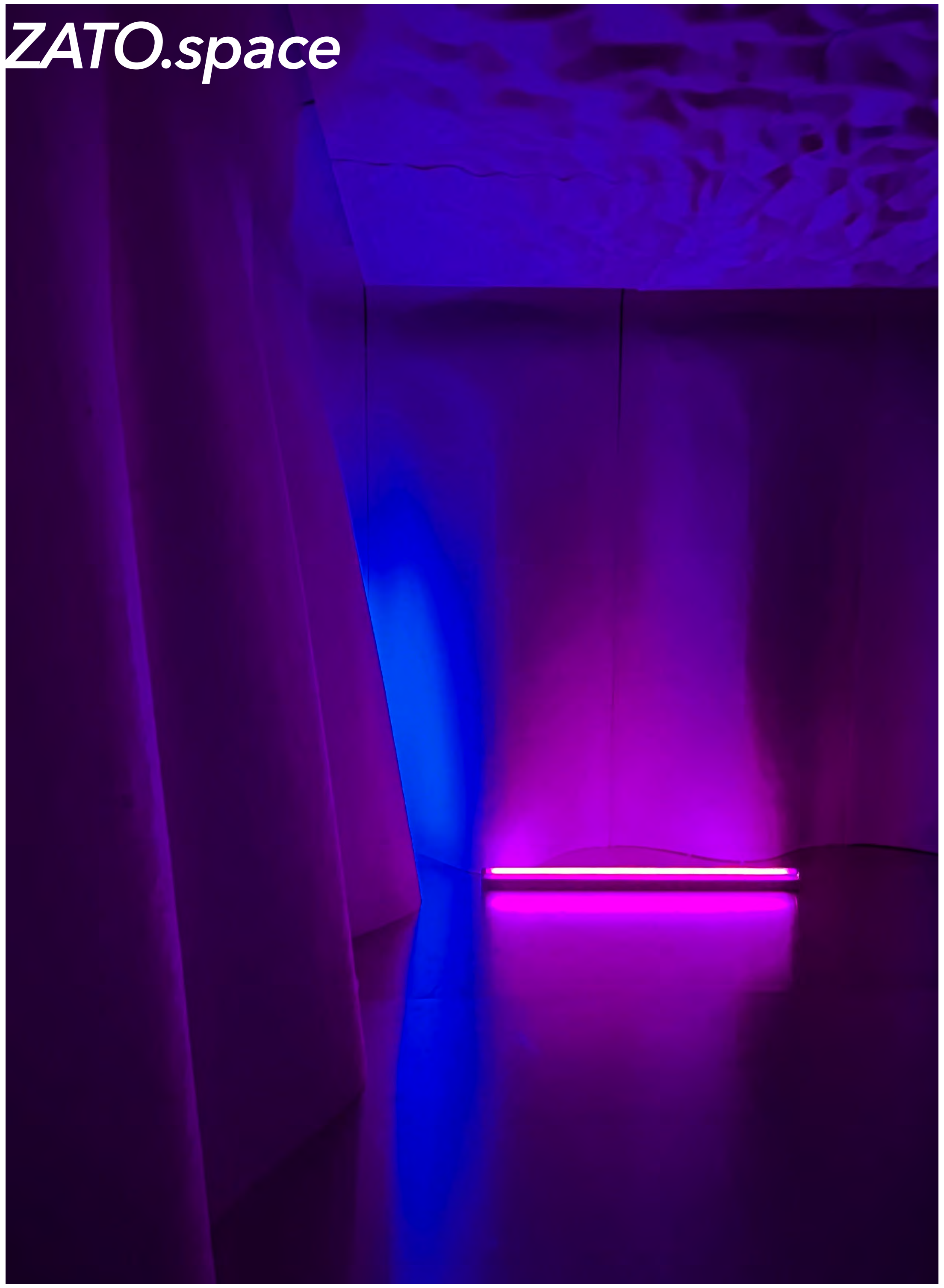
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FOR
A
GRAND
PIANO

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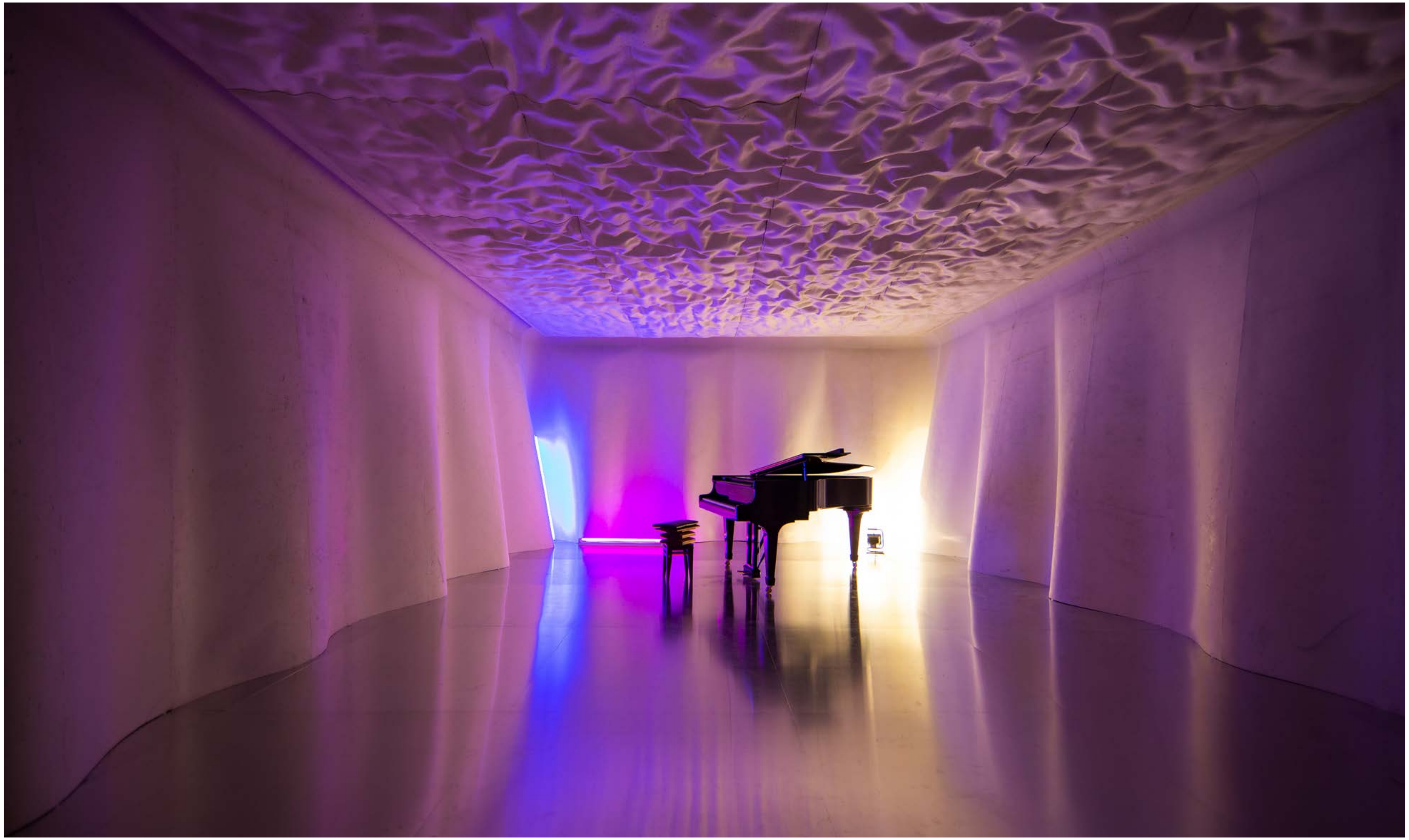
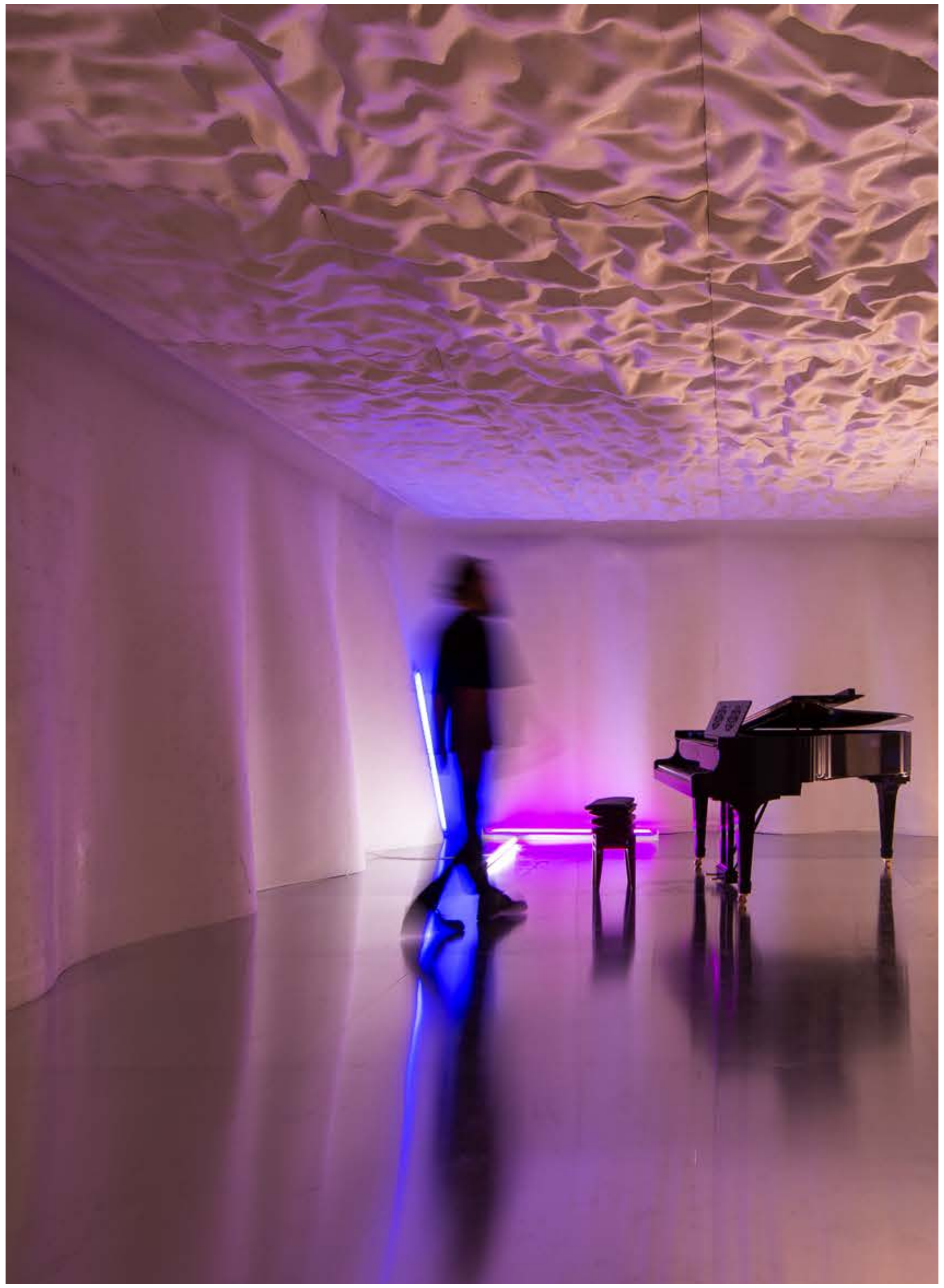
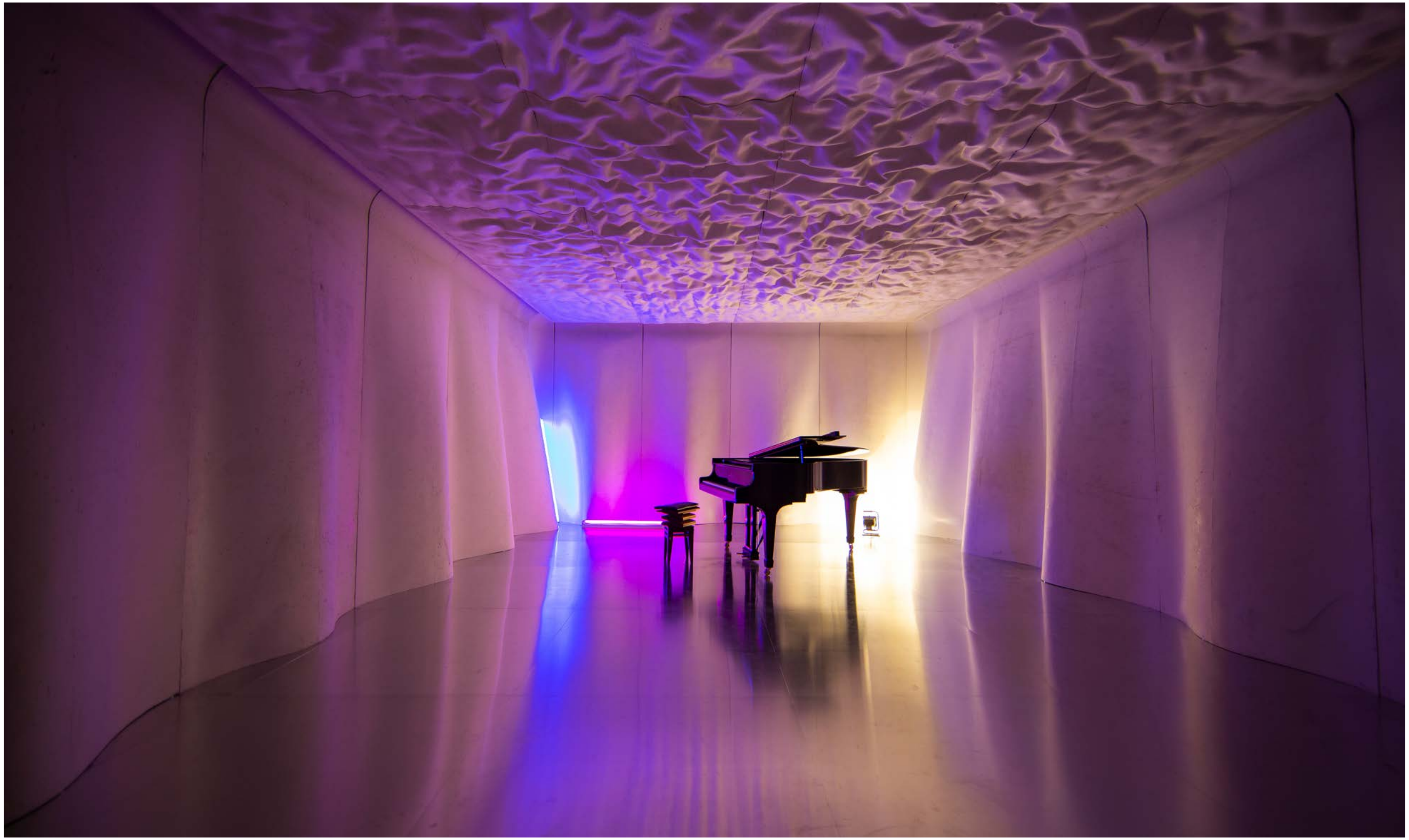
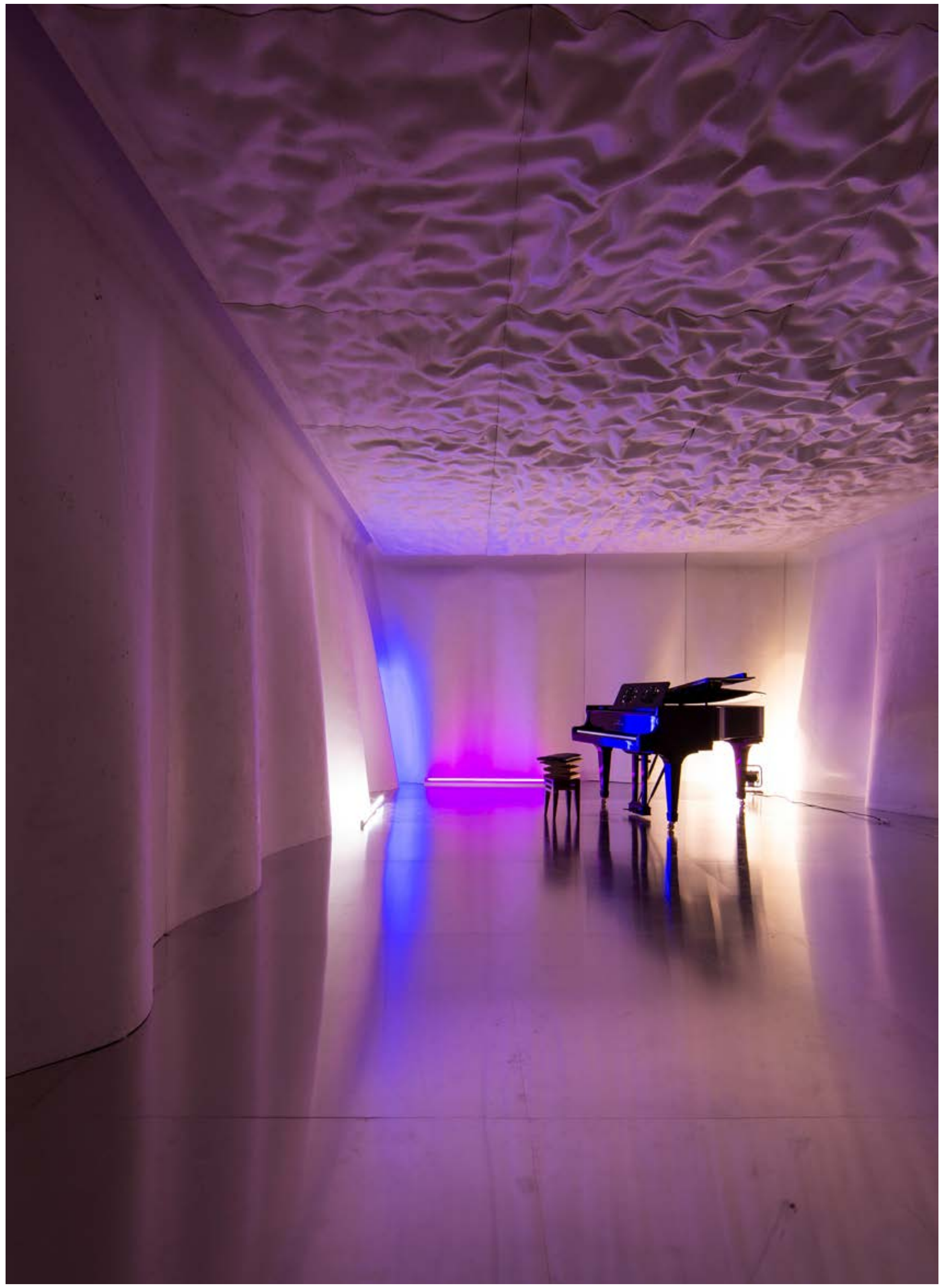
The passion for music will be celebrated in a series of concerts an performances by professionals and students in the first four weeks of the upcoming spring semester 2022.

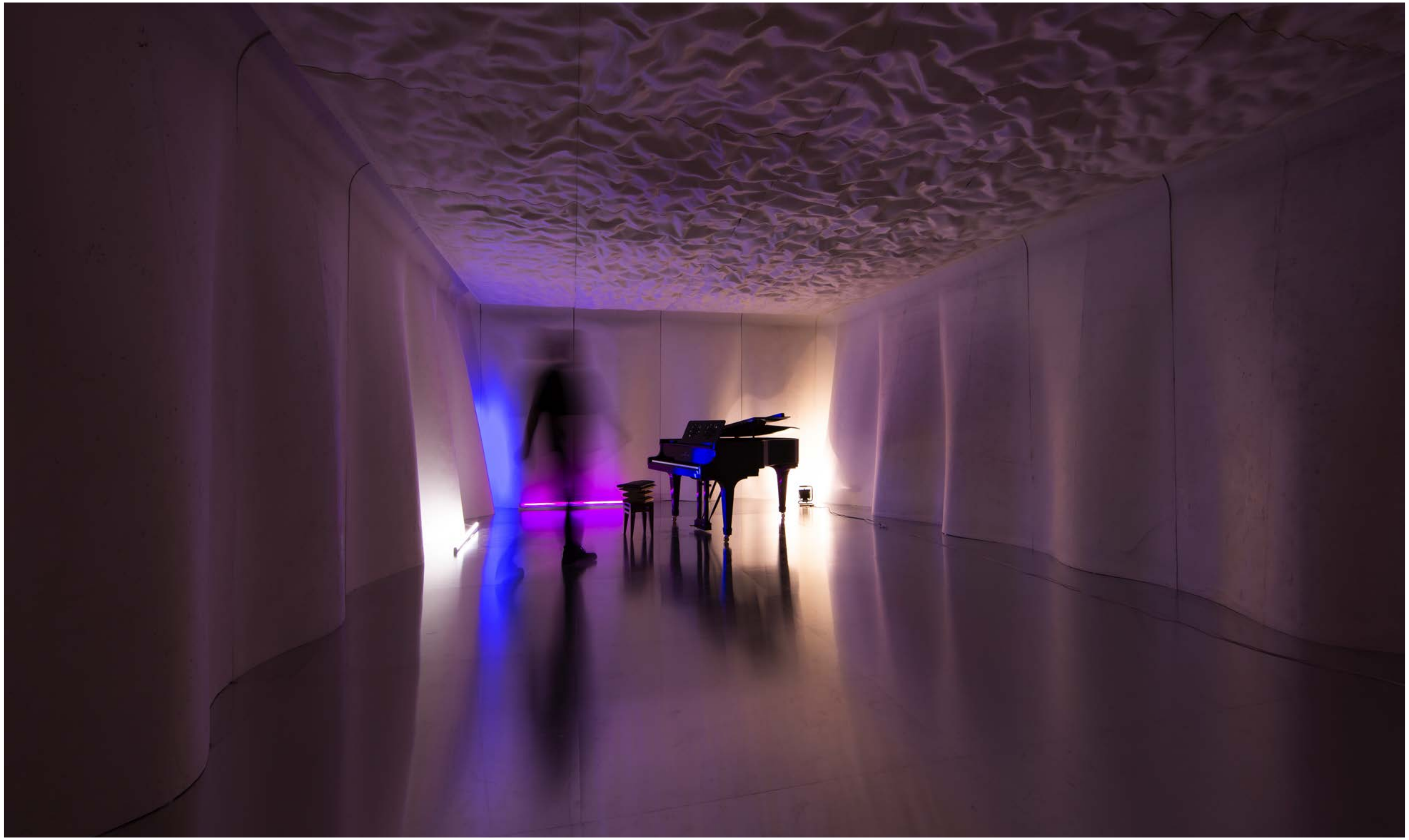
The series of concerts and discussions begin February 22nd and will end March 19th.











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POSTERS

FOR

THE

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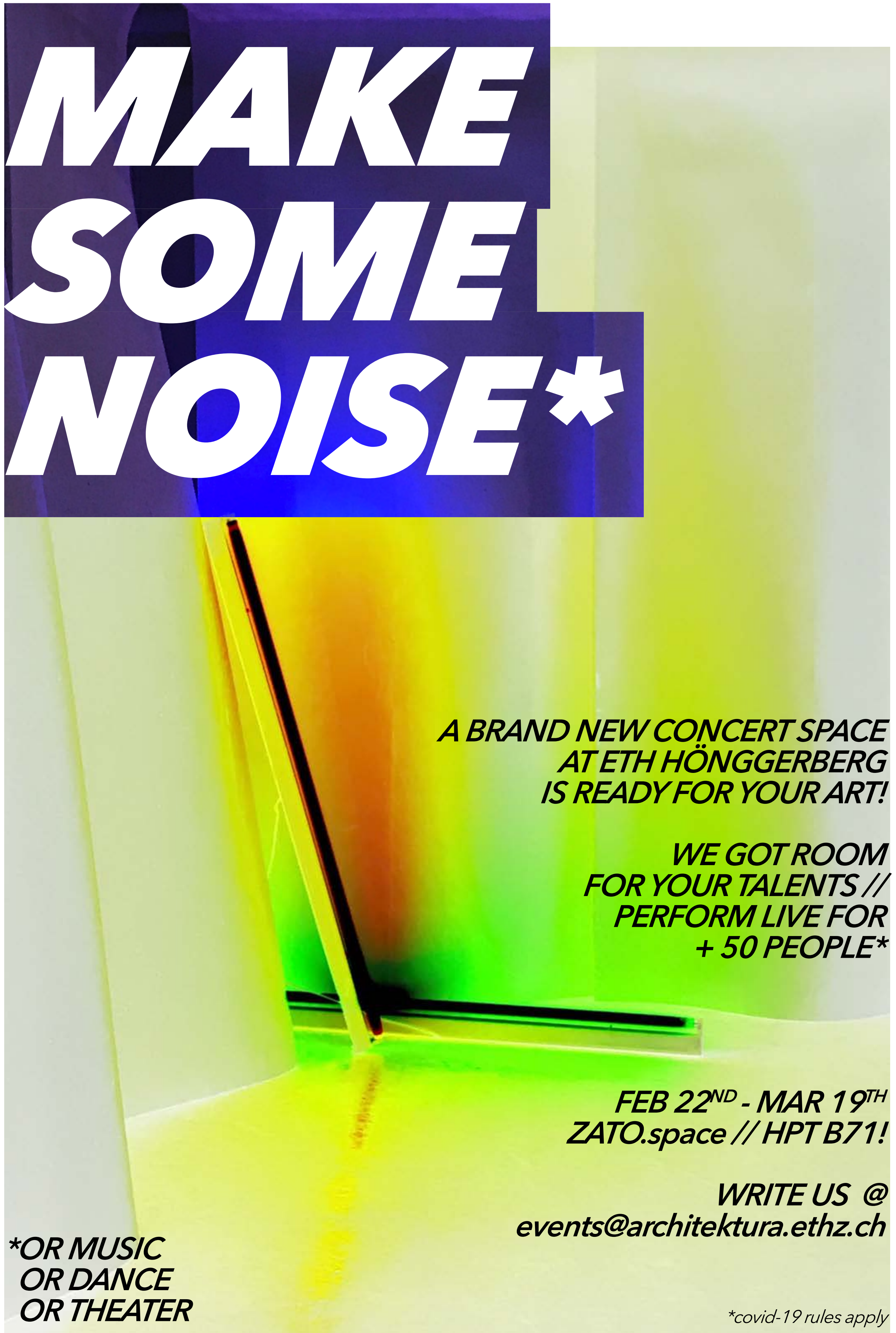
CALL

Students as well as assistants and professors are warmly welcomed to visit the space and contribute with a small performace or lecture to celebrate the love for music and architecure.



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LITERATURE // GOOD READS

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IMAGE DIRECTORY

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fig 3: Gaudi, A., Sagrada Familia Hanging Model, 13.1.2022, https://twitter.com/areasvellas/status/1280082332893003778/photo/1

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fig 18:Schmid, J., Schubertiade, 1897, Wien, Männergesangsverein, 4.3.2021, https://commons.wikimedia.org/wiki/File:Julius_Schmid_Schubertiade.jpg

fig 19: Horvath, M., Sala Terrena, 4.3.2021, https://www.manfredorvath.at/suche/sala+terrena/f1l490118/

fig 20: fig. 4: Michele, M., Ali Qapu Music Hall, 4.3.2021, https://i.pinimg.com/originals/07/0b/69/070b69c432b24b819938cb375f9677c4.jpg

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fig 24: THE room mode calculator,Zürich, 22.4.2021,https://amcoustics.com/tools/amroc?l=1067&w=607&h=310&r60=0.6

fig 25-26: Meyer, J., Akustik und musikalische Aufführnungspraxis, 6. Auflage, PPV Medien, Bergkirchen, 2015, S. 133

fig 27: Meyer, J., Akustik und musikalische Aufführnungspraxis, 6. Auflage, PPV Medien, Bergkirchen, 2015, S. 89-90

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