Research report Robotic Building

responsible urban density

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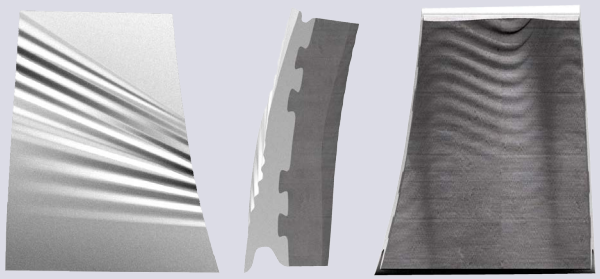
For my thesis I'm designing a new urban high-density housing typology. Several workshops were done over the course of last semester (2018-2019 Q1-2) to inform this design in specific ways. This report describes how each of the workshops informed the design.

workshop 1
Dessau



cast concrete shell element with EPS

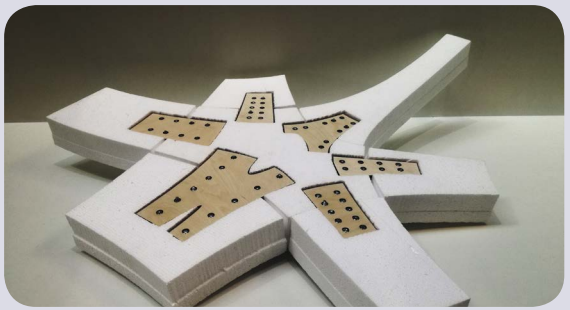
"How to digitally design and robotically produce a structural concrete shell element using a casting method, and how to incorporate hybridity?"

workshop 2
Delft

responsive architectural installation

"How to design kinematic/responsive architecture and which applications could they serve?"

workshop 3
Delft



connection between precast concrete elements

"How to digitally design and produce connections between concrete shell elements? "

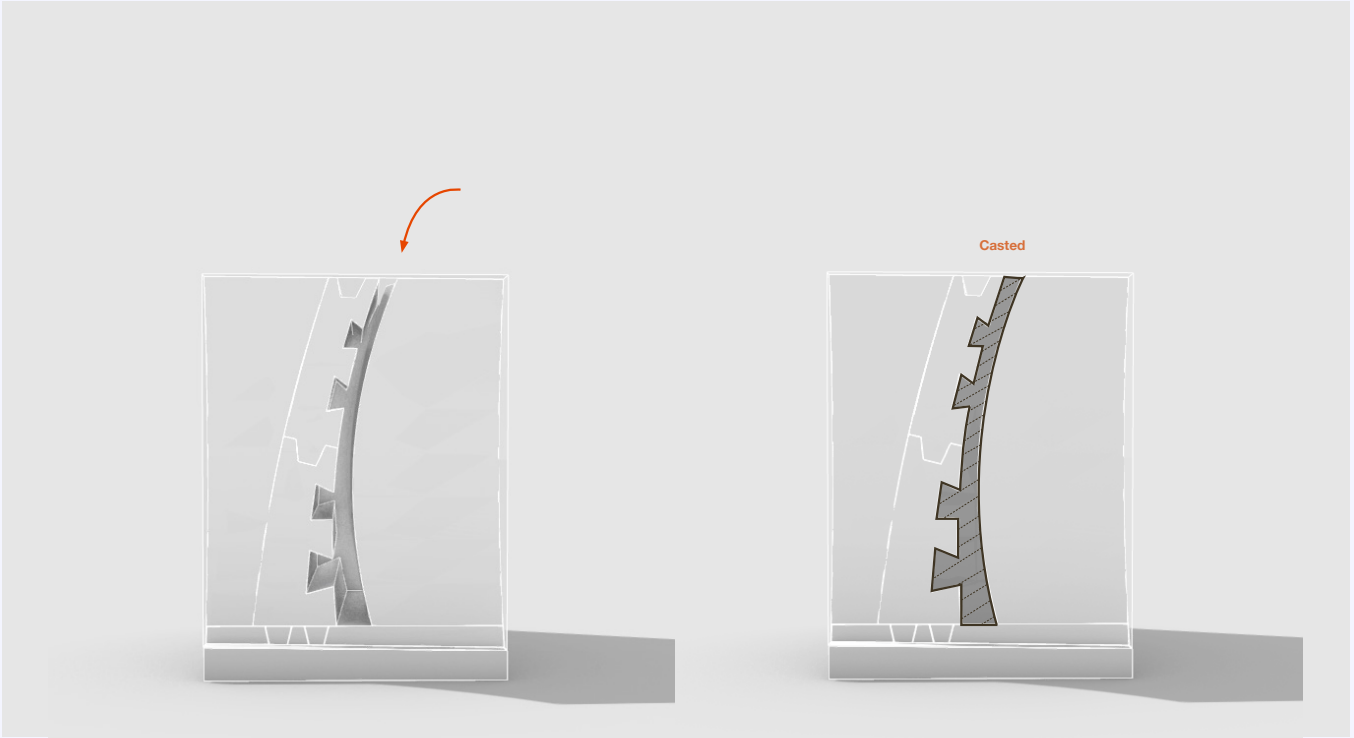
Thesis: High-density **housing** with **non-standard spatial organization**

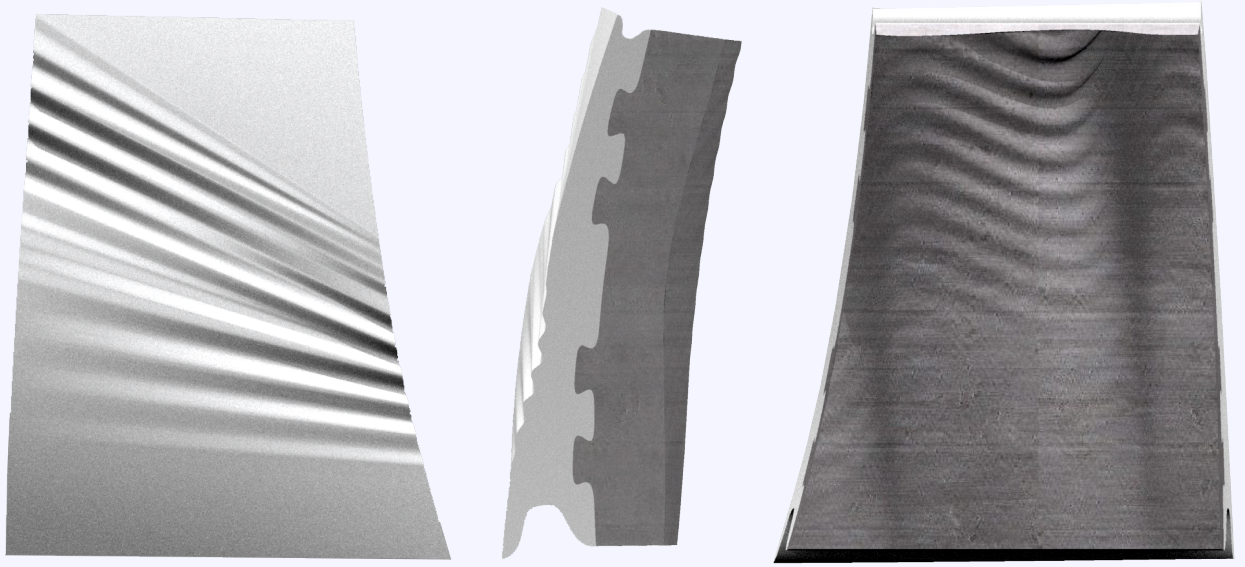
parametrically designed and robotically fabricated concrete shell structure

responsive architecture in housing

1

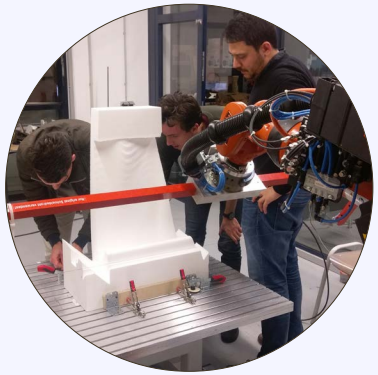
In the first workshop a single concrete shell element was produced by making a mold out of EPS which was used as a cast. Part of this EPS cast was incorporated in the element itself, which represents a form of insulation or finishing in the shell element. The combination of both thermal insulative properties as well as load bearing was chosen because these properties are vital when designing an apartment building.





1

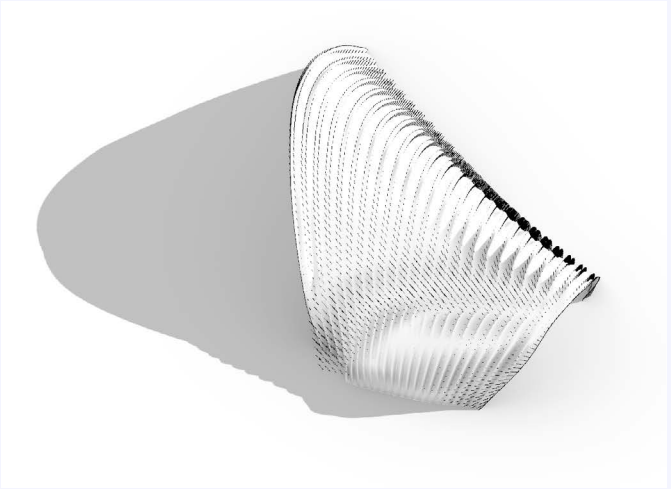
Here, the process of robotic production and casting can be seen.

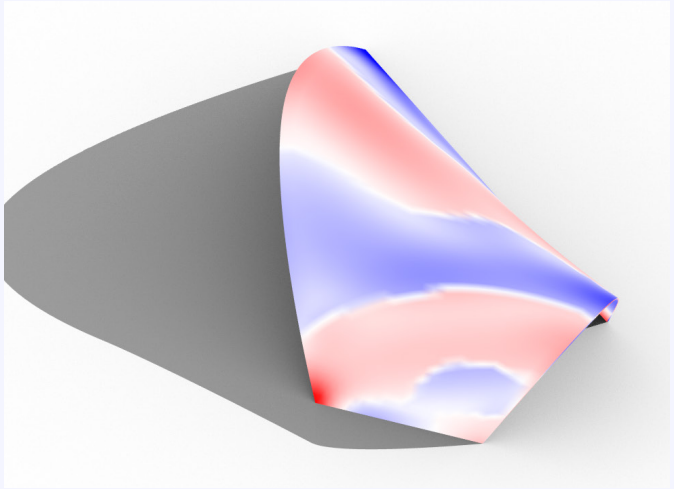


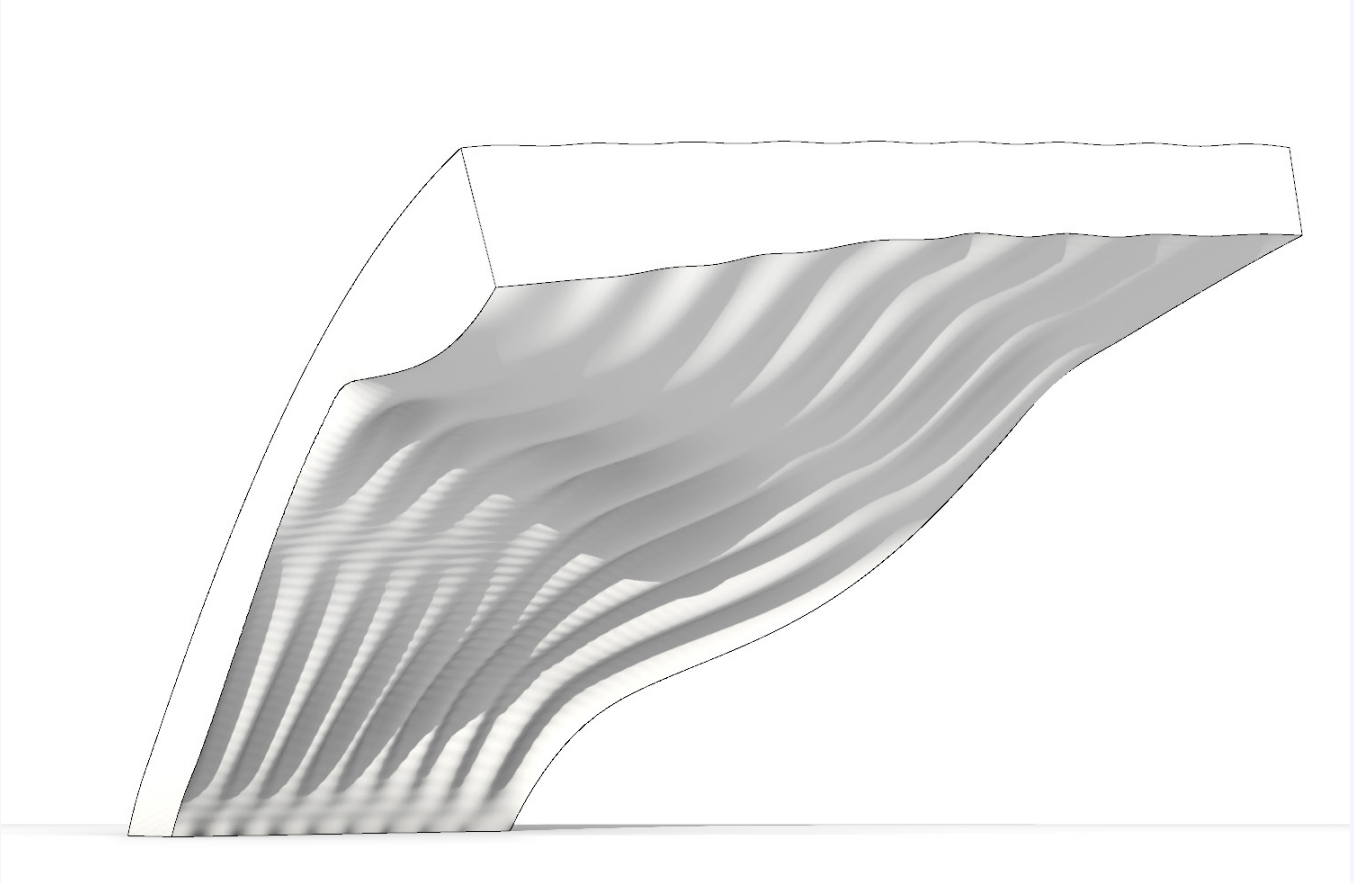



1

The element itself was designed using structural analysis, which informed a thickness variation in the shell structure where pressure was needed the most. This is important for my own design because the non-standard character of my design will highly likely result in a non-standard structure. For the design of this structure it is much more effective to rely on digital analysis which informs mass-customized elements instead of mass-produced elements.



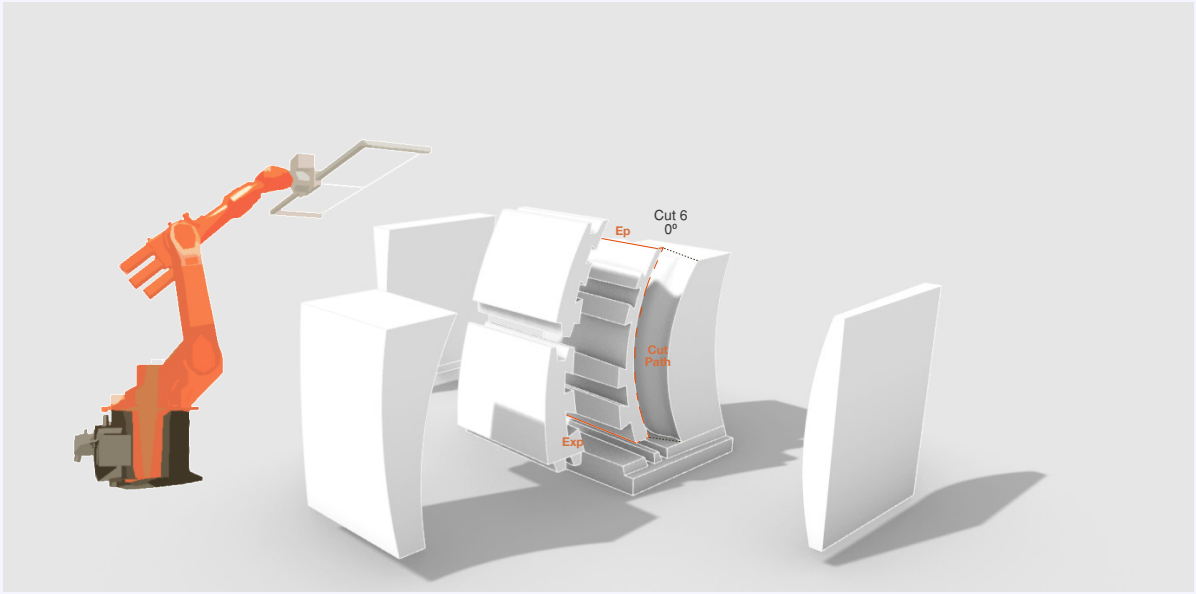




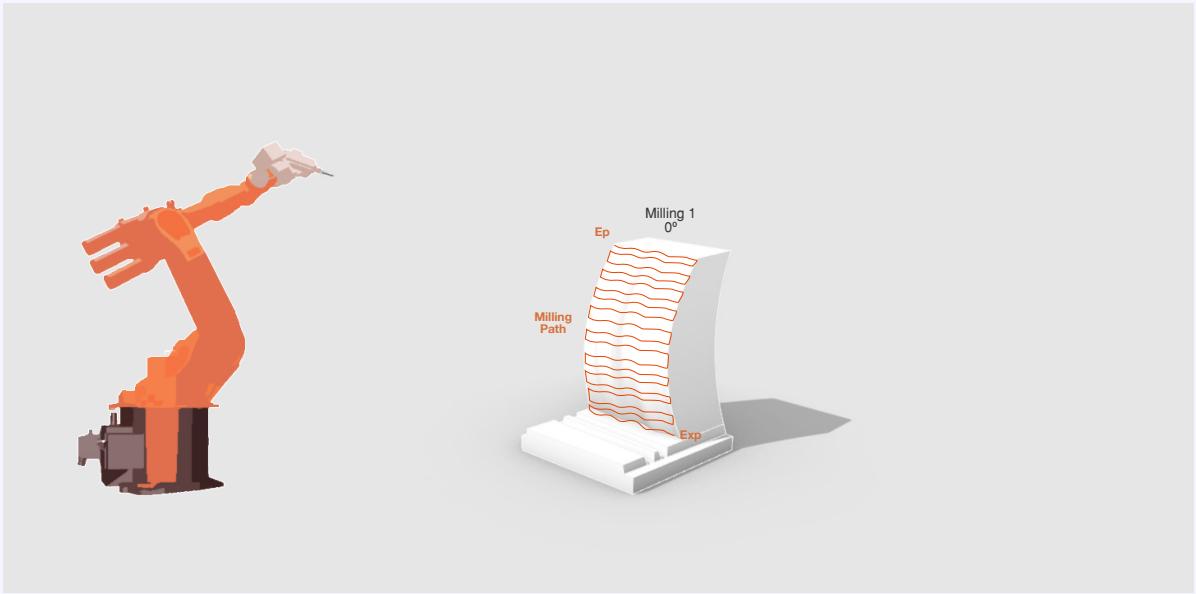
1

The mold for casting the concrete was robotically produced using both hot-wire cutting and milling. This combination was used because hot-wire cutting is a very time-effective production method, while milling enables a higher formal freedom.

hot-wire cuts

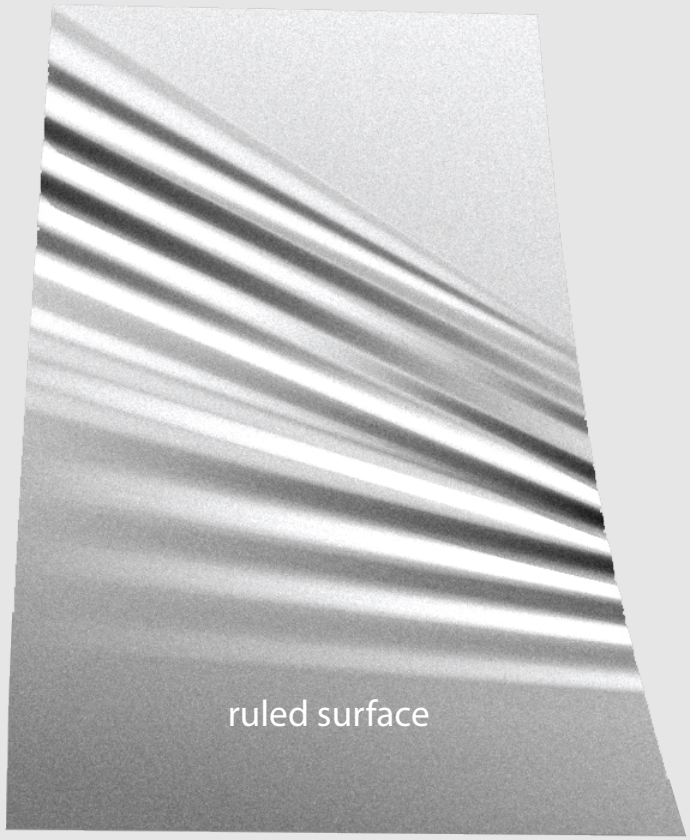


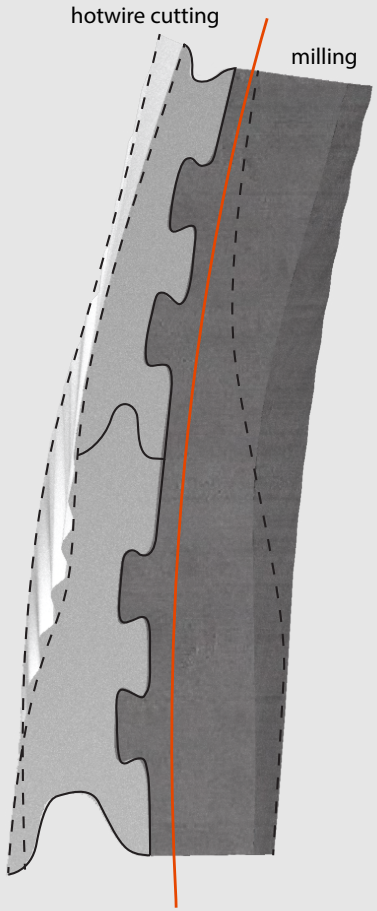
milling path

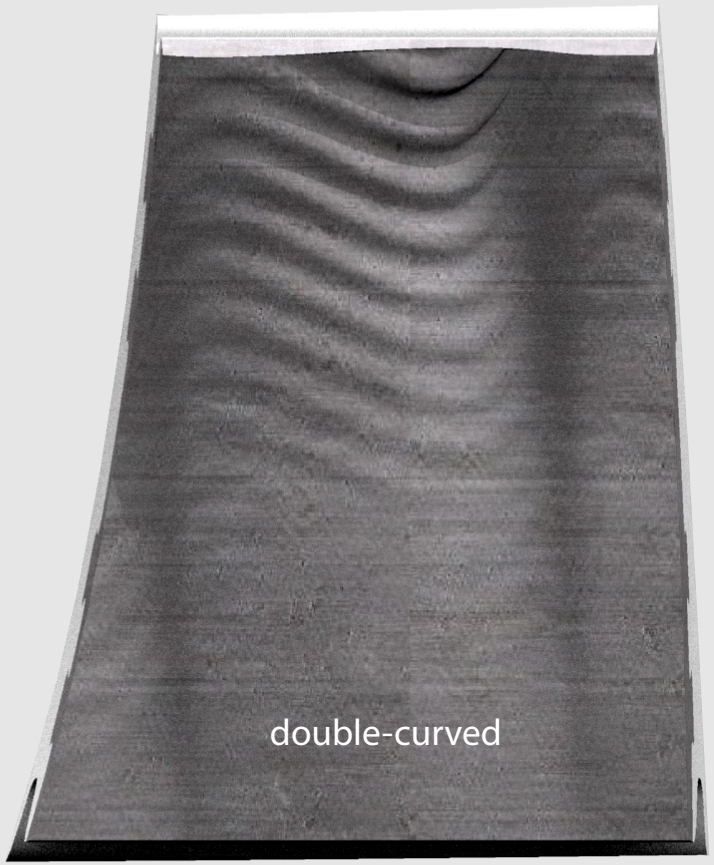


1

The limitations of these production methods form an important input for the design. We found out that the maximum formal freedom with hot-wire cutting was a ruled surface (a surface generated between two potentially curved lines). By varying the shape of the two lines which form the ruled surface different aesthetic or functional design options can be incorporated, while maintaining the speed of production of hot-wire cutting.
Milling was used for the back of the element. This was necessary because structural analysis-based thickness variation created a double curved surface.
For my own design I will have to apply each method locally where it is most efficient.

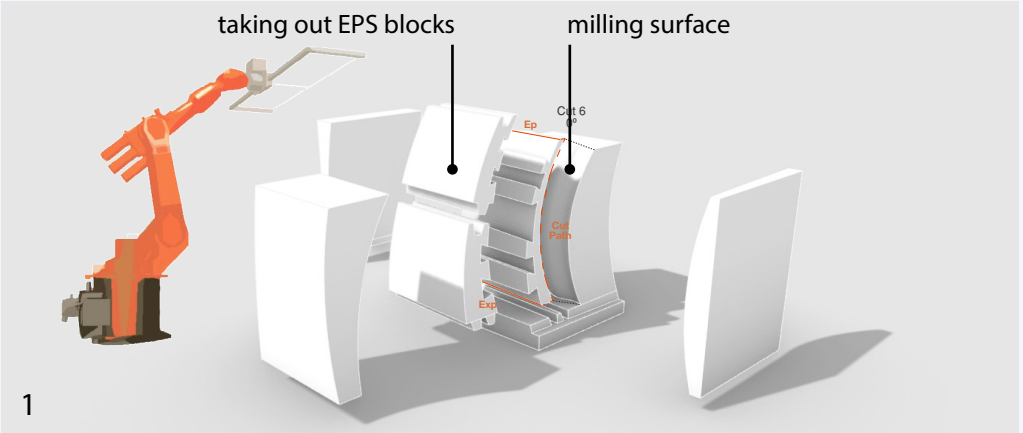




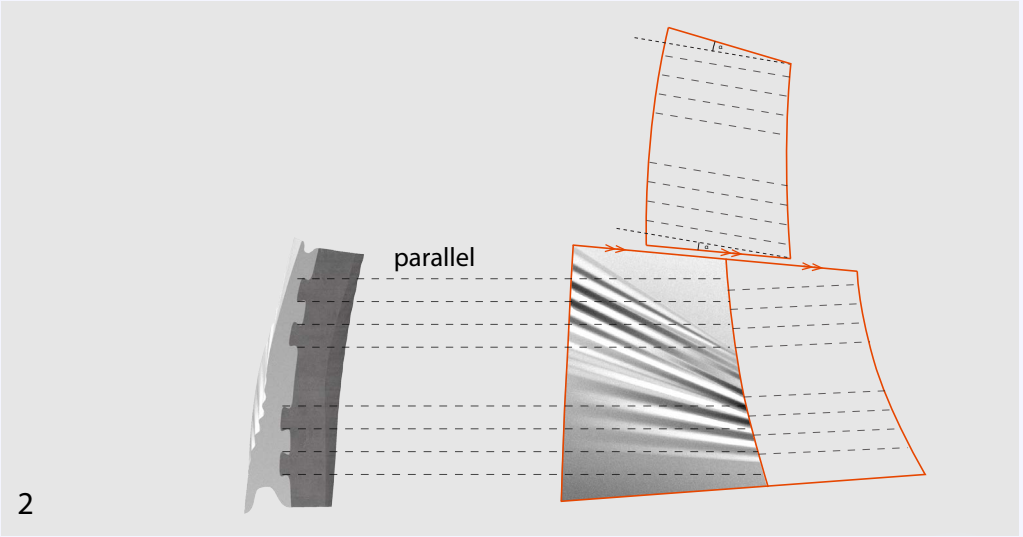


1

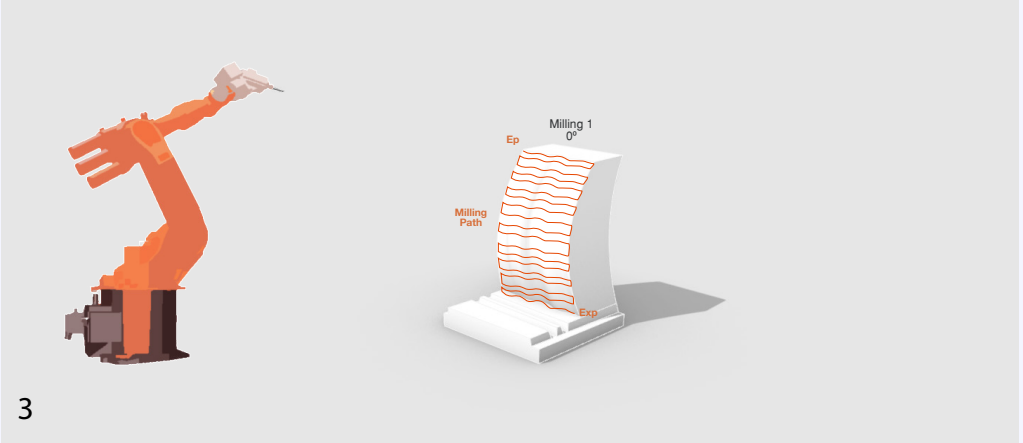
When incorporating part of the EPS mold in the element itself one has to be careful in designing the concrete-EPS connection. If this connection is not parallel (see image 2), it will be impossible for the EPS to be taken out (image 1). If the EPS block cannot be temporarily taken out, it will be impossible to reach the milling surface with the robot arm (image 3).



1

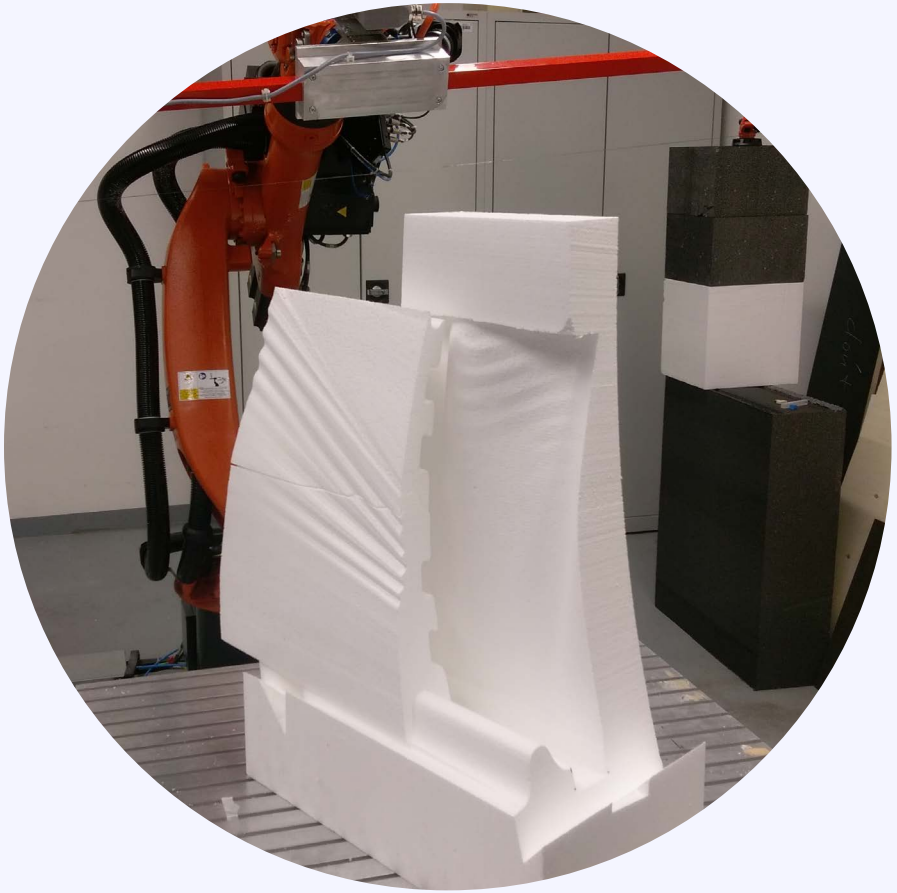


2



3

1

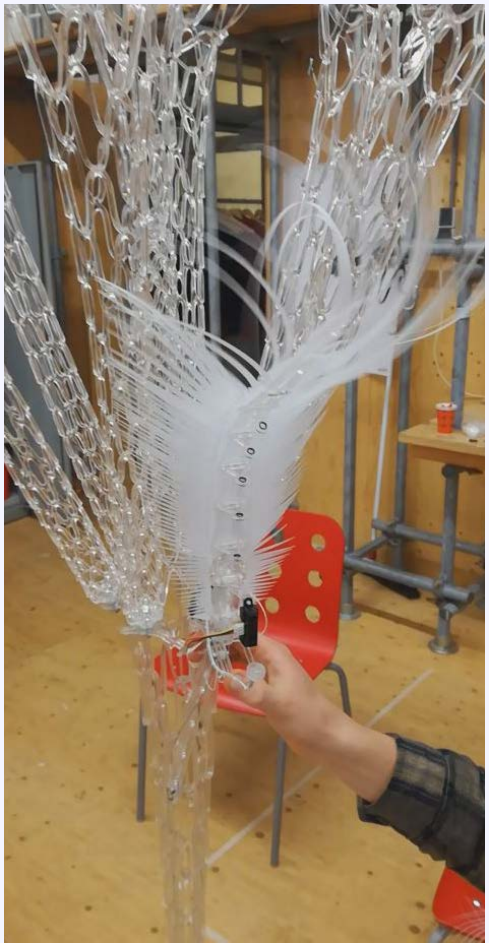
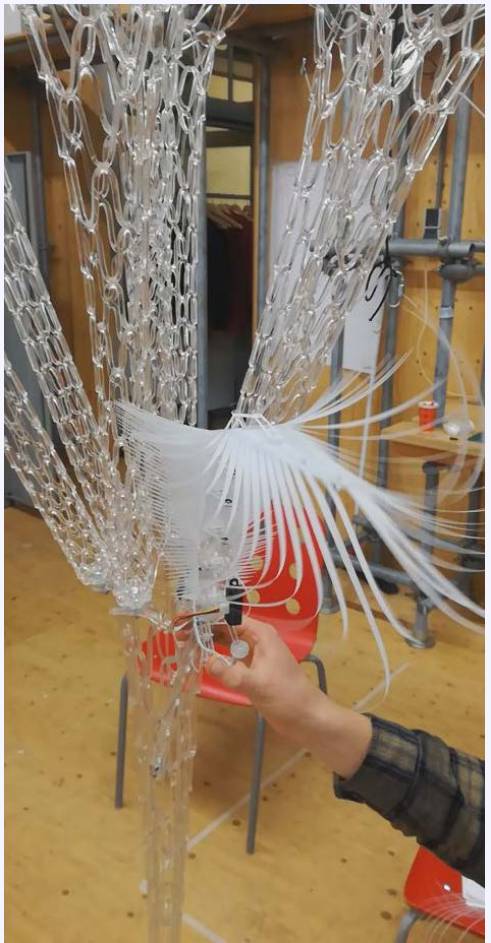
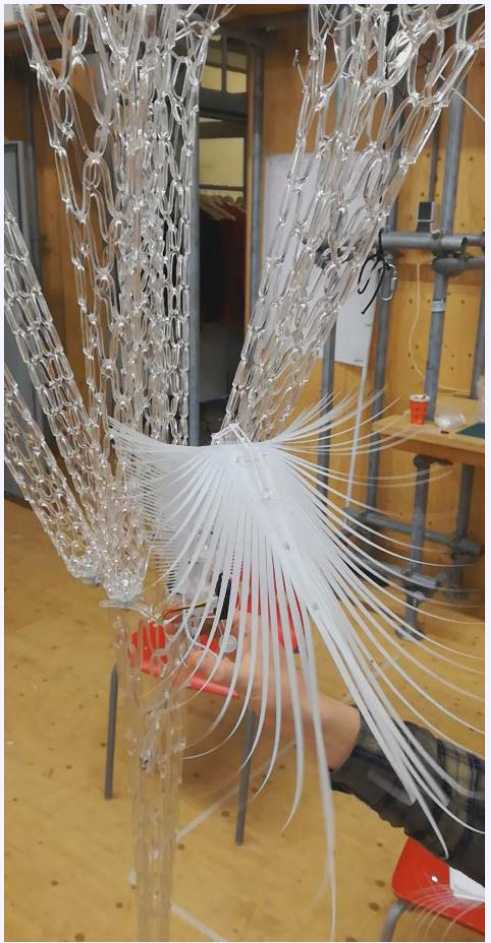


2

In the second workshop an interactive architectural installation was made in collaboration with Philip Beesley's Living System Architecture Group.

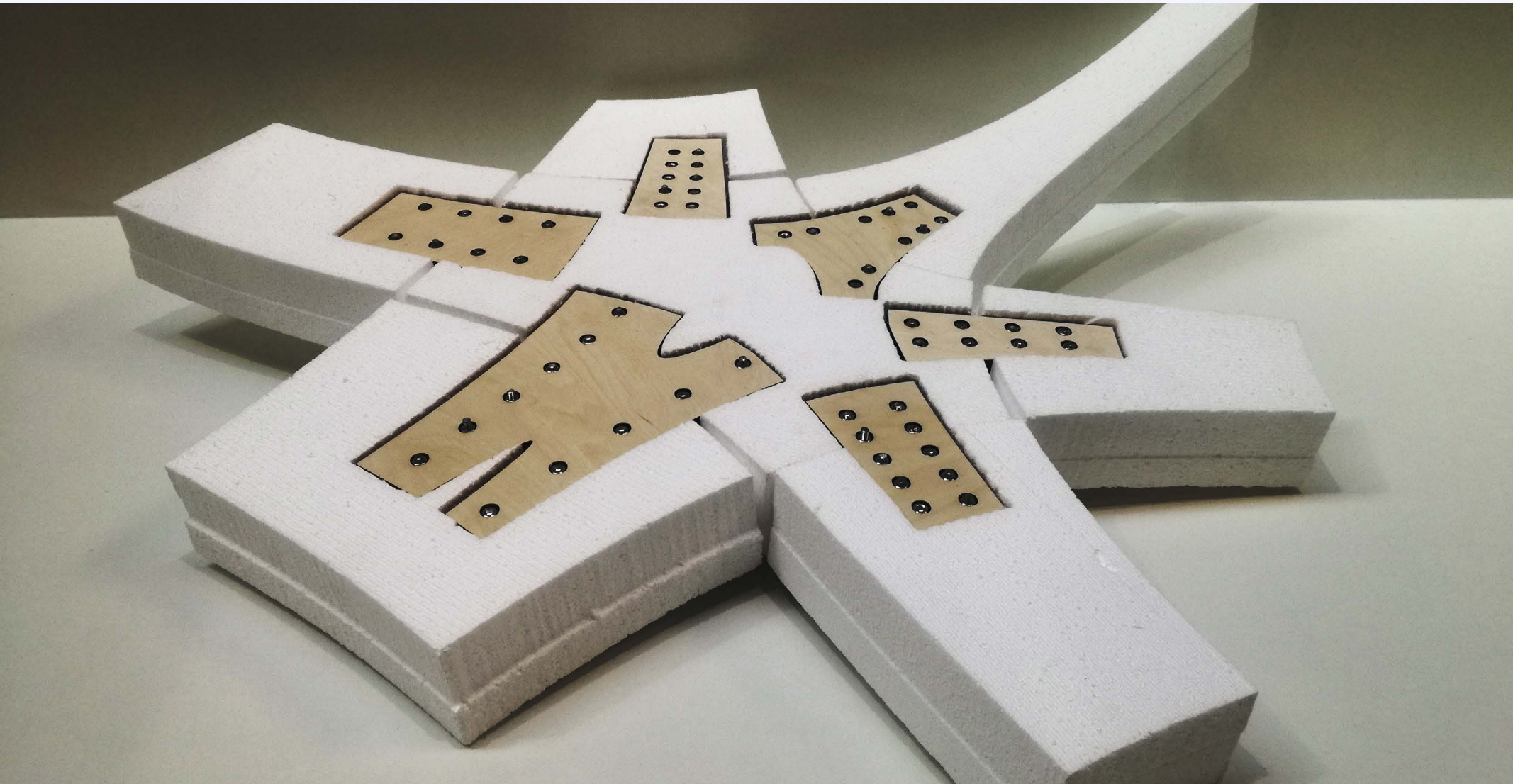
2

Here I mainly worked on the mechanical assembly of interactive parts of the installation. It gave me insight in other possibilities for making interactive architecture (besides the use of loud motors). The system used a metal wire which was heated by an electric current when the sensor recorded a signal. This caused movement in the element. While the wire cooled down the feather returned to its resting shape.
Similar interactive systems are interesting for my project because its silence makes it very suitable for application in housing, for example in automatic shading devices.

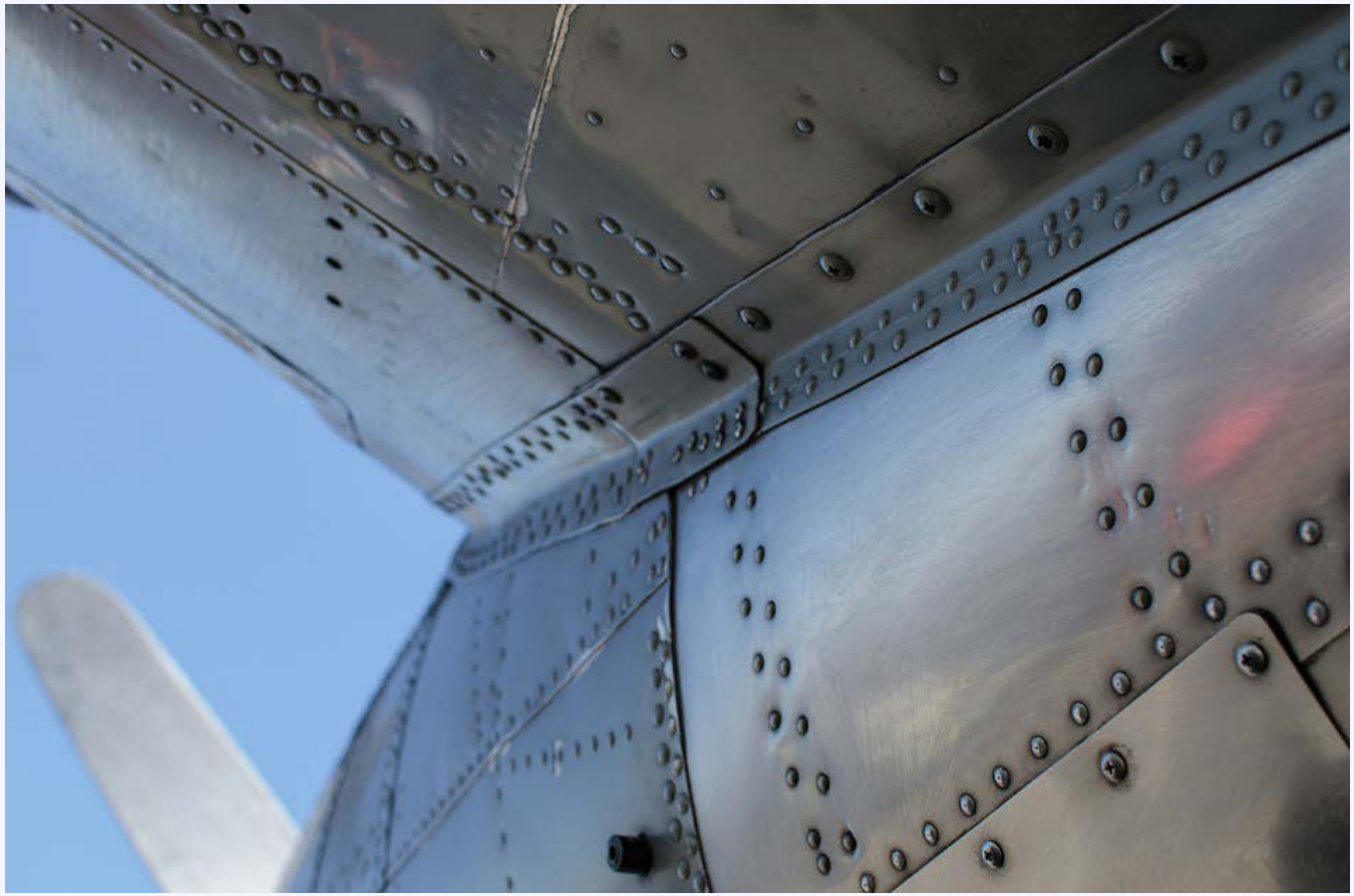
3

The third workshop continued the work done in the first. It explored the options when connecting multiple concrete shell elements together using dry connections. A focus on dry connections was chosen because this connects to applications in housing where functional change of spaces is highly likely. Dry connections between shell elements make it easier to alter these spaces.



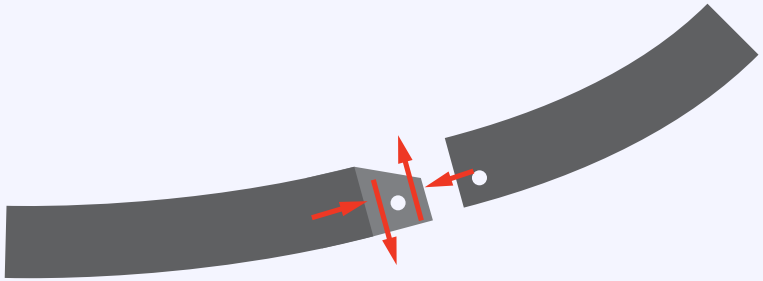
3

For the connections between several shell elements, shell structures in aviation formed an important reference. It shows how a row of rivets is able to divide the forces within a shell more evenly, approaching how wet connections (like glue) work in practice.

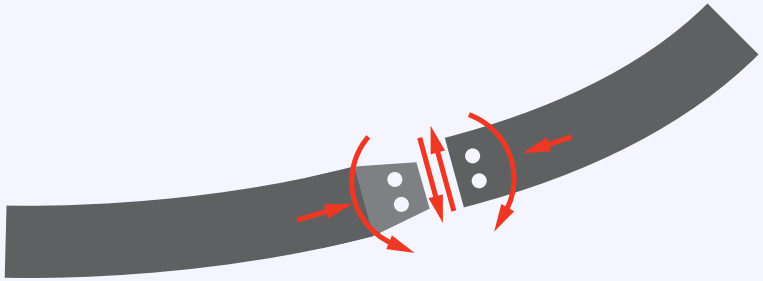


3

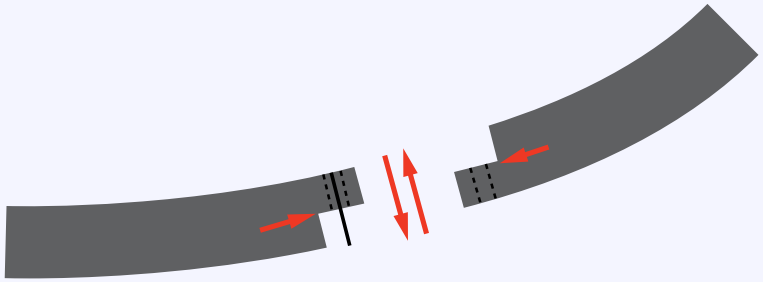
However, these shells are usually connected to a secondary structure, while in our scenario the shell itself is the main load-bearing structure. This means that besides shearing forces and normal forces the connection has to be able to restrict the element from bending.



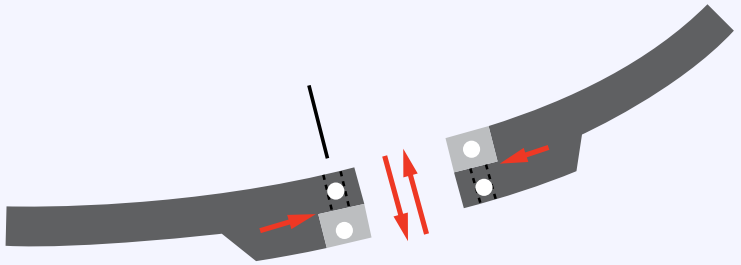
normal force
shearing force



shearing forces
normal forces
rotational forces

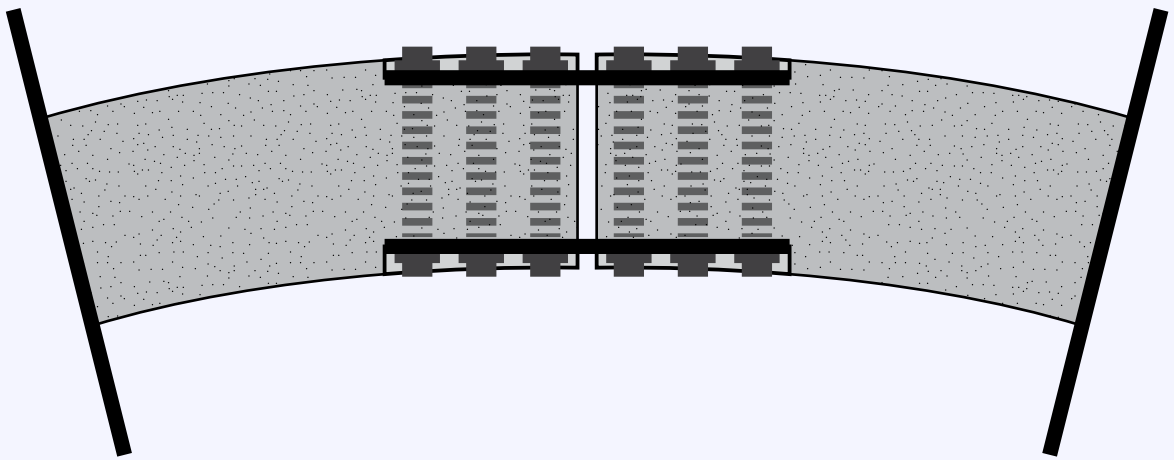


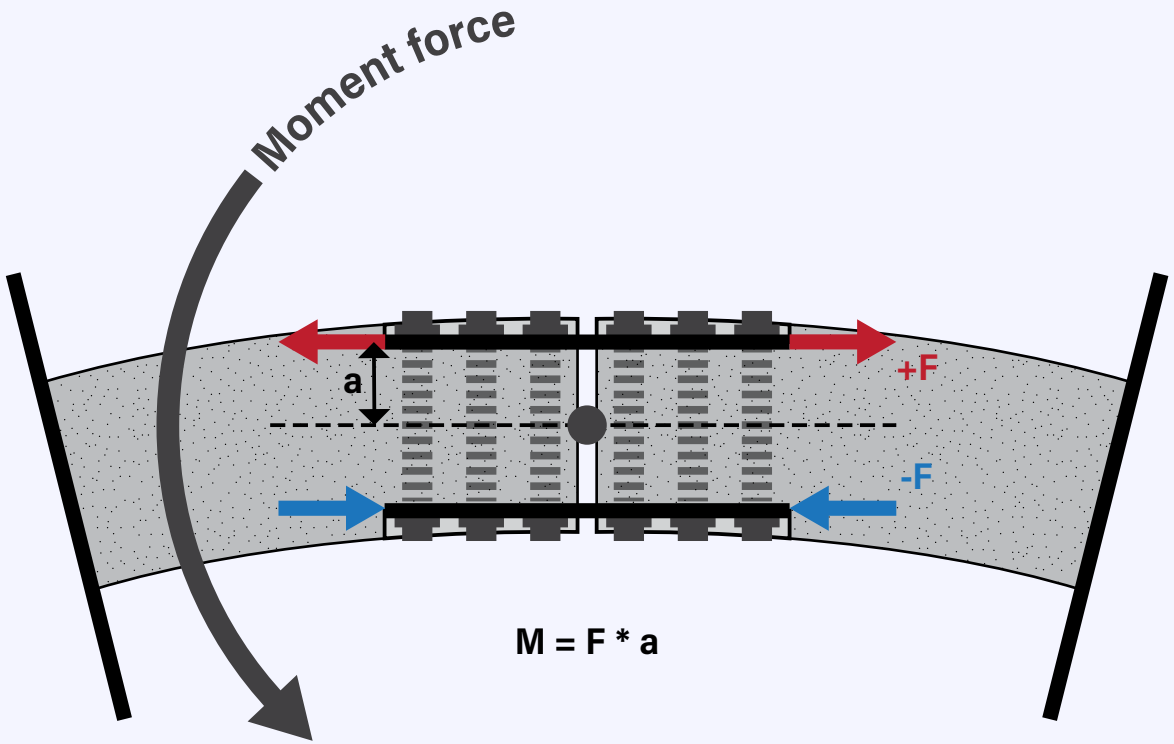
normal force
shearing force



shearing forces
normal forces
rotational forces

3 Therefore we designed a connection with two plates that are bolted together. The use of two plates at a certain distance from eachother enables the connection to resist a bending moment.



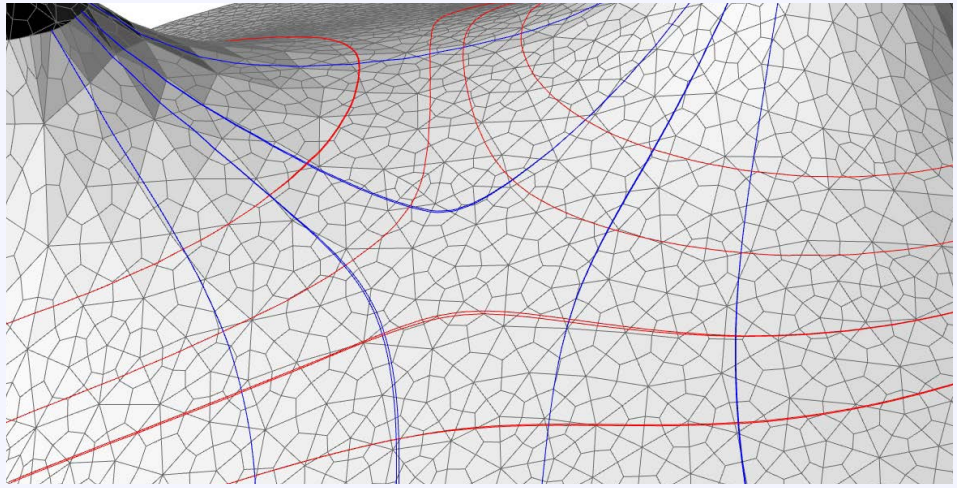


3

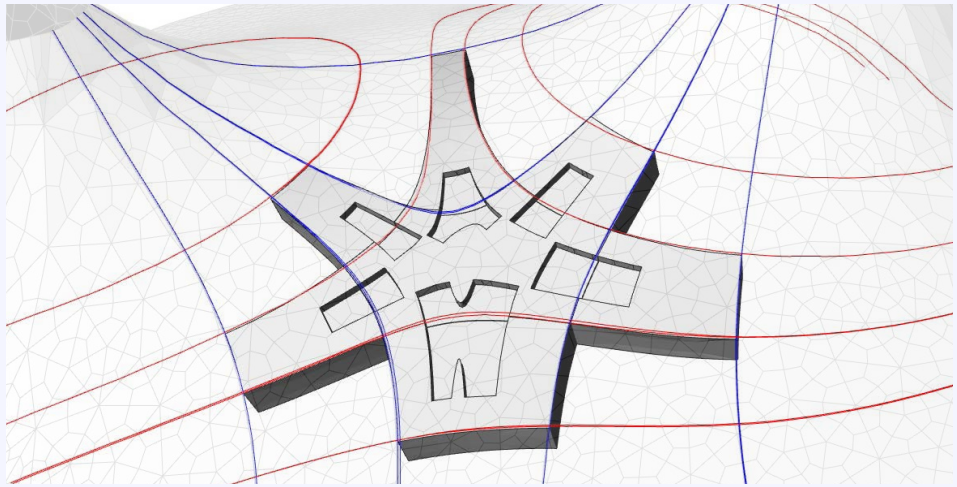
Besides this we developed a componential logic where the division of a surface into individual shells is based on the flow of the forces within the material. This surface division is supposed to generate a structurally sound force trajectory, even when the surface consists of individual elements.

The connections between the elements follow a similar logic. The rivets are placed on the path along which the force travels through the surface, which enables the rivets to better transfer the load from one element to the other. Besides its effectiveness the connection creates a certain aesthetic as it shows the flow of the forces through the shell.

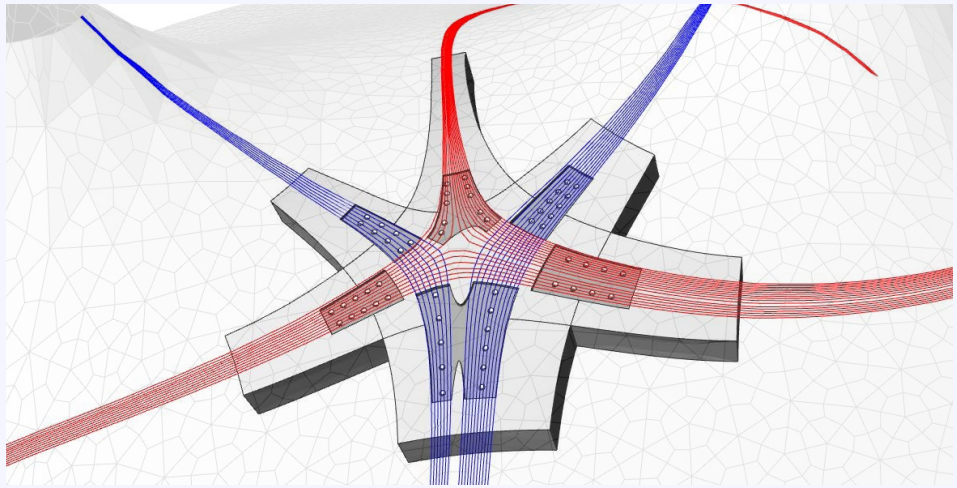
structural analysis

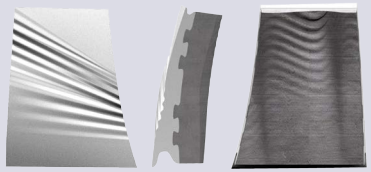


componential logic based on structural analysis



connections based on structural analysis

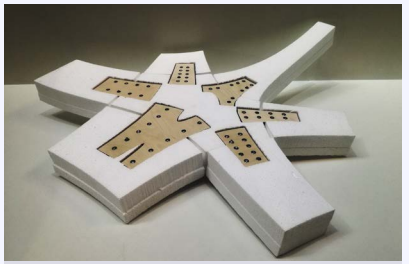




robotic production of concrete shell element

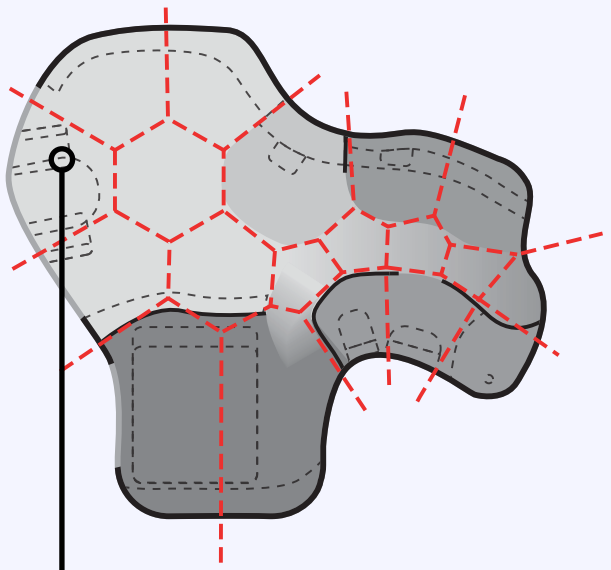
- robotic production (milling + hot-wire cutting)
- hybridity
- concrete casting
- structural analysis informs shell thickness

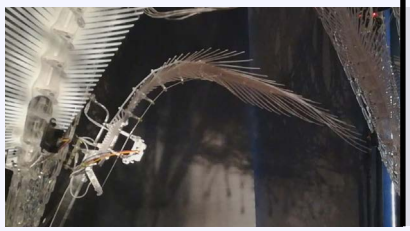
urban high-density housing



connections between shell elements

- dry connections
- componential logic
- structural analysis informs connections and comp. logic





interactive building skin

- silent actuators
- responsive systems