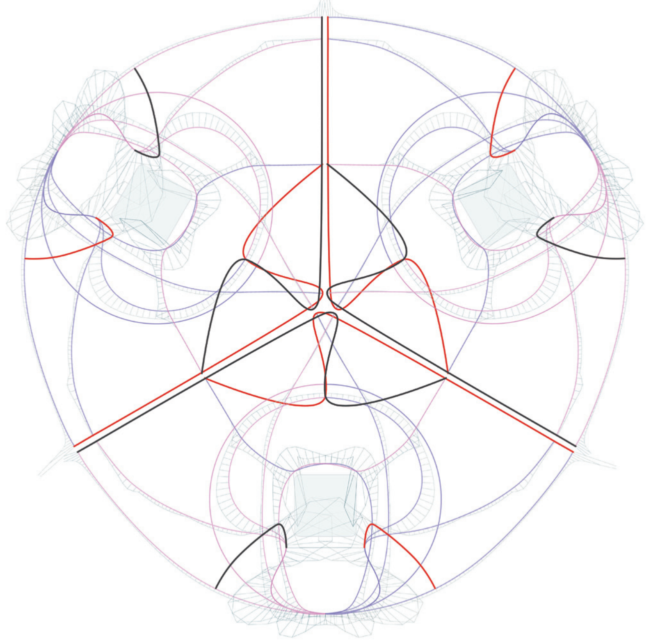
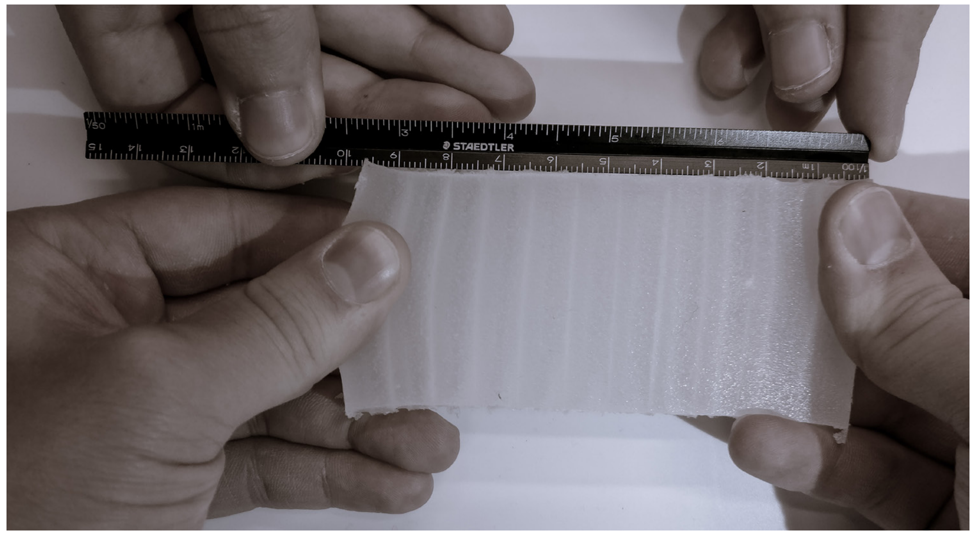
THE MOVING WALL

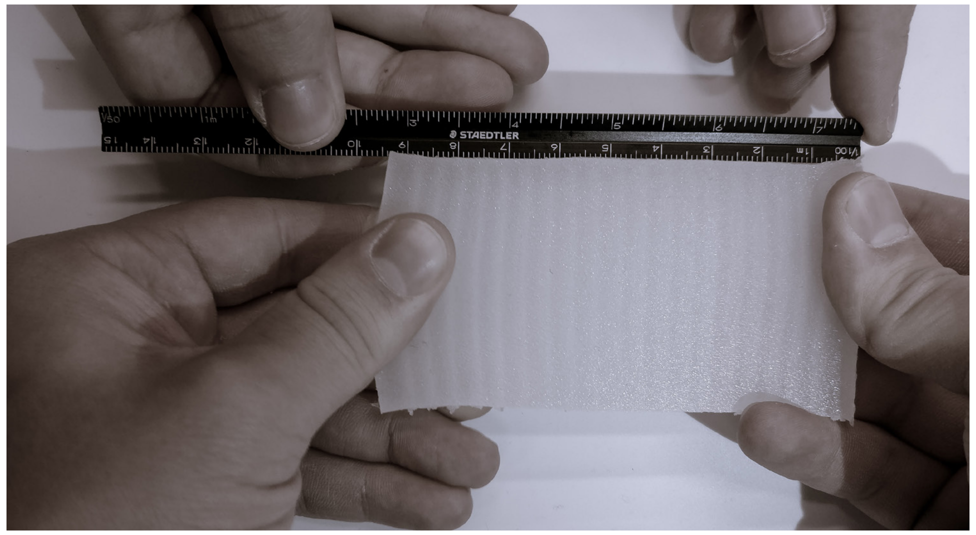
Core to our concept is the moving wall system, which allows for the flexible adaptation of spaces.

Through qualitative data gathered from the user data, the configurations of the spaces was distilled down to 5 different possible layouts. Within each of the layouts, a certain curvature had to be achieved to enable the space.



In working with the curvature, one of the first experiments conducted was the research into porosity to conclude if the variance of the porosity could passively drive the shape of the wall when force was applied.

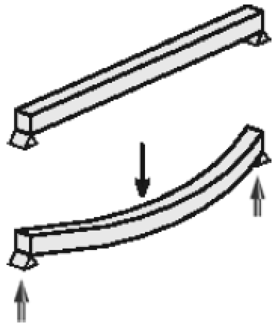




In these experiments however, we discovered that much more force had to be applied in order the shape to take place. We realised that porosity in this context, did not affect much of the final form of the material. The flexibility came from the material's own embodied properties.

In order to use porosity for passive optimization, we needed a better understanding of both the embodied property of the material itself and what porosity can ultimately help us achieve by leveraging those properties.

To understand how a material behaves, we started with the simple model of two supports and a single point of force applied in the middle of the beam to find the basic curvature and flexibility of the material. This simple model of deformation provides the starting point for the structural investigation.



To understand the principles, MDF was chosen as a test platform, as it is widely available and inherently unbendable.

To successfully test and understand the materials, basic knowledge of the physical and mechanical properties of the material must be known. Notably, the elasticity, axial stresses and yield stresses.[1] This is shown in the table below[2] :

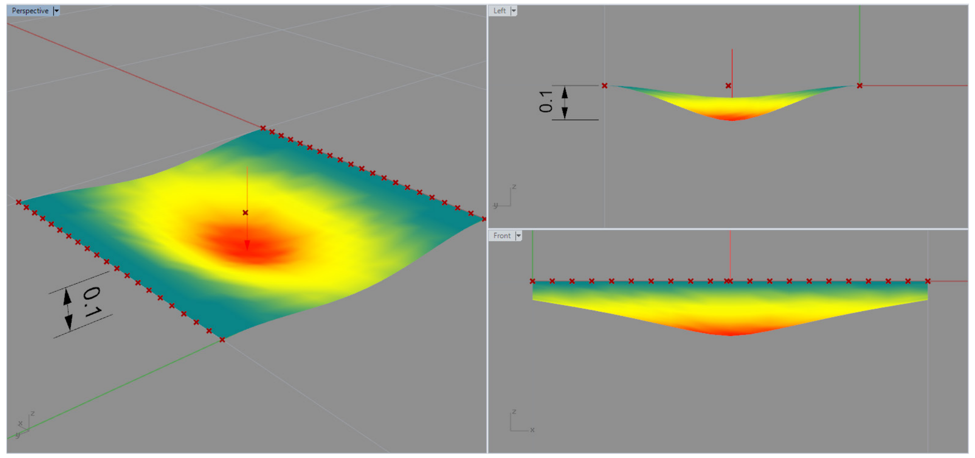
Compressive (Crushing) Strength	10 MPa (1.5 x 10^3 psi)
Density	0.75 g/cm^3 (47 lb/ft^3)
Dielectric Strength (Breakdown Potential)	0.5 kV/mm (0.020 V/mil)
Elastic (Young's, Tensile) Modulus	4.0 GPa (0.58 x 10^6 psi)
Elongation at Break	0.5 %
Poisson's Ratio	0.25
Shear Modulus	2.5 GPa (0.36 x 10^6 psi)
Specific Heat Capacity	1700 J/kg-K
Strength to Weight Ratio	24 kN-m/kg
Tensile Strength: Ultimate (UTS)	18 MPa (2.6 x 10^3 psi)
Thermal Conductivity	0.3 W/m-K
Thermal Diffusivity	0.24 m^2/s
Thermal Expansion	12 µm/m-K

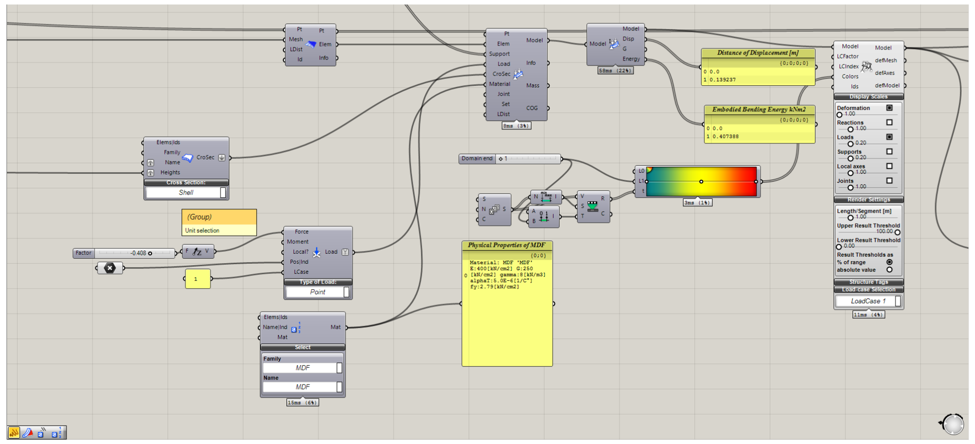
1. Sandaker, Bjørn Normann, and Arne Petter. Eggen. 1992. "The Structural Basis of Architecture." New York: Whitney Library of Design. Page. 84
2. Makeitfrom.com, 2016 "Medium Density Fiberboard (MDF)." Medium Density Fiberboard (MDF)

TESTING THE MATERIAL

Immediately, one can see that MDF is a stiff non bending material, especially because of the Young's Modulus. In MDF, there is not much room for bending before the material will break.

With these basic parameters, it is possible to computationally test and discover how much force is needed to bend the material to it's full elastic capability through the use of Finite Element Analysis plugin karamba/millipede in Grasshopper.





Here, the example is a 1000 x 1000 mm MDF board with a thickness of 4mm and a force of 0.4 kilonewtons (kN) and supported from both sides is seen to have a deformation of 139mm. Looking at the embodied elastic energy which is 0.407 kNm^2 it is evident that this is beyond the young's modulus, which means the material is then deformed beyond recovery.

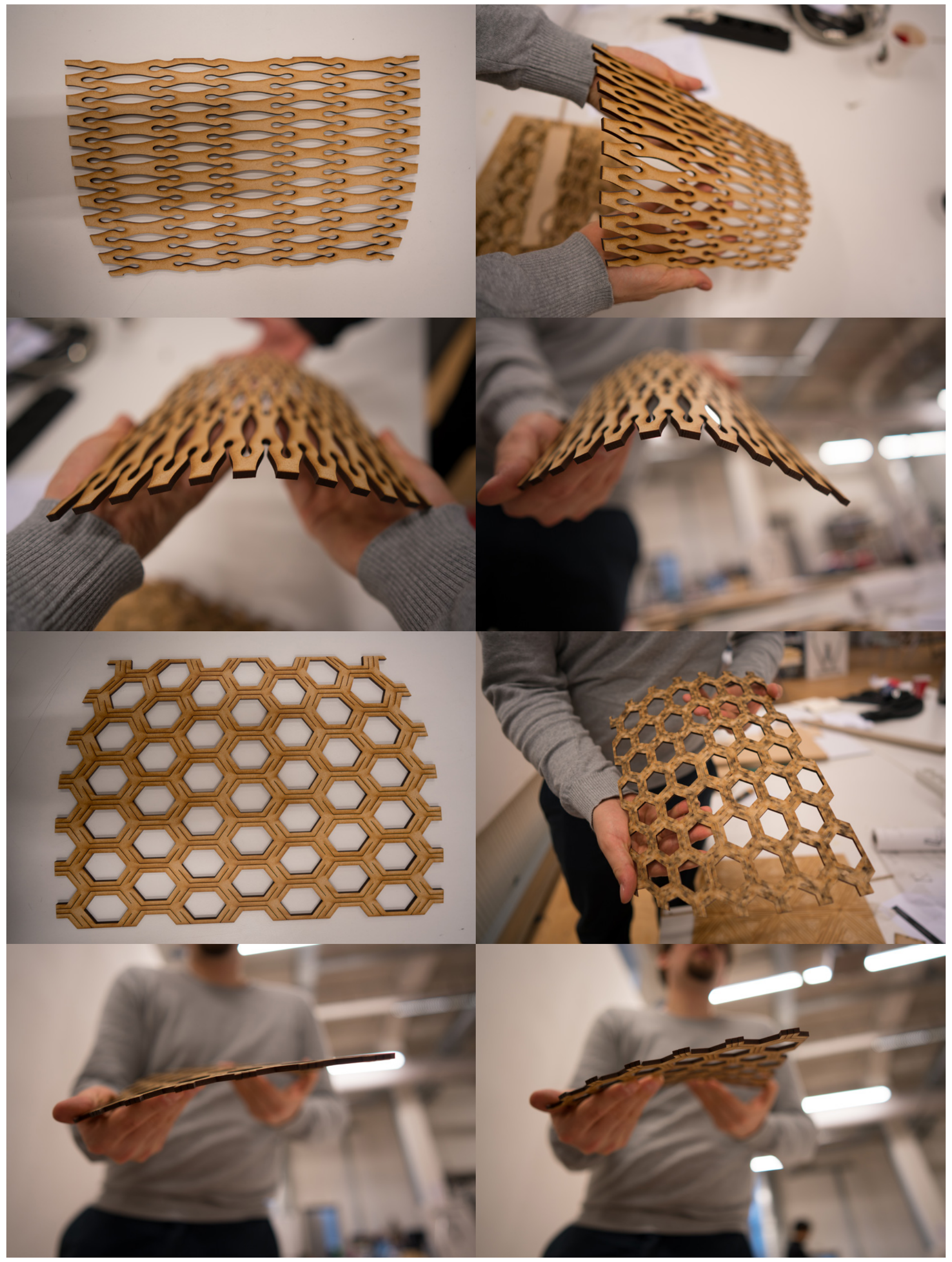
Humans can exert a force of 0.667kN from a static position. [3] Therefore will break the MDF sheet at these configurations.

To prove this theory, we conducted a quick test upon a physical piece of MDF. The material behaved similarly to the simulation.

Karamba is quite limited in terms of FEA. Due to the formulas it uses. It is only capable of 2D analysis, or beam structures, and thus is not a complete accurate representation when it comes to modifying geometry. We found that we had needed to switch to Millipede, which is capable of geometry FEA, through using voxels.

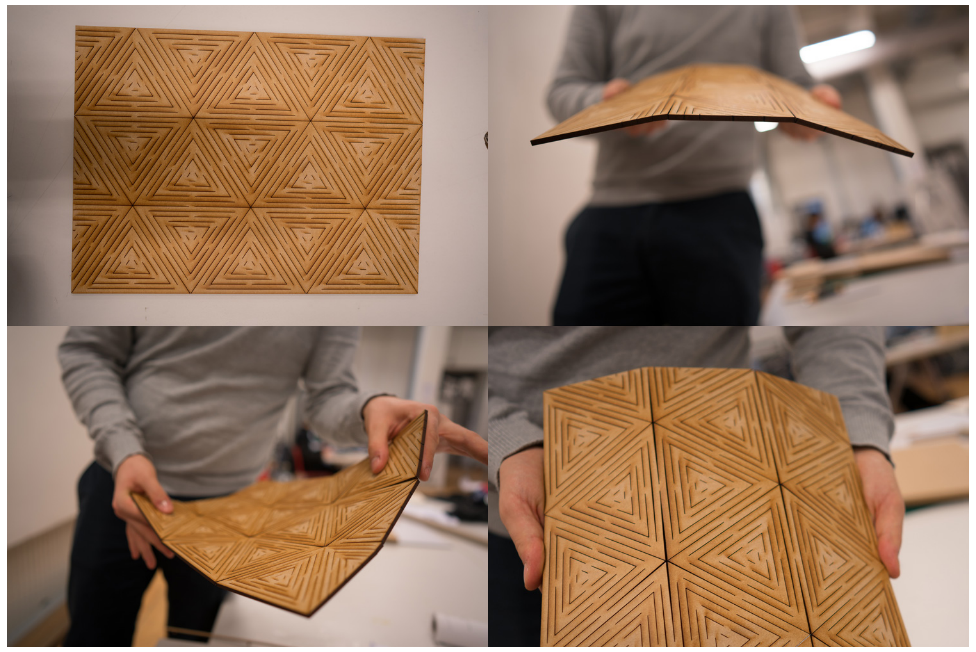
With these tools, we began to experiment with modifying the geometry property of the material to enable bending. The most common method with MDF is kerf bending. We started with some preliminary kerfing patterns to test and understand how geometry affected the bending property. [4]

We had chosen to utilize the patterns with the most extreme shapes.



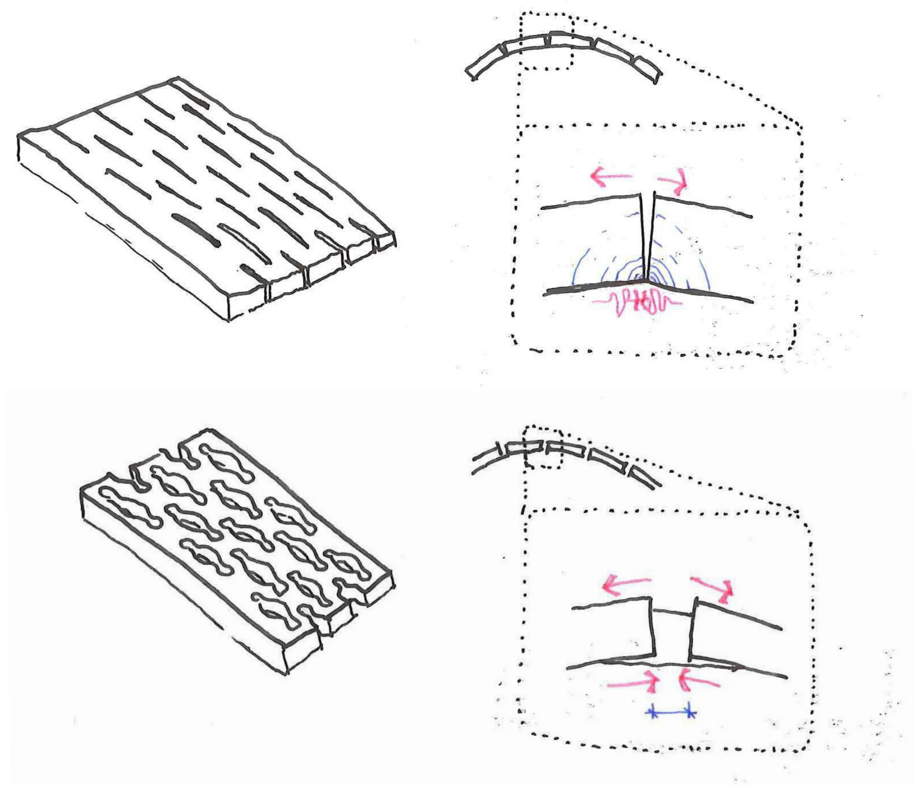
3. NASA. 2008 "4 HUMAN PERFORMANCE CAPABILITIES." NASA.
4. Form=Function. 2016. "Parametric Kerf Bending" f=f.

TESTING THE MATERIAL

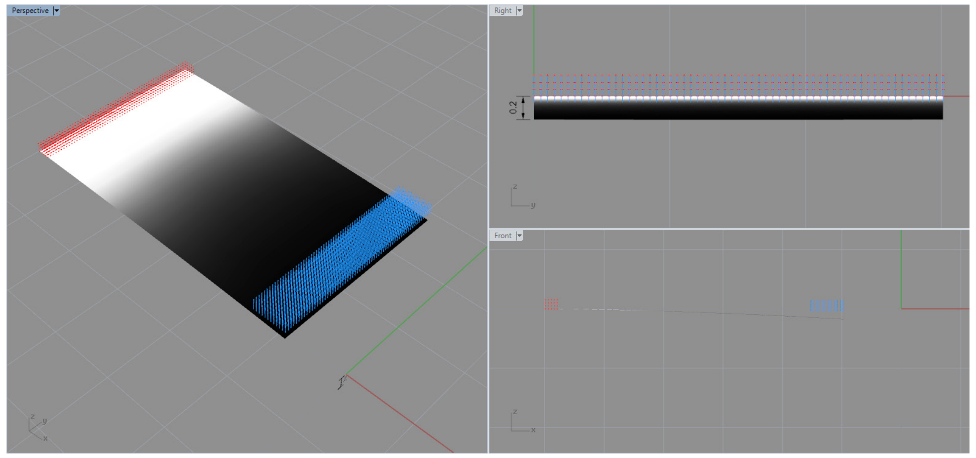


What we discovered in these tests is that, the most efficient pattern is the first pattern. It was the space between the elements which allowed for more bending.

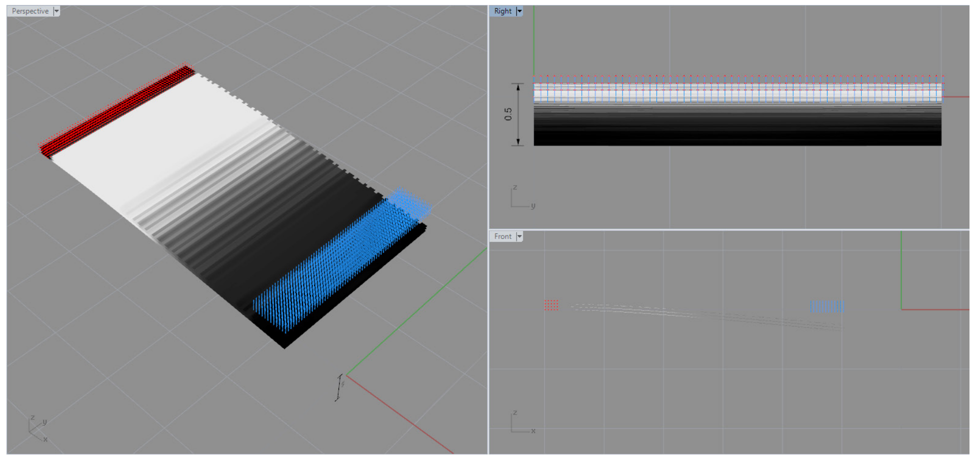
The patterns in the 2nd and 3rd configurations only relied on the cut of the laser itself. Therefore under a bending force, the lower part of the material would compress against eachother. In the first configuration, this would not be an issue.



The conclusion that can be drawn from these tests is by controlling the width of the kerf, the geometry can be optimized. Instead of using a laser cutter, the CNC can be used, where the height of the subtraction can be controlled and optimized.
A simulation can then be run to prove the theory.

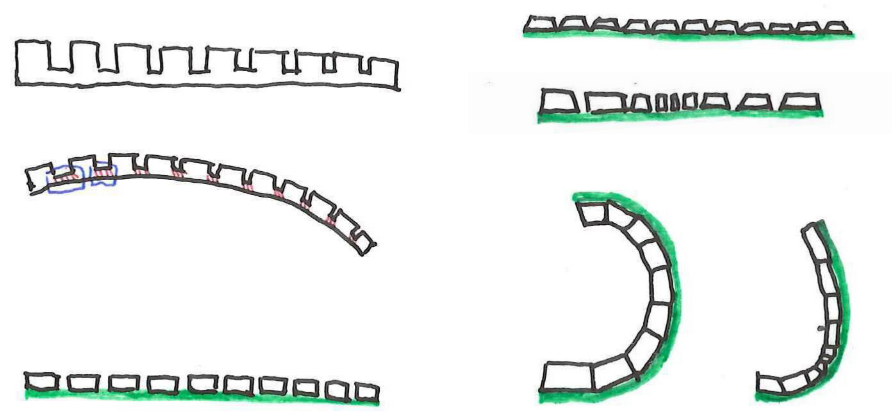


The first example here show's a solid block of MDF with a thickness of 100mm. With a force of 0.8kN returns a deformation of 200mm.

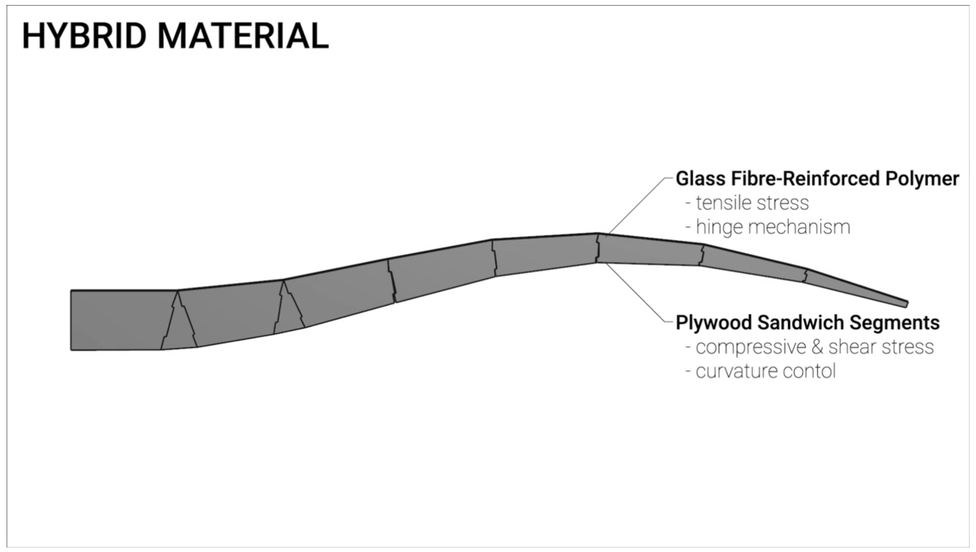


The second example here shows a solid block of MDF with a thickness of 100mm and cuts of 40mm deep. With a force of 0.8kN returns a deformation of 500mm.
These two simulations also led to another insight. Looking at the stress patterns in the second simulation shows that there's resistance especially in the thicker part of the model.

The thicker elements give the geometry stability, and the bending motion is completely reliant upon the material that is left over. Realizing this, another form of optimization is discovered through using composite materials.
If the left over material was replaced with a material with more ideal embodied properties of bending, a composite system can be created.

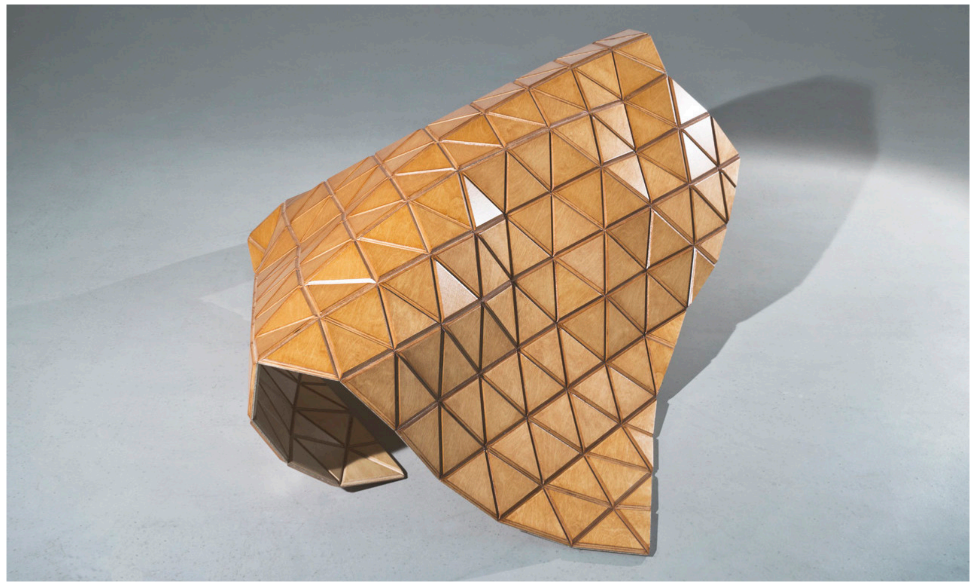


One example is the University of Queensland Centre for Future Timber Structures Research pavilion which I previously worked on. In this pavilion, Glass Fibre Reinforced Polymer acts as the tension and flexible element, which allows for a degree of flexibility. The geometry of the solid elements becomes what controlls the final curvature.

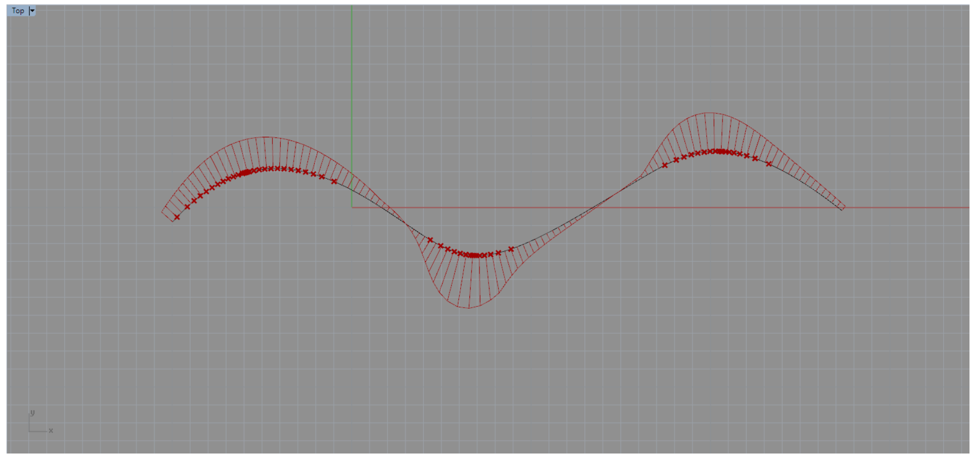


THE SOLUTIONS

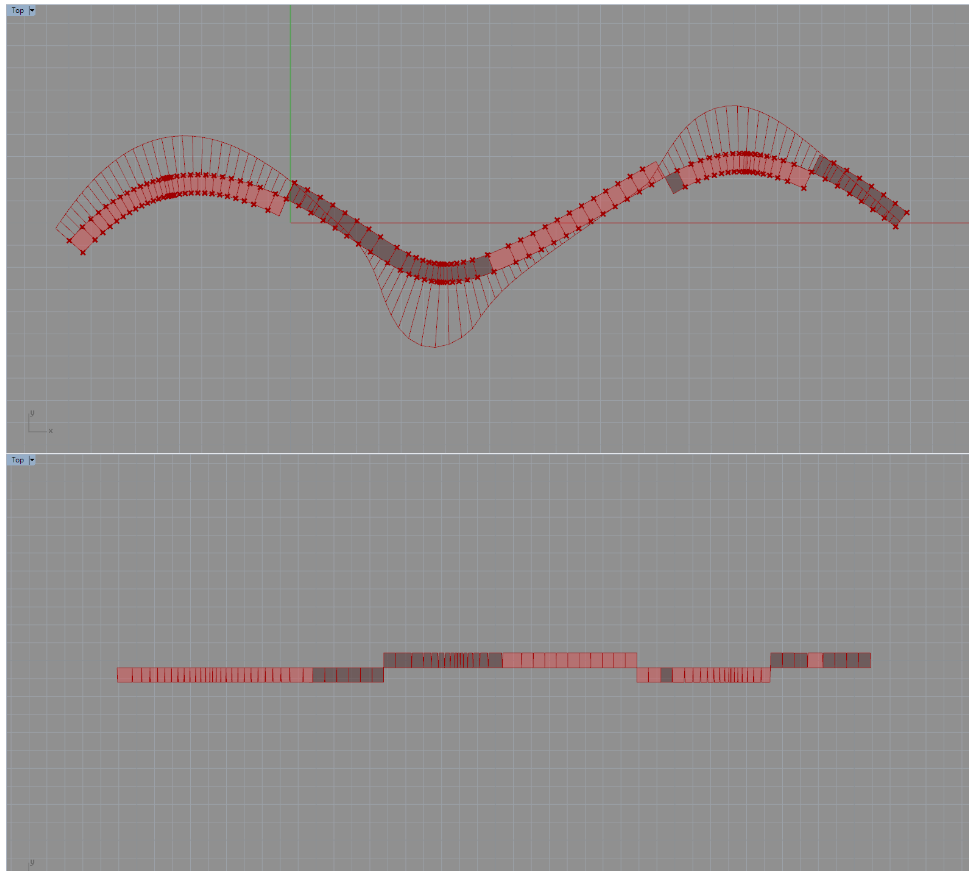
One other example is the woodskin by the design studio MammaFotogramma.[5] Here the flexible element is replaced by a textile like material which is extremely flexible. Here the solid elements are used in a different way, to provide structural rigidity while allowing for more freedom of curvature, not limited to one direction.



In both of these examples however, the curvature is controlled in one direction only, in the context of the wall, we realised we need to have control over both sides of the curvature, so the wall falls into the exact configurations desired.
Knowing these parameters, we can computationally calculate where the curvature occurs, and as such where the patterns are required.



The next step is to implement the principles discovered through the previous experiments.



Here, the optimized results are generated and can be prototyped and produced directly with either the CNC or the robot arms.
The processes developed throughout the project is completely flexible and can be applied to any configuration or any material.
In this sense, it becomes an infinitely adaptable solution for any situation.

5. Rackard, Nicky, 2013 "Woodskin: The Flexible Timber Skin." ArchDaily.

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