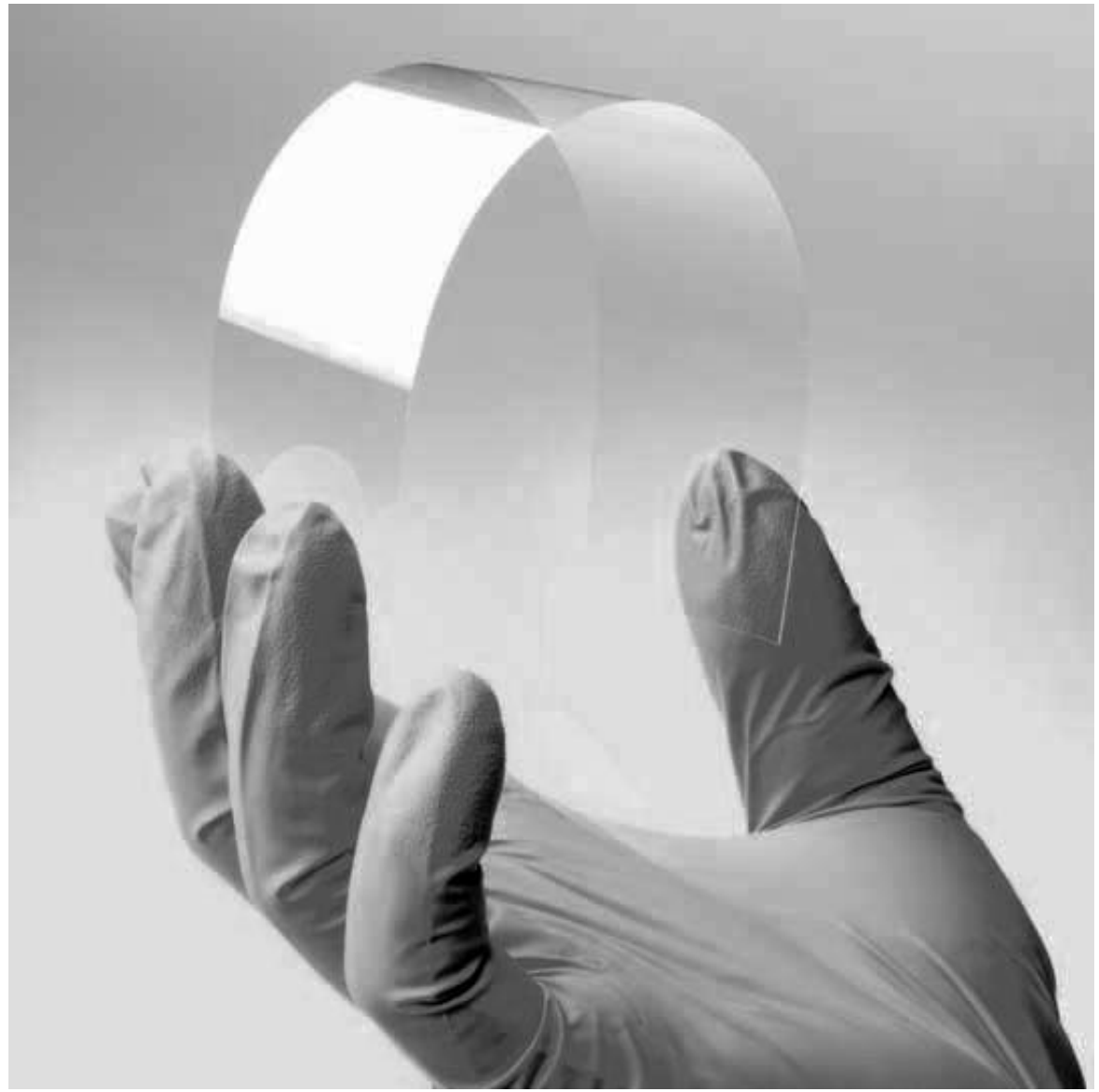
Thin glass composites.

Based on a structural efficiency increasing design strategy.


1997


2014



Content

- Research plan – Literature – Design – Verification – Case study – Conclusions –

Research plan

Research question

‘How can **thin glass** and a **3D printed spacer pattern** work together to create a **stiff** and **self supporting sandwich panel** which **increases the structural efficiency** of the material?’

Objective

- Explore the possibilities
- Weight reduction of 75%
- Structural efficiency

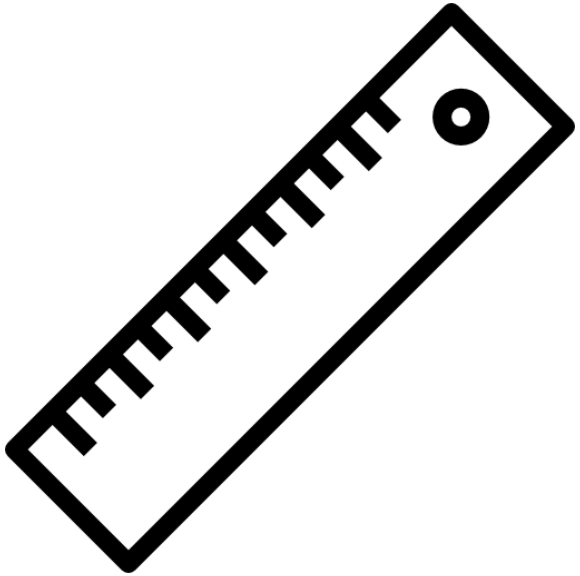
Literature

Conclusions

- Bending Glass
- Sandwich panel
- FDM makes results anisotropic
- Thermal expansion coefficient

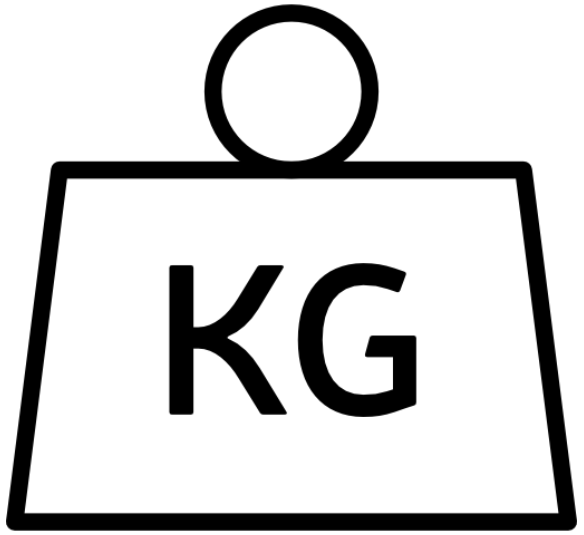
Criteria

- 1210 x 660 mm
- 6232 x 2825 mm
- 300 x 150 mmm



Criteria

- 4 – 15 – 5 HR++ = 18 kg
- 2 sheets thin glass = 0,4 kg
- Weight reduction of 75%

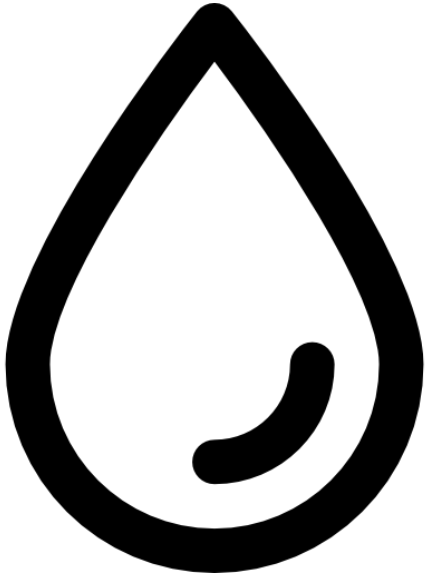


Criteria

- $L_{diag}/65$ = max deflection
- 21,2 mm for the window
- 105,3 mm for the facade

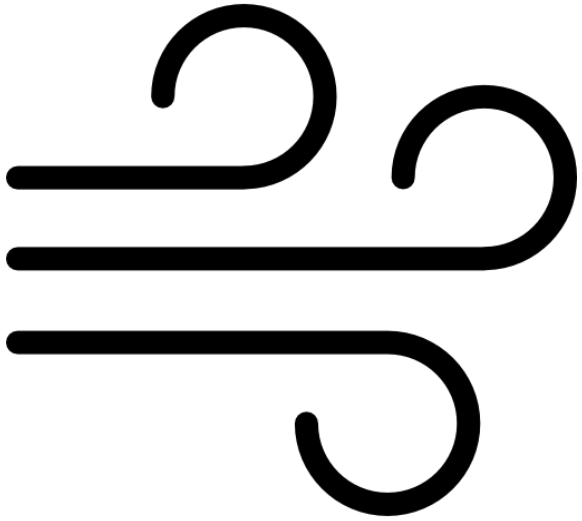
Criteria

- Edge around panel



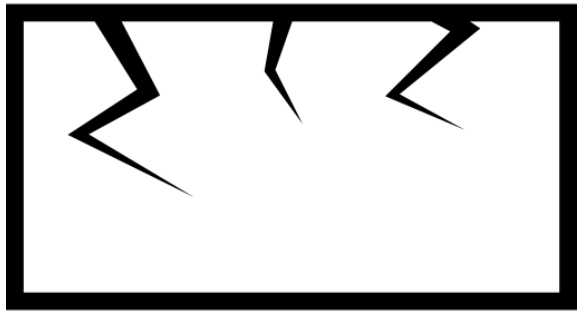
Criteria

- 1 kN/m^2
- Profound calculation for case study



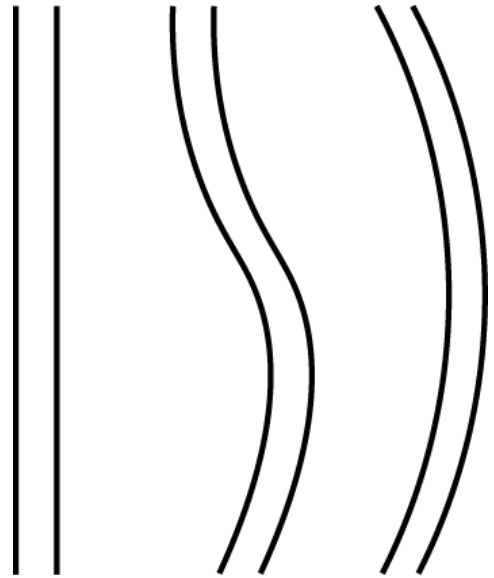
Criteria

- 40000 kN/m^2
- Maximum cell size 300 x 250 mm
- $$\frac{0{,}75 * wa^2}{t^2 * (1{,}61\left(\frac{a}{b}\right)^3 + 1}$$



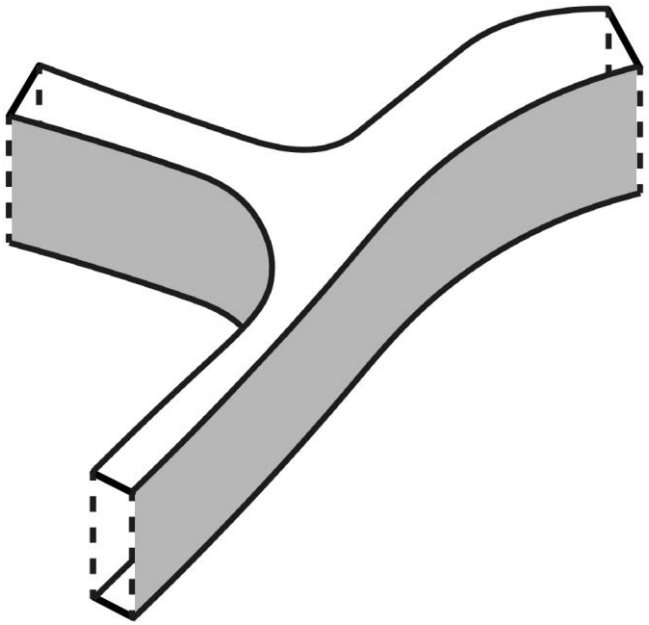
Criteria

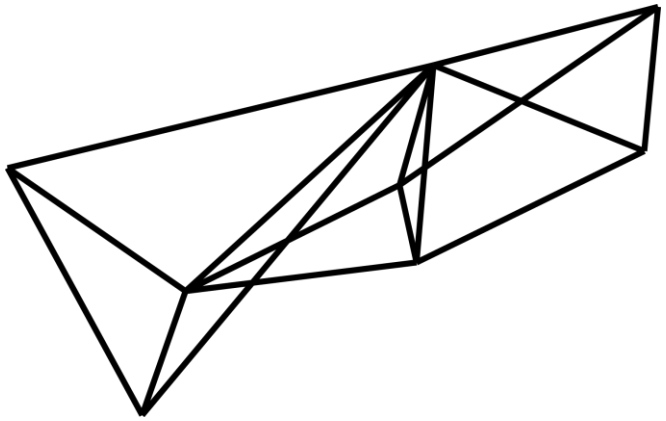
- Even thickness
- 16 mm

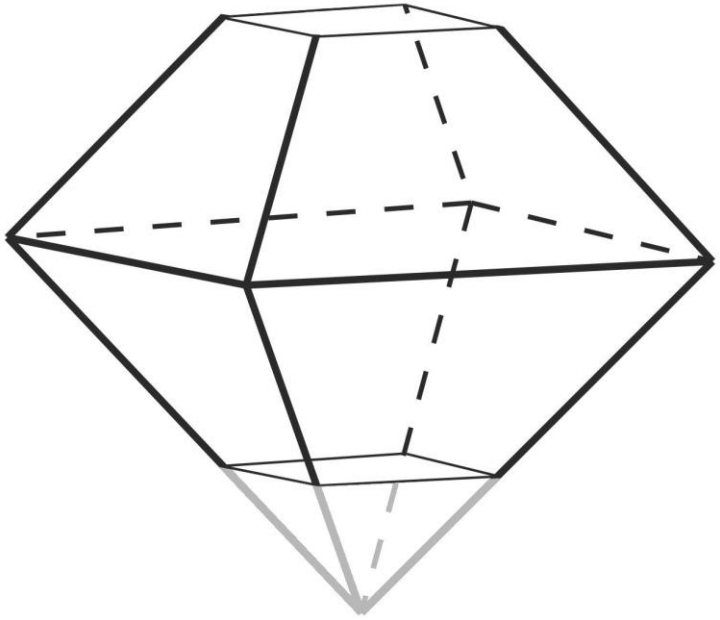


Design

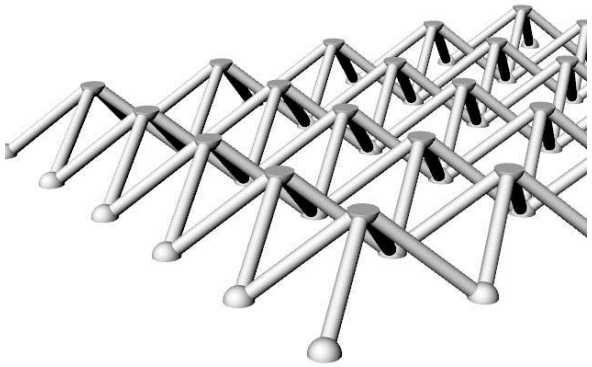
Topology

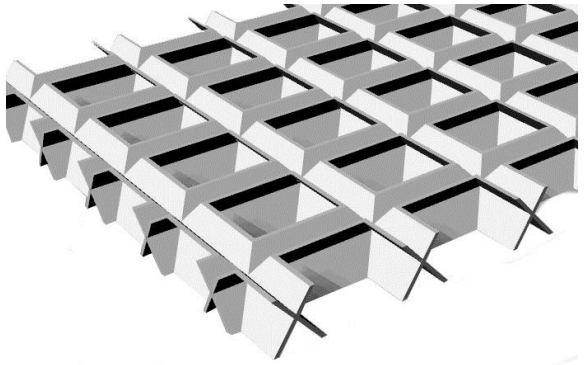


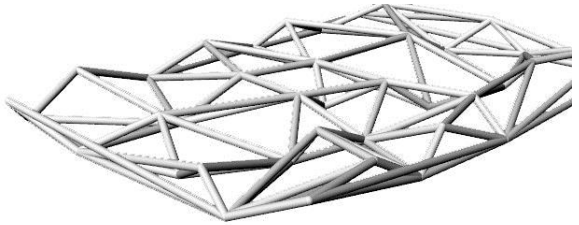


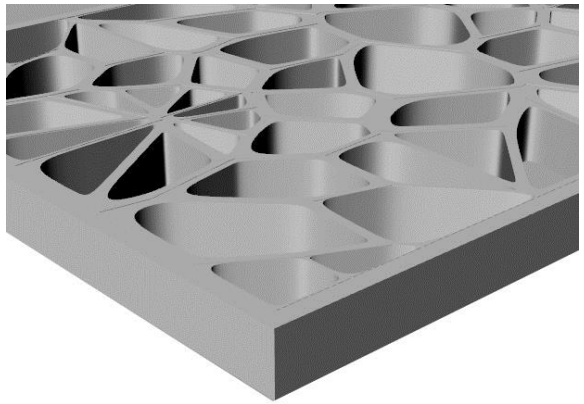


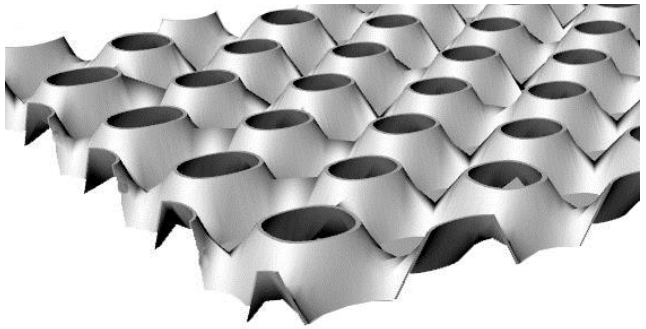
Designs



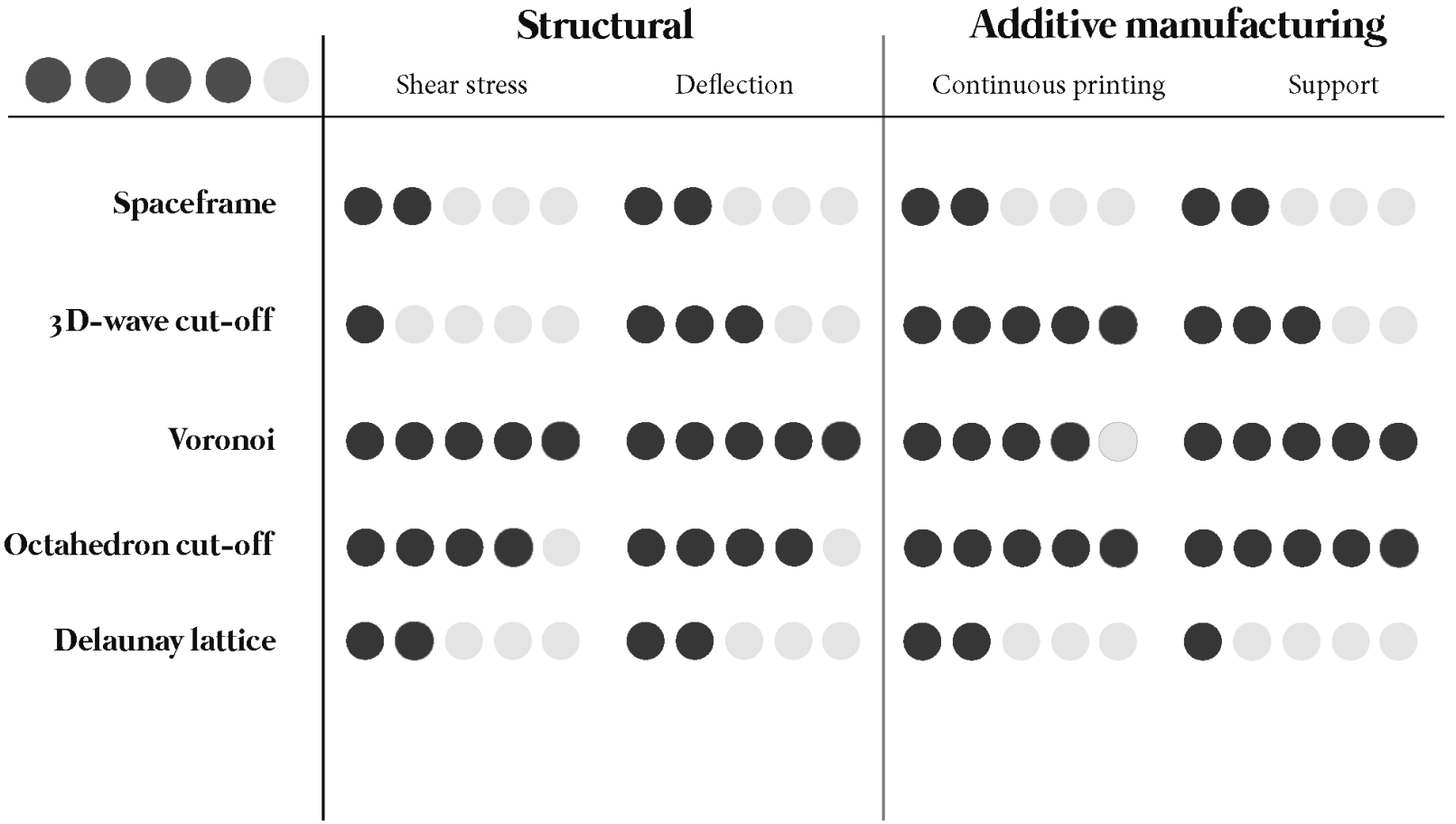






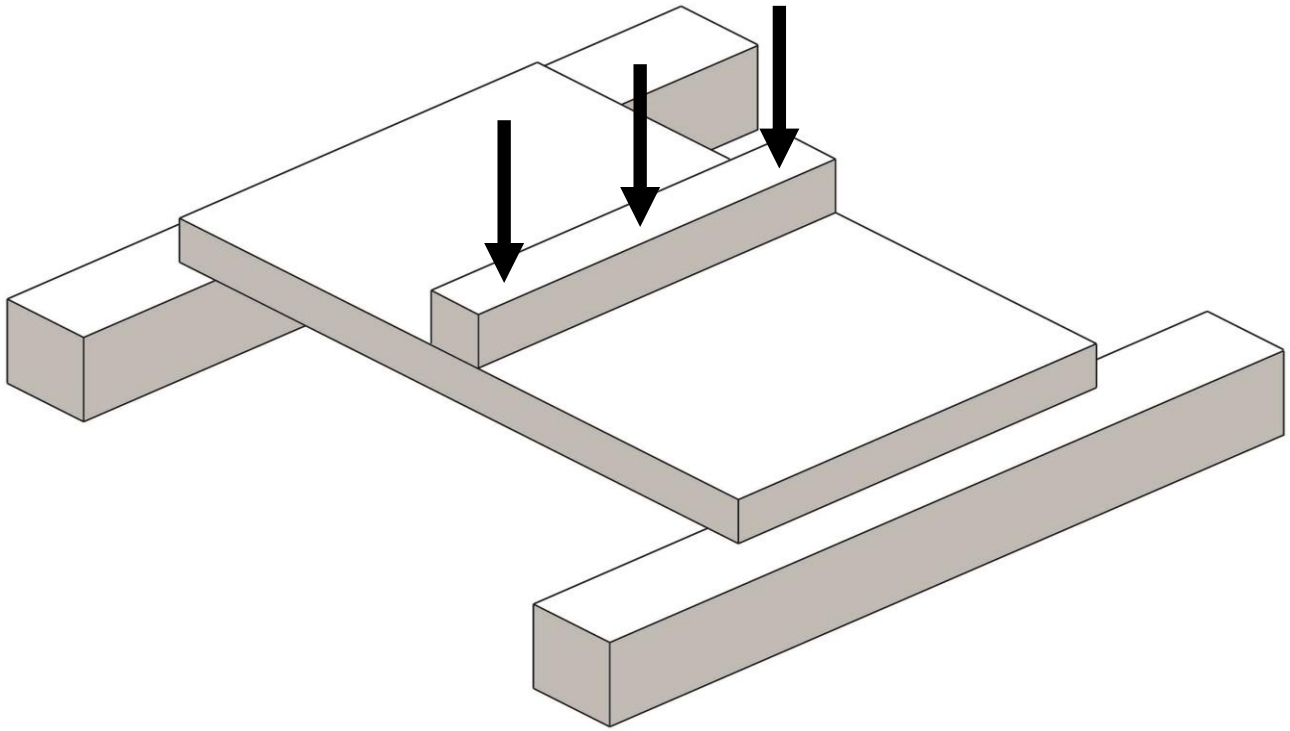


Designs

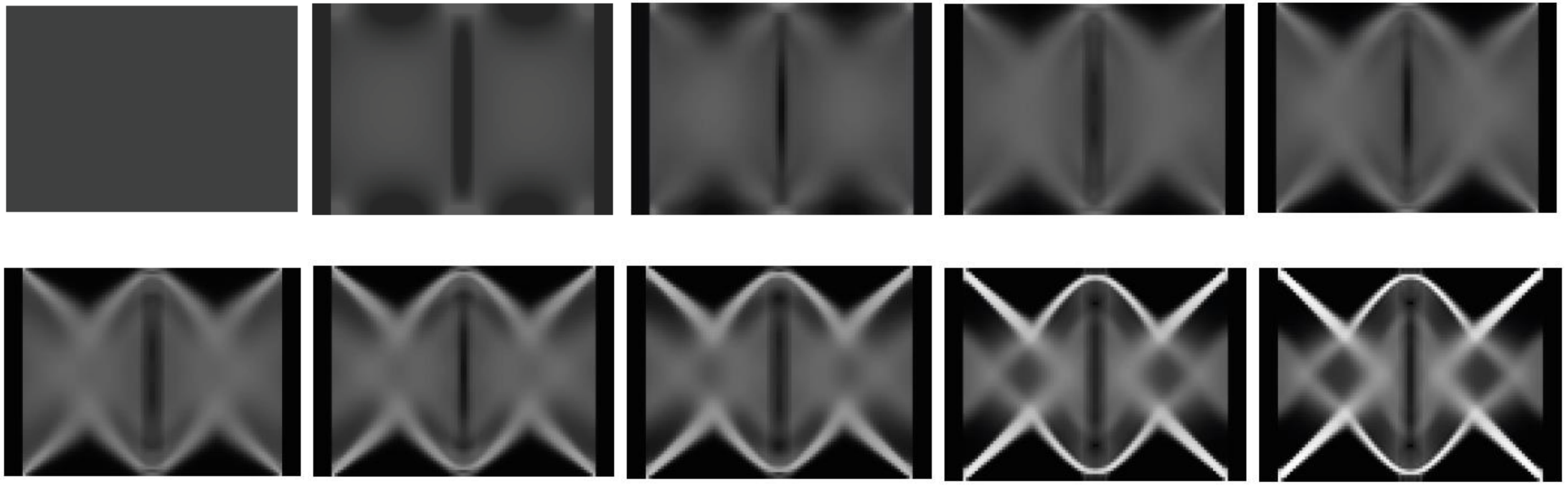

Structural
Additive manufacturing
Shear stress
Deflection
Continuous printing
Support
Spaceframe
3D-wave cut-off
Voronoi
Octahedron cut-off
Delaunay lattice

Design strategy

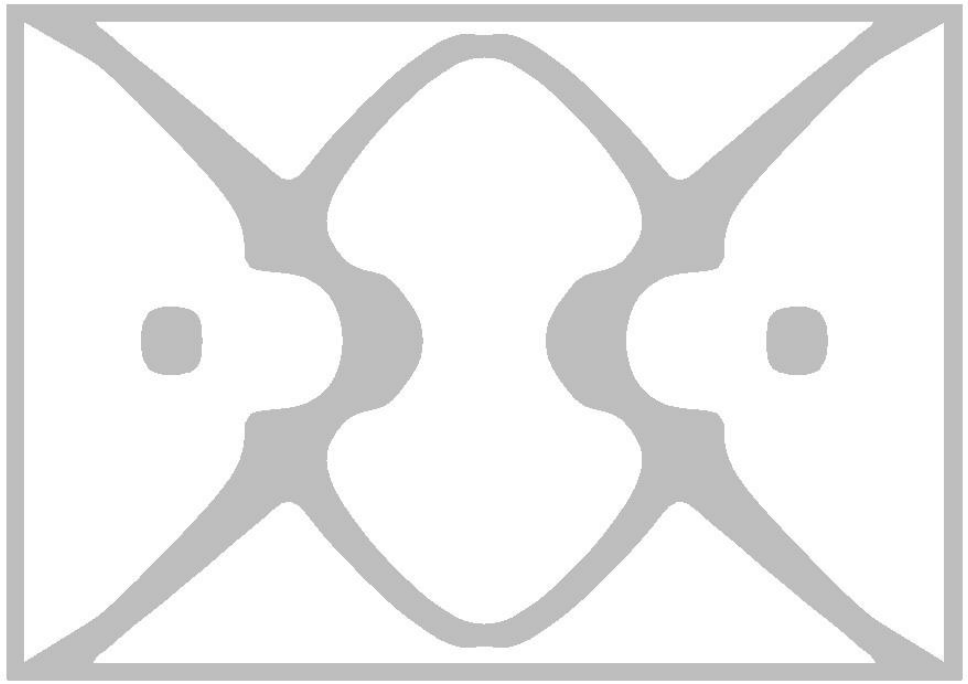
- Topology optimization



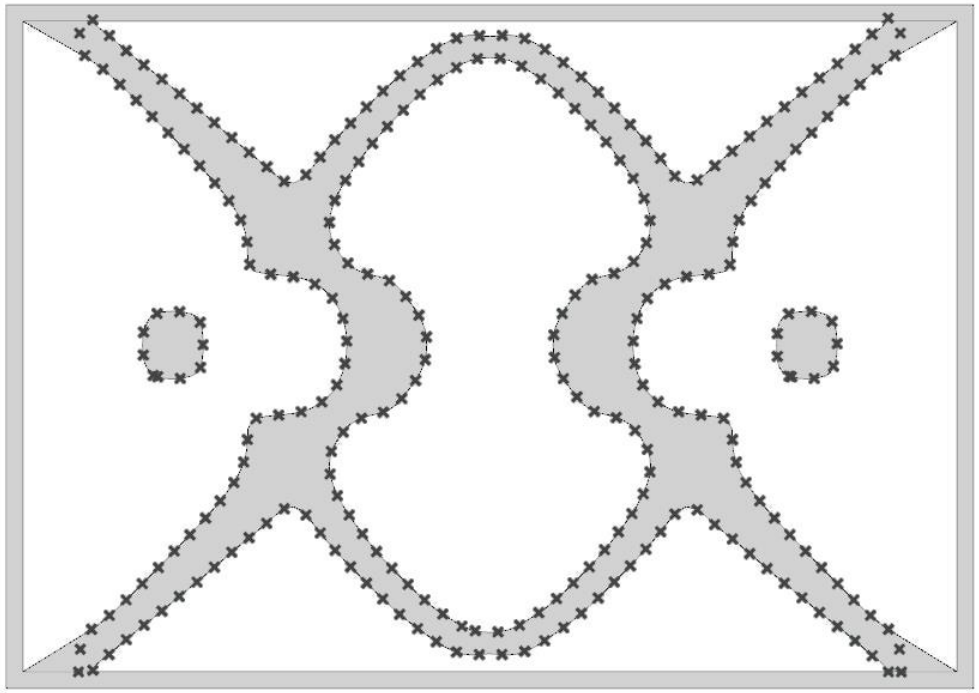
Design strategy



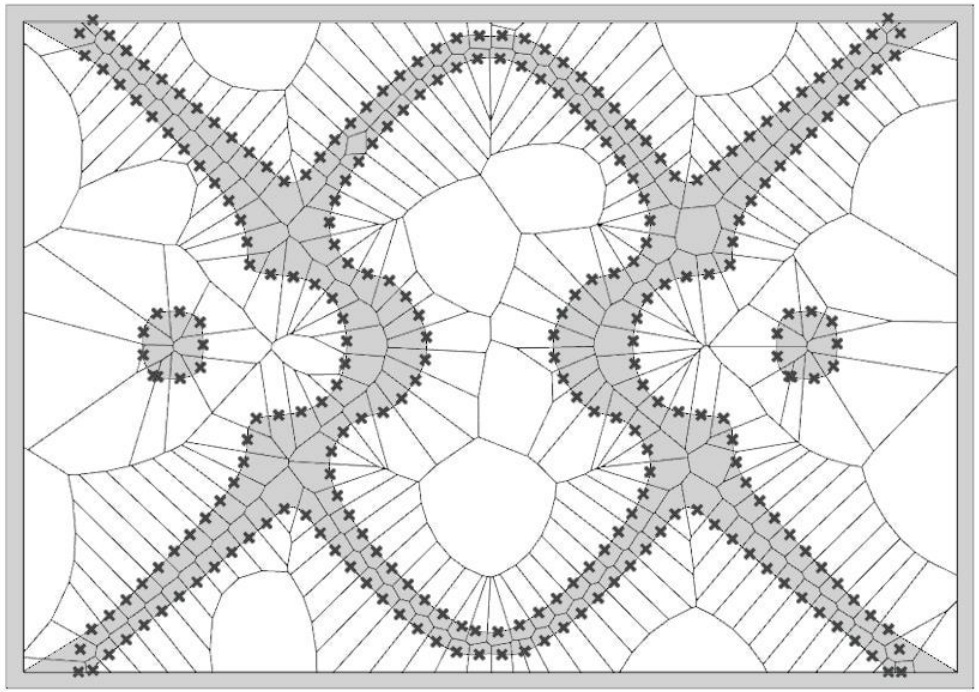
Design strategy



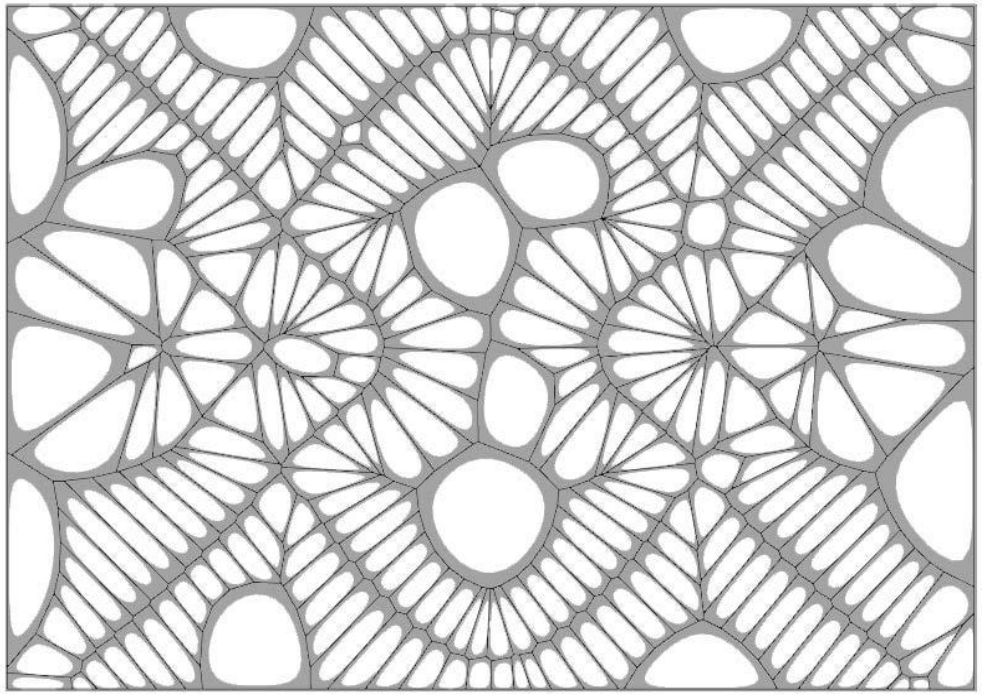
Design strategy



Design strategy



Design strategy

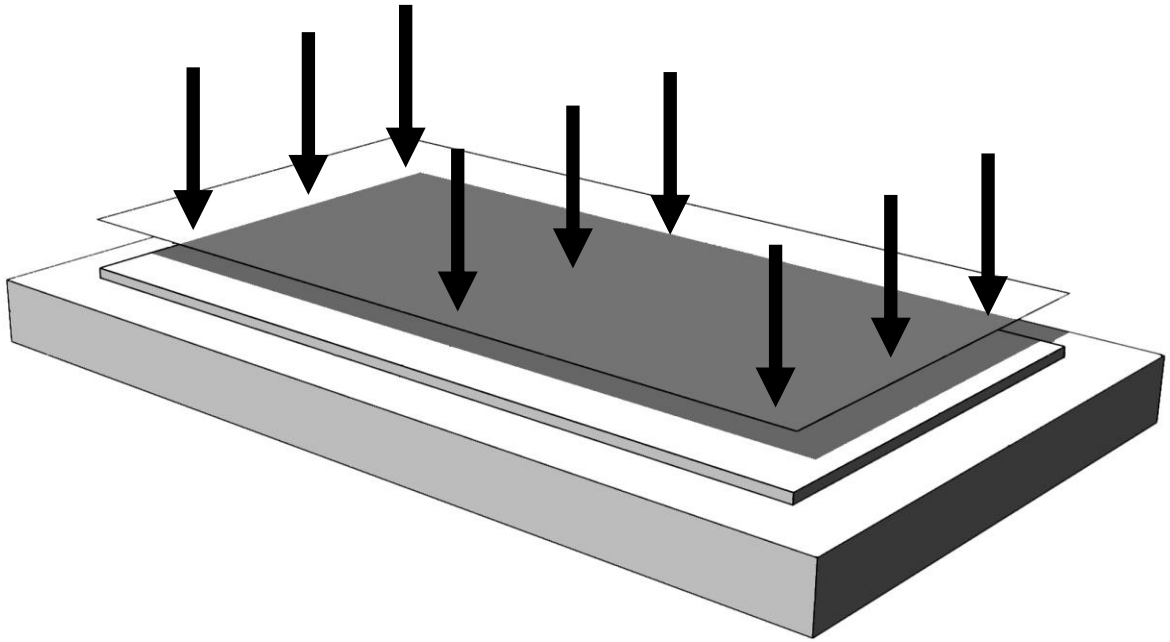


Design strategy

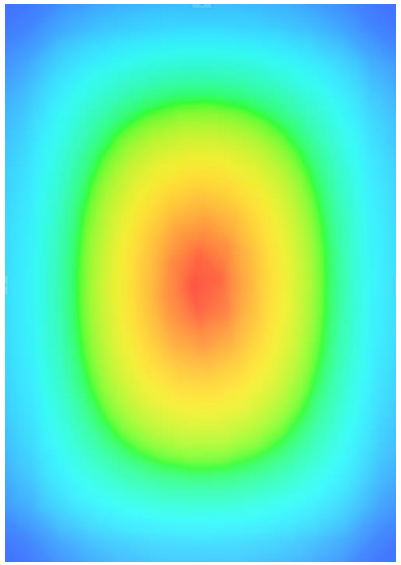
250 200 150 100 50

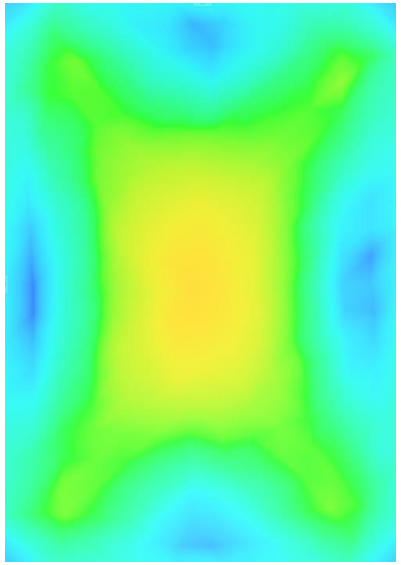
Design strategy

- Gradient mapping



Design strategy





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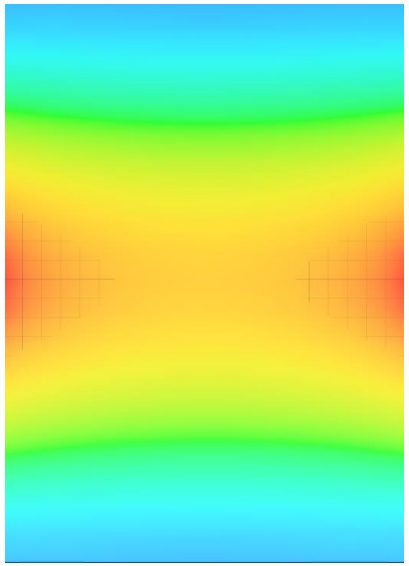
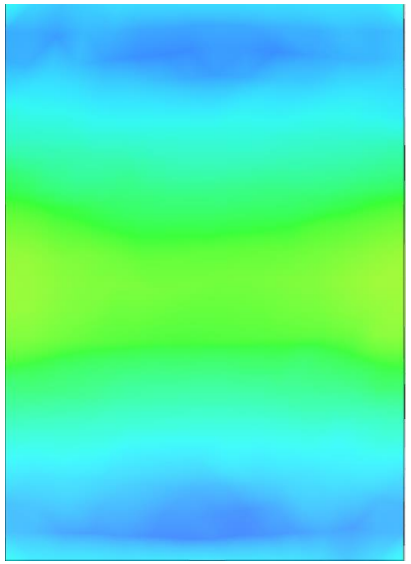
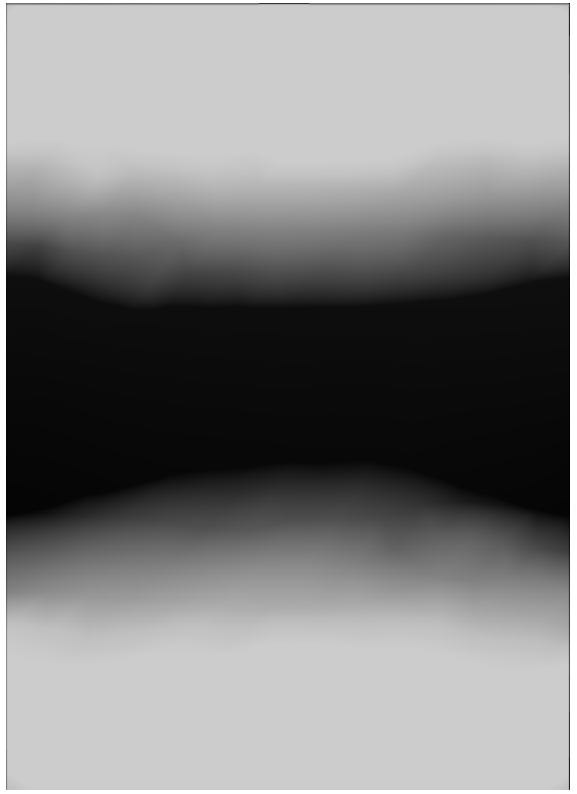




2 side supported

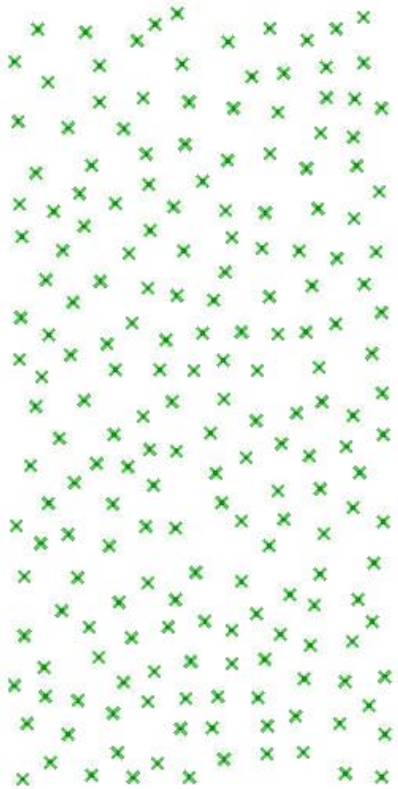
Design strategy

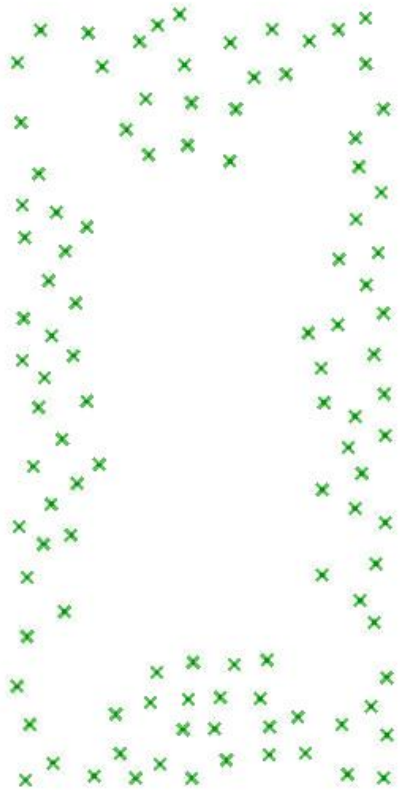
4 side supported

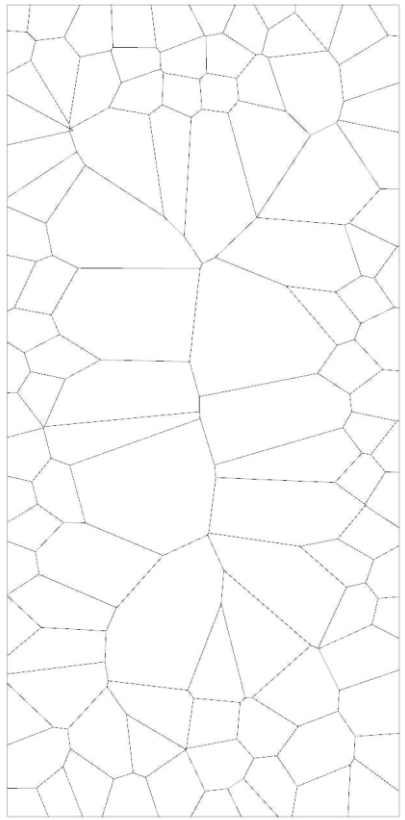


2 side supported

Design strategy







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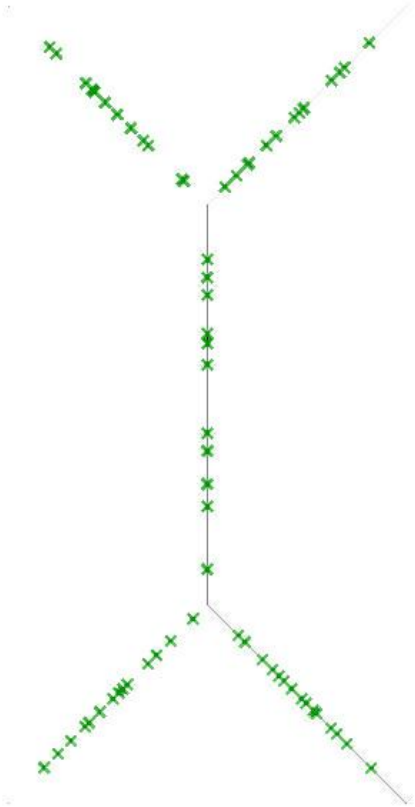
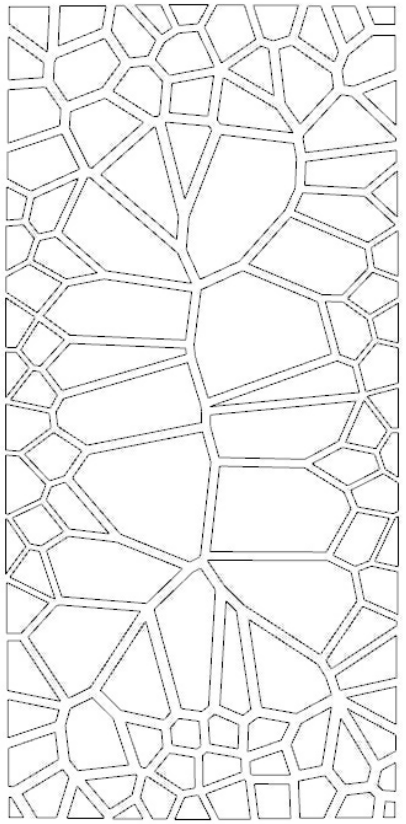
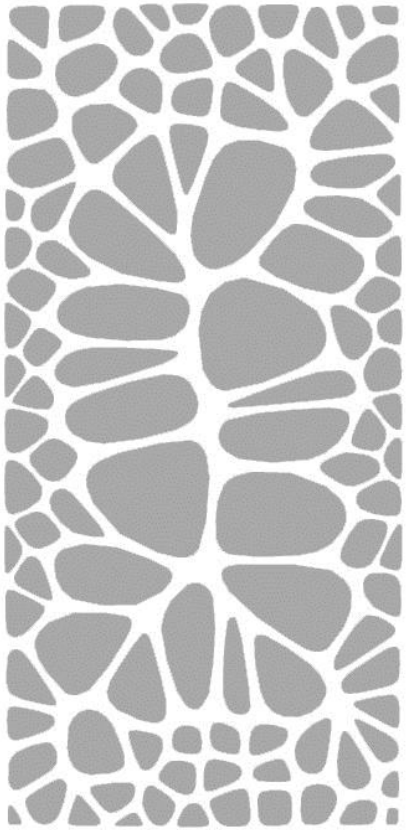
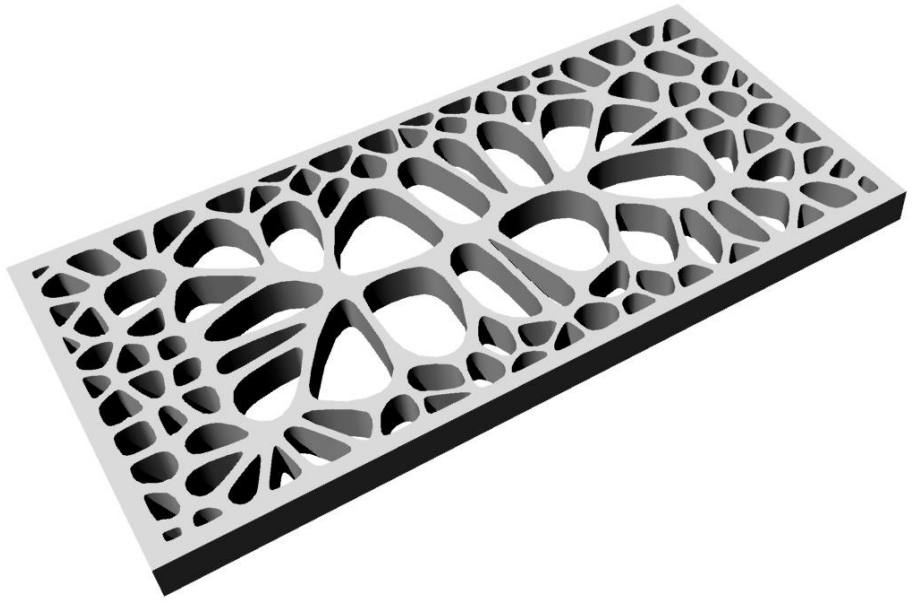




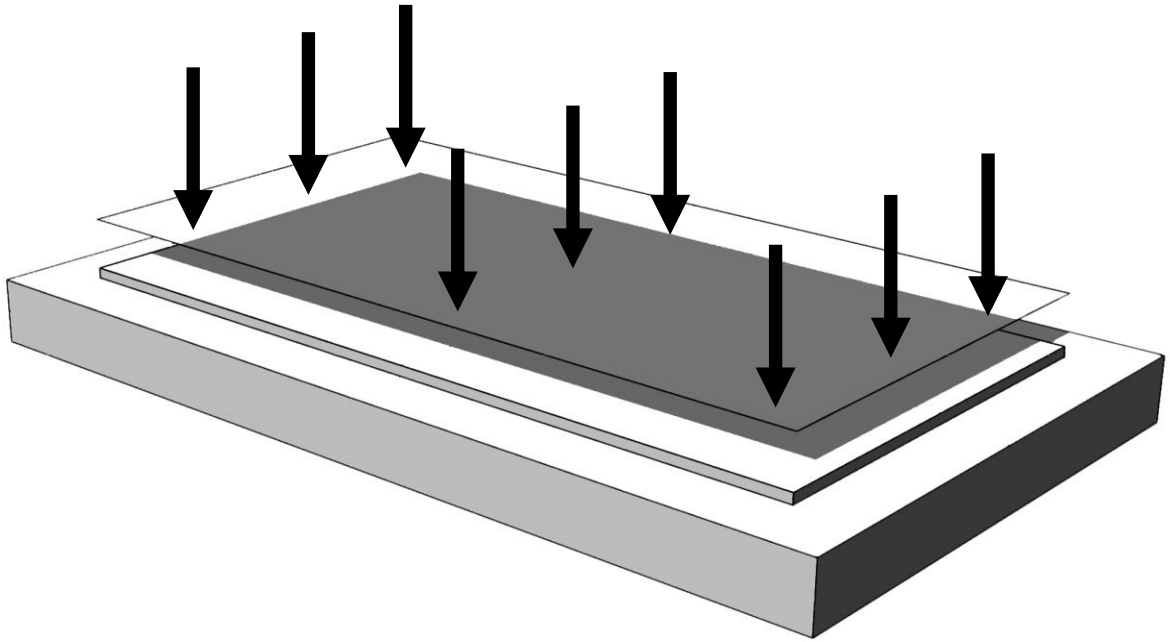
Design strategy



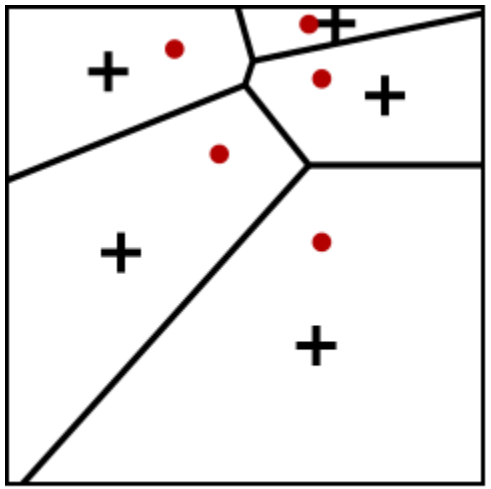


Design strategy

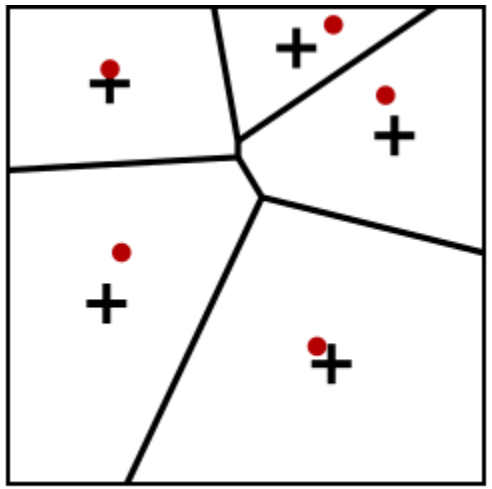
- Lloyd's algorithm



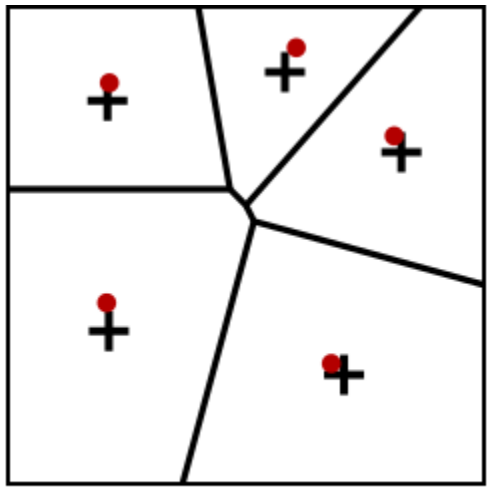
Design strategy



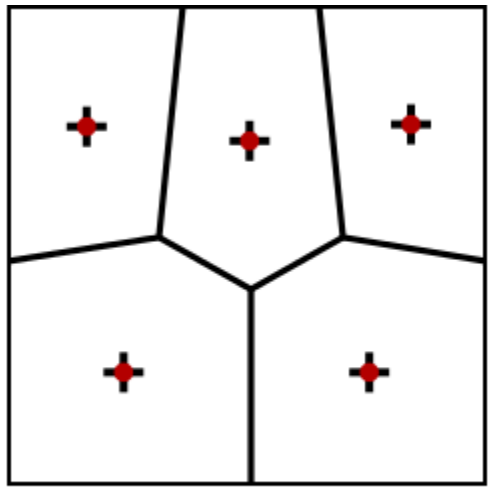
First iteration



Second iteration

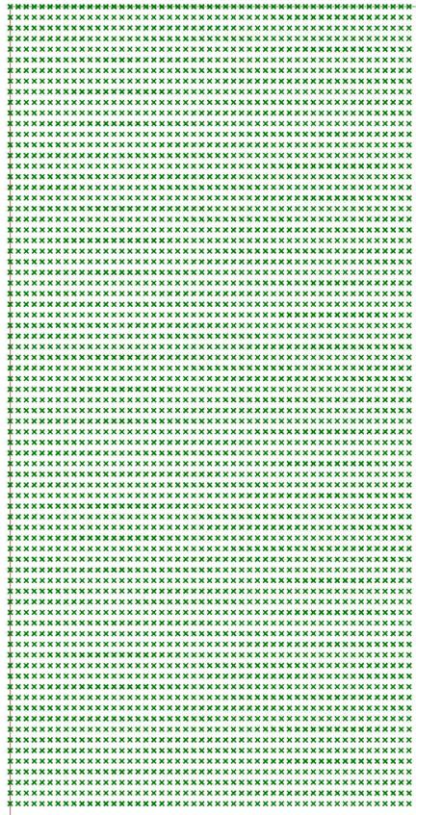


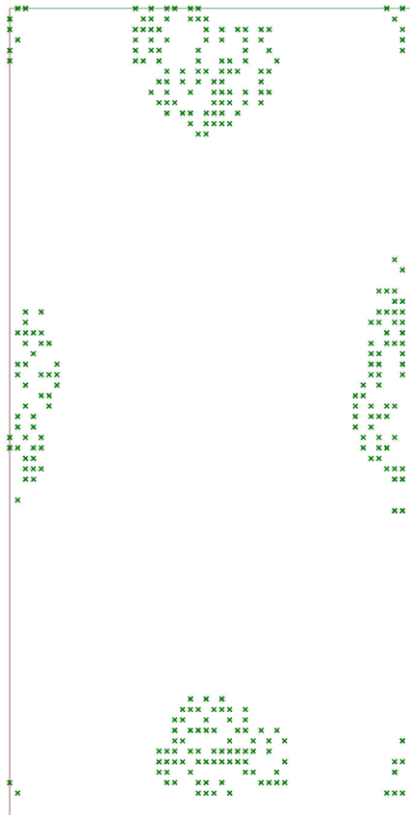
Third iteration

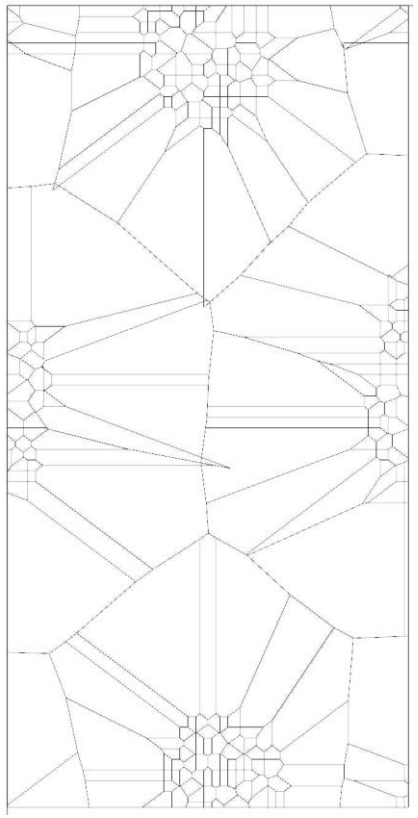


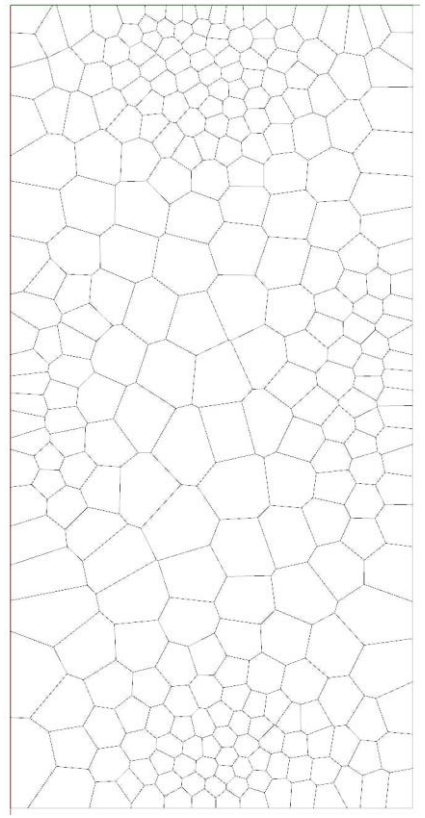
15th iteration

Design strategy





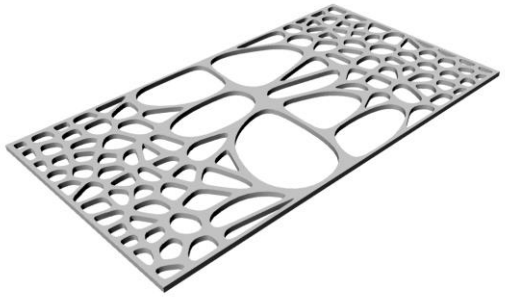


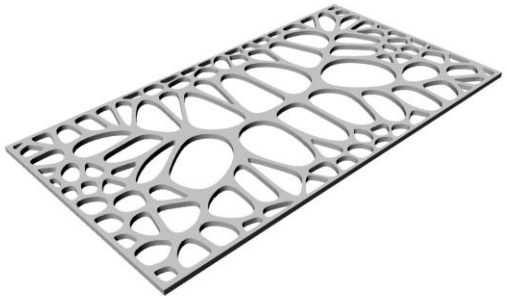


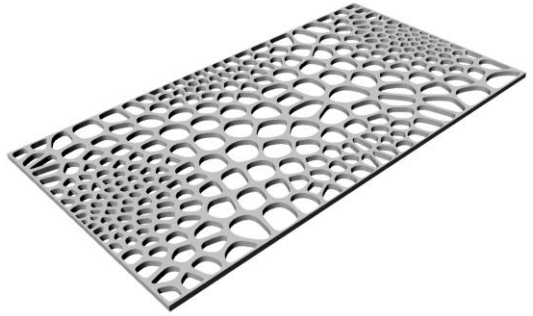
Panel generation

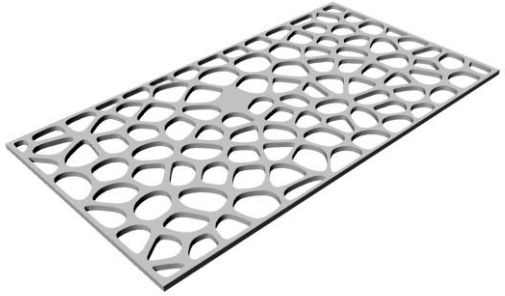
- Reference panels
- Gradient mapping panels
- Random Voronoi panels
- Lloyd's algorithm panels
- Lab test specimen

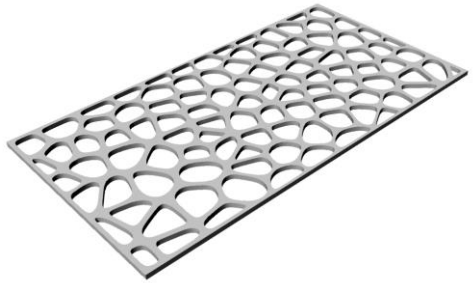
Models

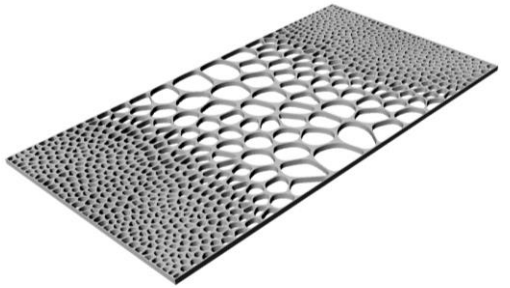












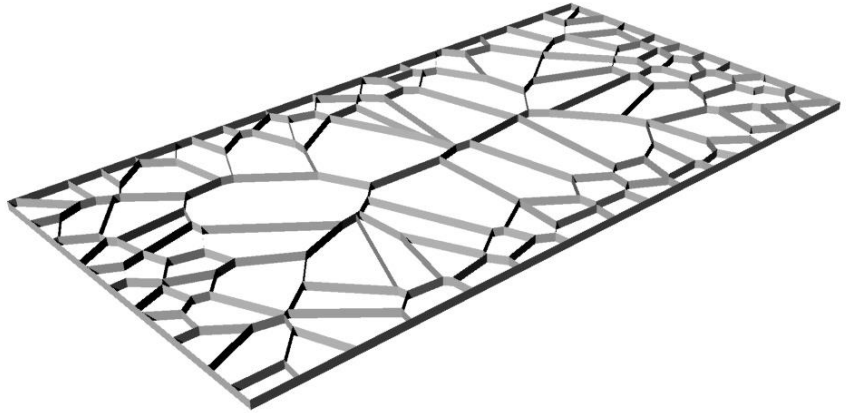
2 side supported

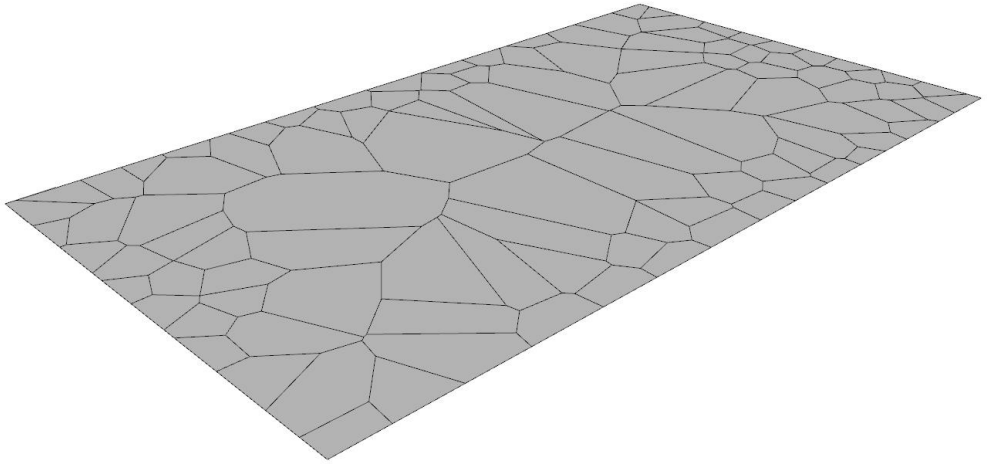
4 side supported

Lloyd's algorithm

Verification

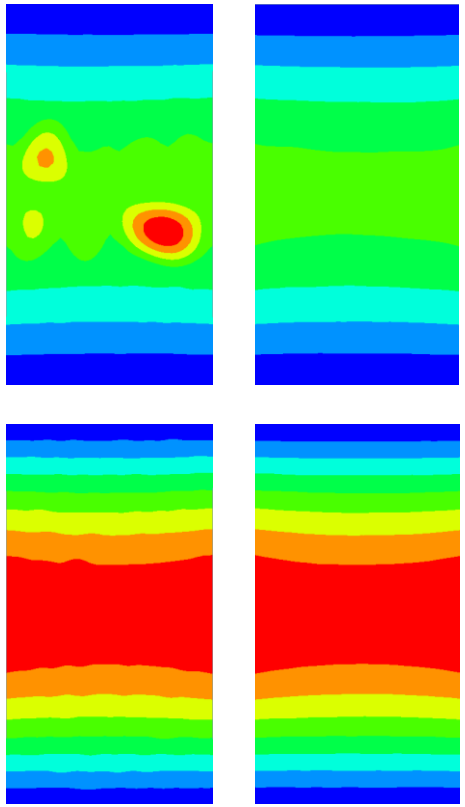
Set-up



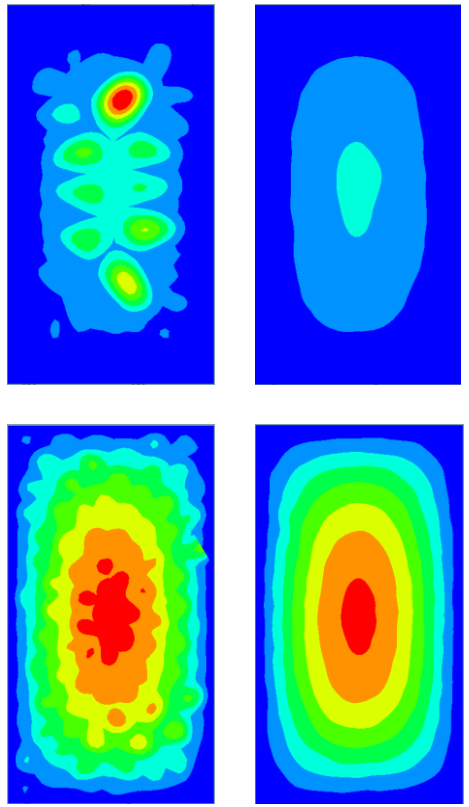


	PETG	Thin Glass
Young's modulus (N/m^2)	$2{,}1 * 10^9$	$7{,}2 * 10^{10}$
Poisson's ratio	0.4	0.23
Density (kg/m^3)	1280	2530
Tensile strength (N/m^2)	/	$2{,}6 * 10^8$

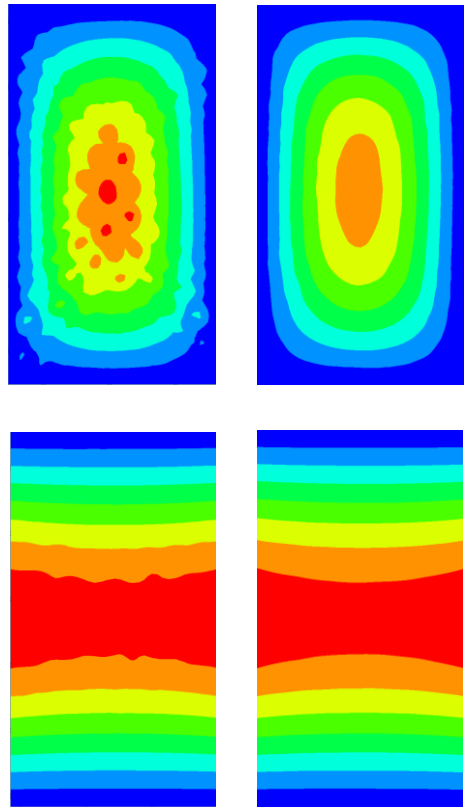
Results - *Deformation*



2 side supported



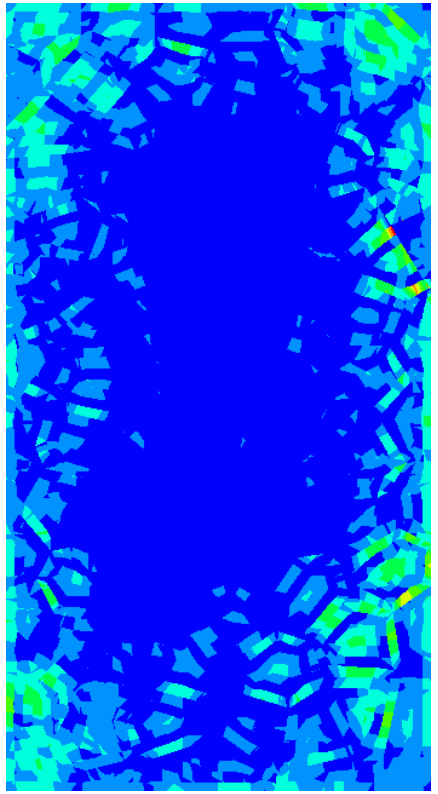
4 side supported



Lloyd's algorithm

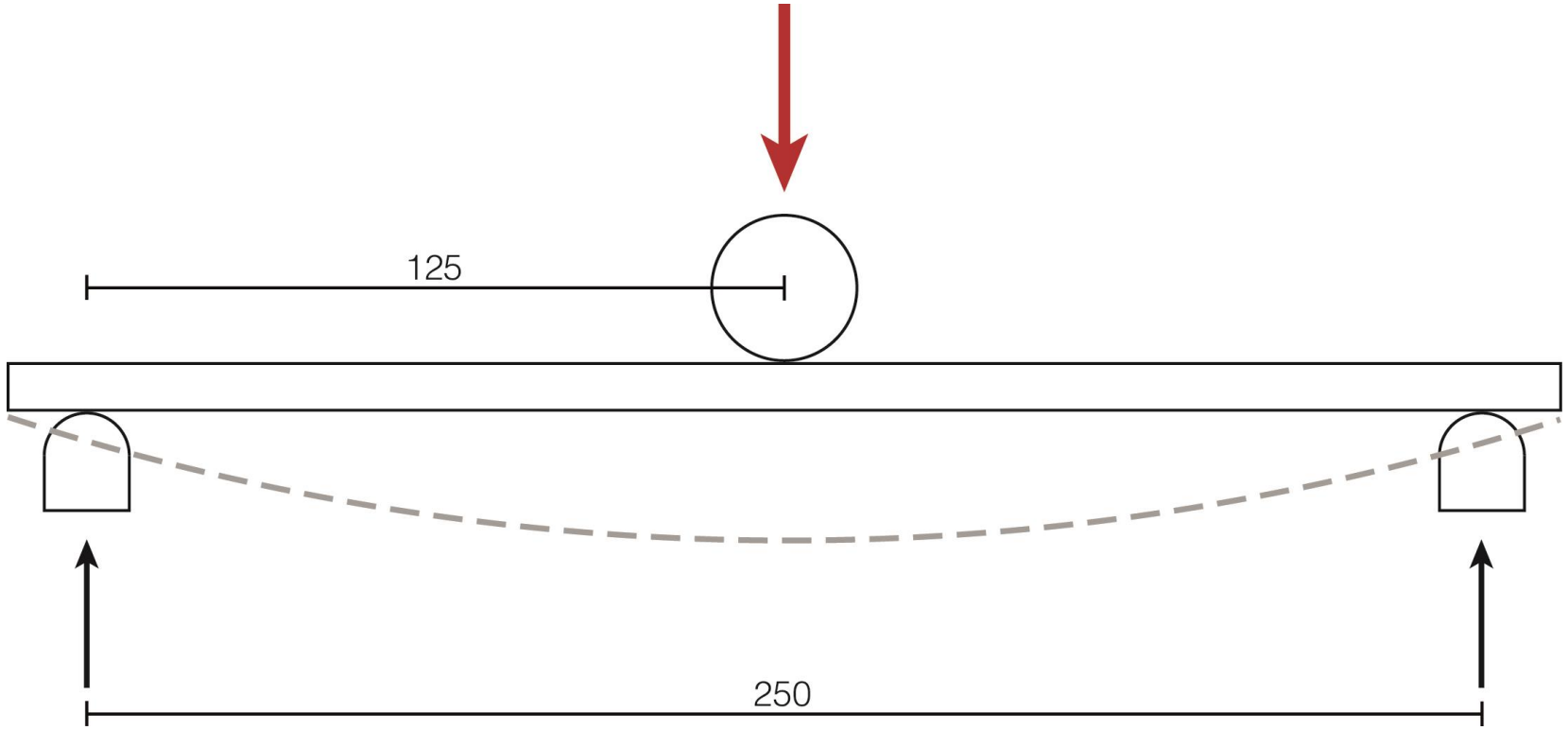
Results - Stresses

Tensile principal stress Structural panel

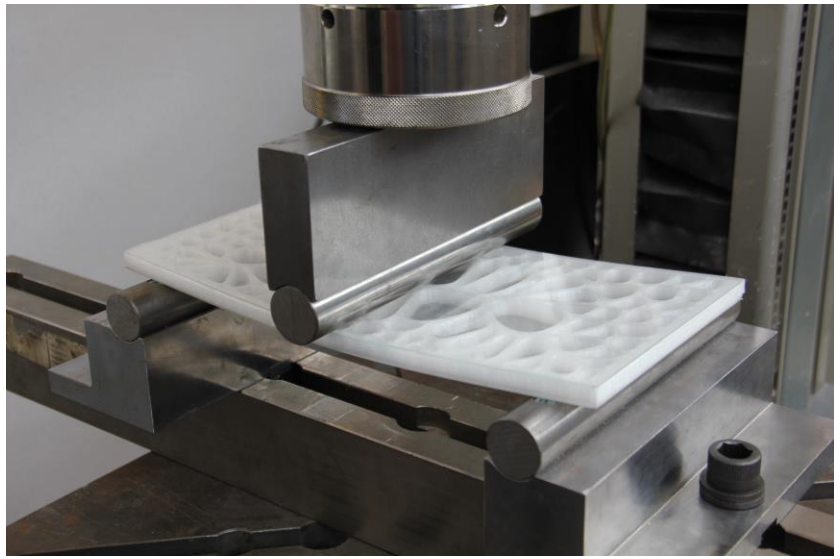


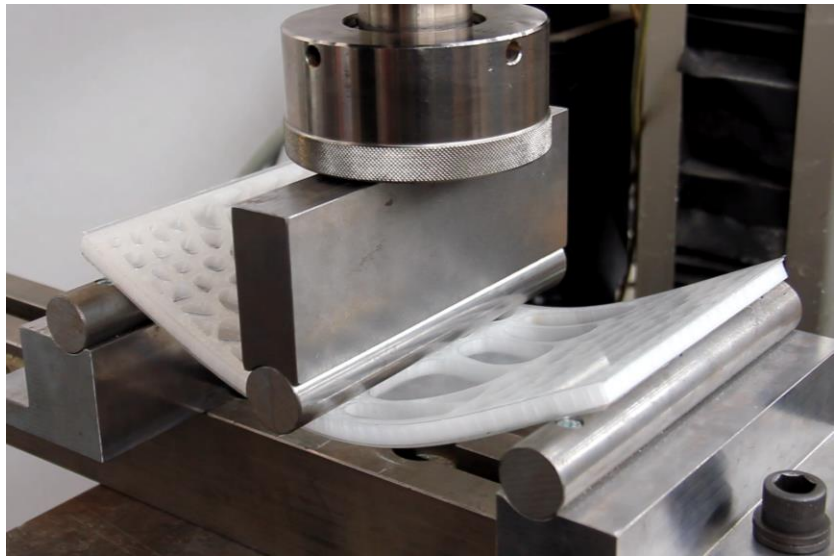
Tensile principal stress Random panel

Lab tests

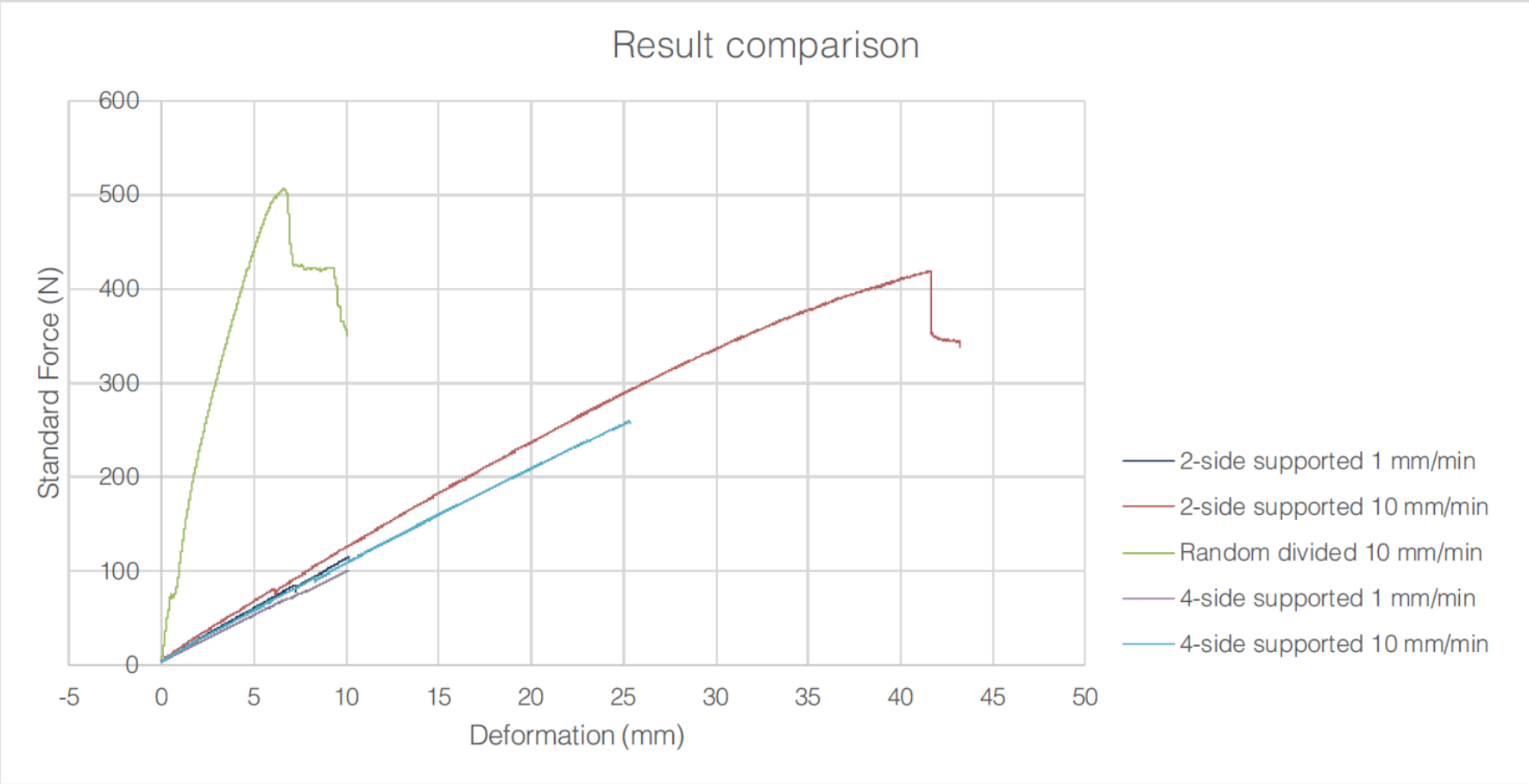


Lab tests





Lab tests


Result comparison
Standard Force (N)
600
500
400
300
200
100
0
-5
0
5
10
15
20
25
30
35
40
45
50
Deformation (mm)
2-side supported 1 mm/min
2-side supported 10 mm/min
Random divided 10 mm/min
4-side supported 1 mm/min
4-side supported 10 mm/min

Lab tests

	2 side supported model	2 side supported test panel	4 side supported model	4 side supported test panel	Random divided model	Random divided test panel
Displacement DtXYZ total (mm)	16,6	0,388035	19,12	0,396343	1,74	0,37835
Displacement DtXYZ local (mm)	/	0,408	/	0,392	/	0,383

Result comparison

2 side supported panels

	Structural	Random	%
Seed 2	0,241089	0,252932	- 4,6
Seed 4	0,244250	0,256866	- 4,9
Seed 6	0,247798	0,256753	- 3,5
Seed 8	0,254126	0,244416	+ 4,0
Seed 10	0,247957	0,258246	- 4,0

4 side supported panels

	Structural	Random	%
Seed 2	2,61235	2,73731	-4,6
Seed 4	2,62153	2,76459	- 5,2
Seed 6	2,51816	2,67233	- 5,8
Seed 8	2,57975	2,68654	- 4,0
Seed 10	2,55741	2,68082	- 4,6

Result comparison

2-side supported	**Structural**	**Random**
Average defl.	2,57784	2,70832

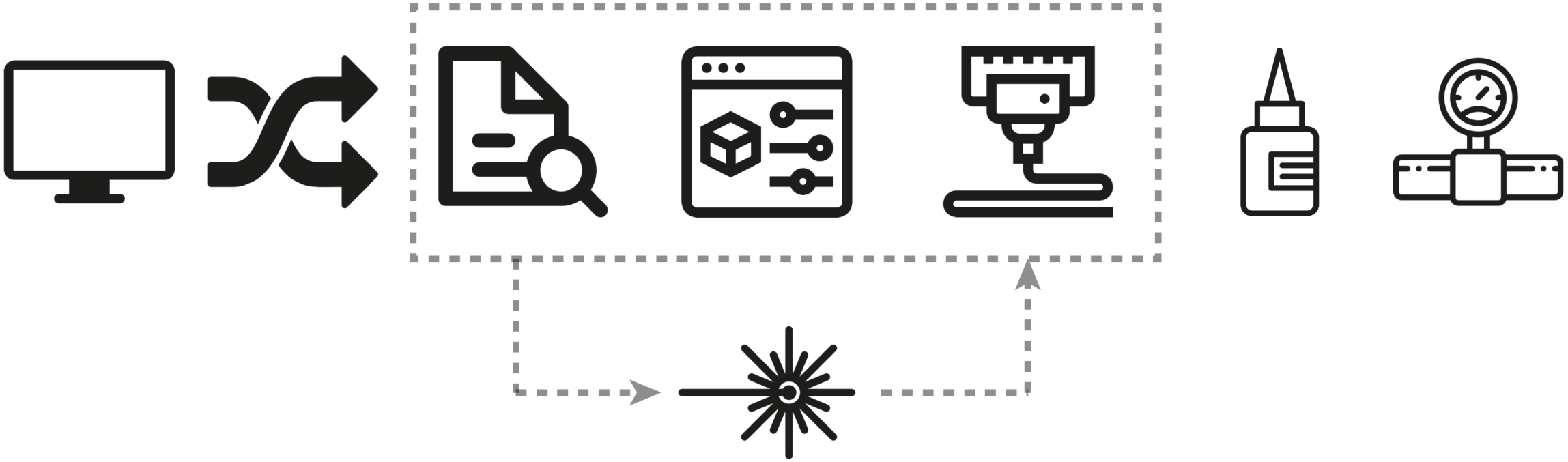
-4,8%

4-side supported	**Structural**	**Random**
Average defl.	0,247044	0,253843

-2,7%

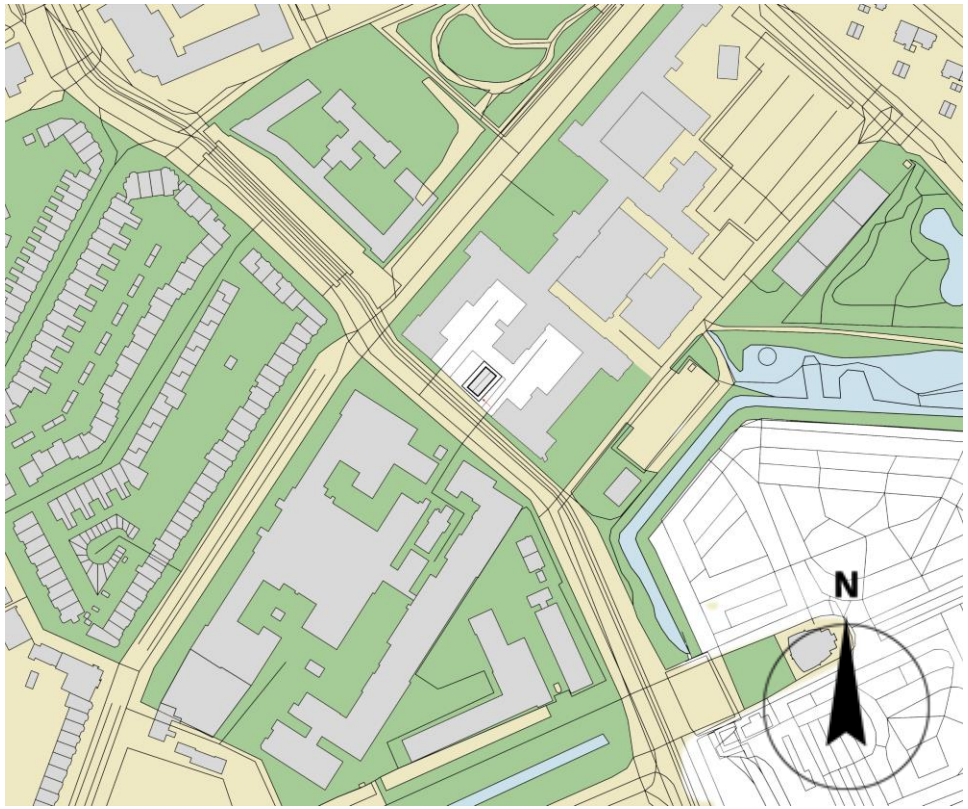
Case study

Production process

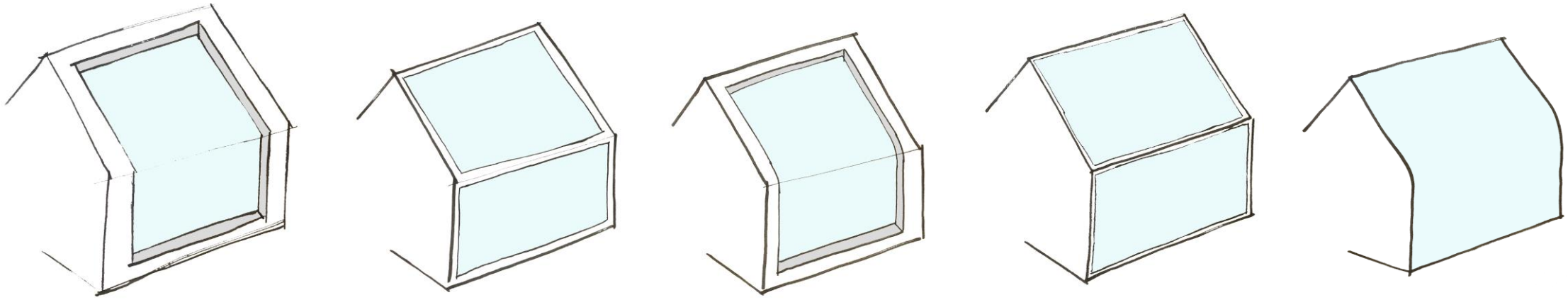


Production process

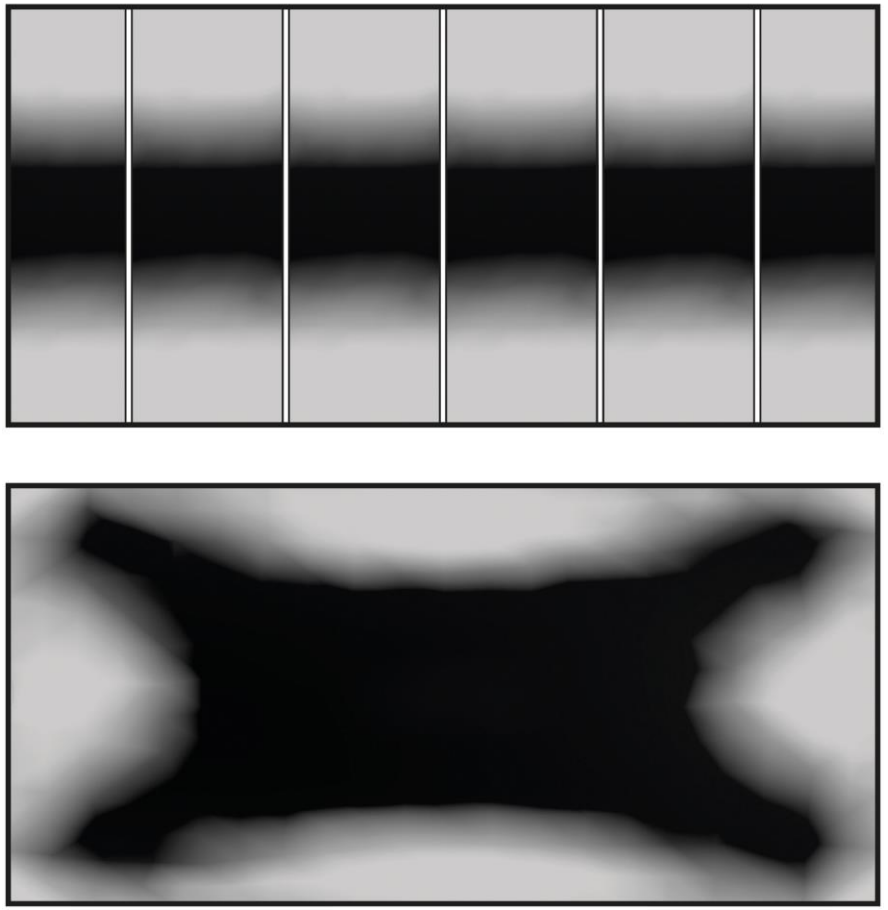
PD Test Lab



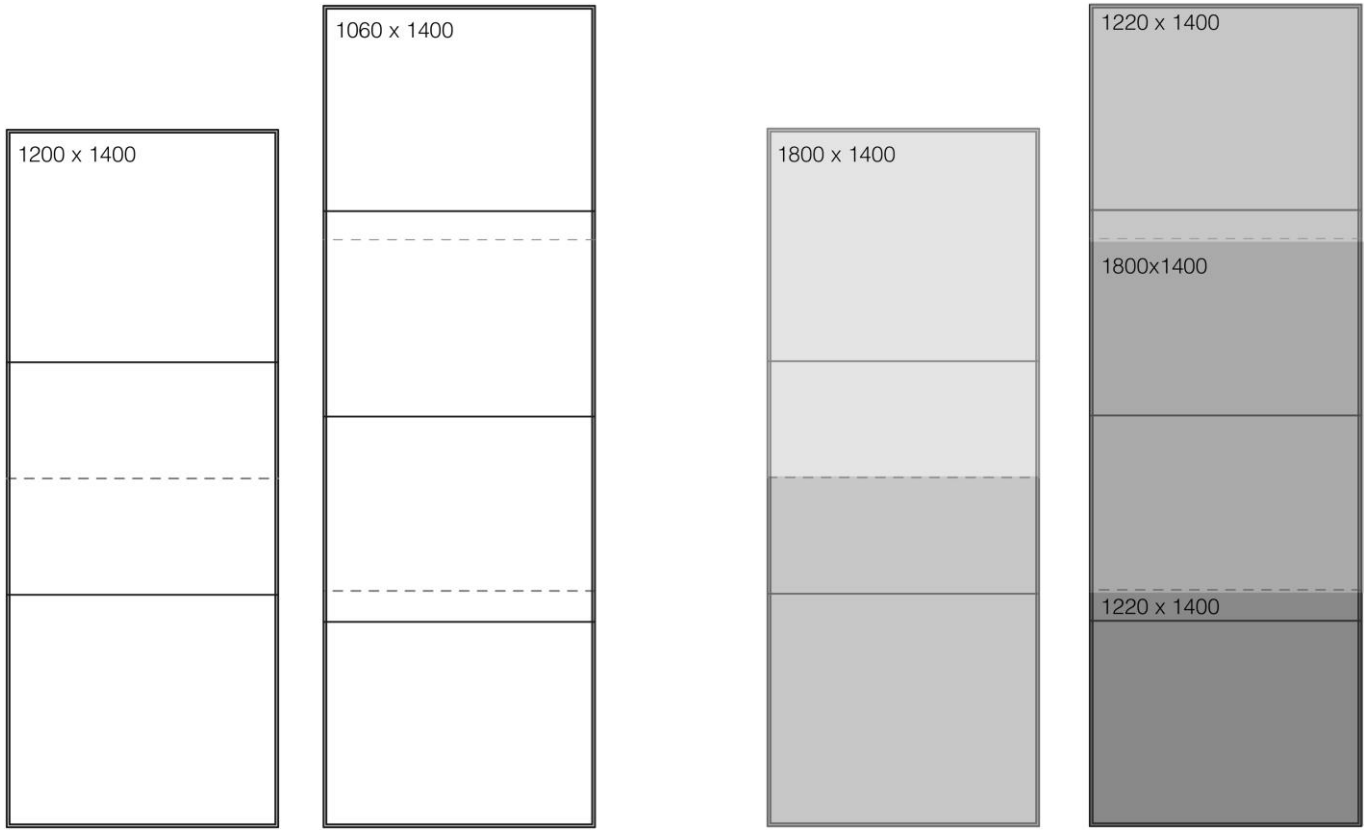
Concepts



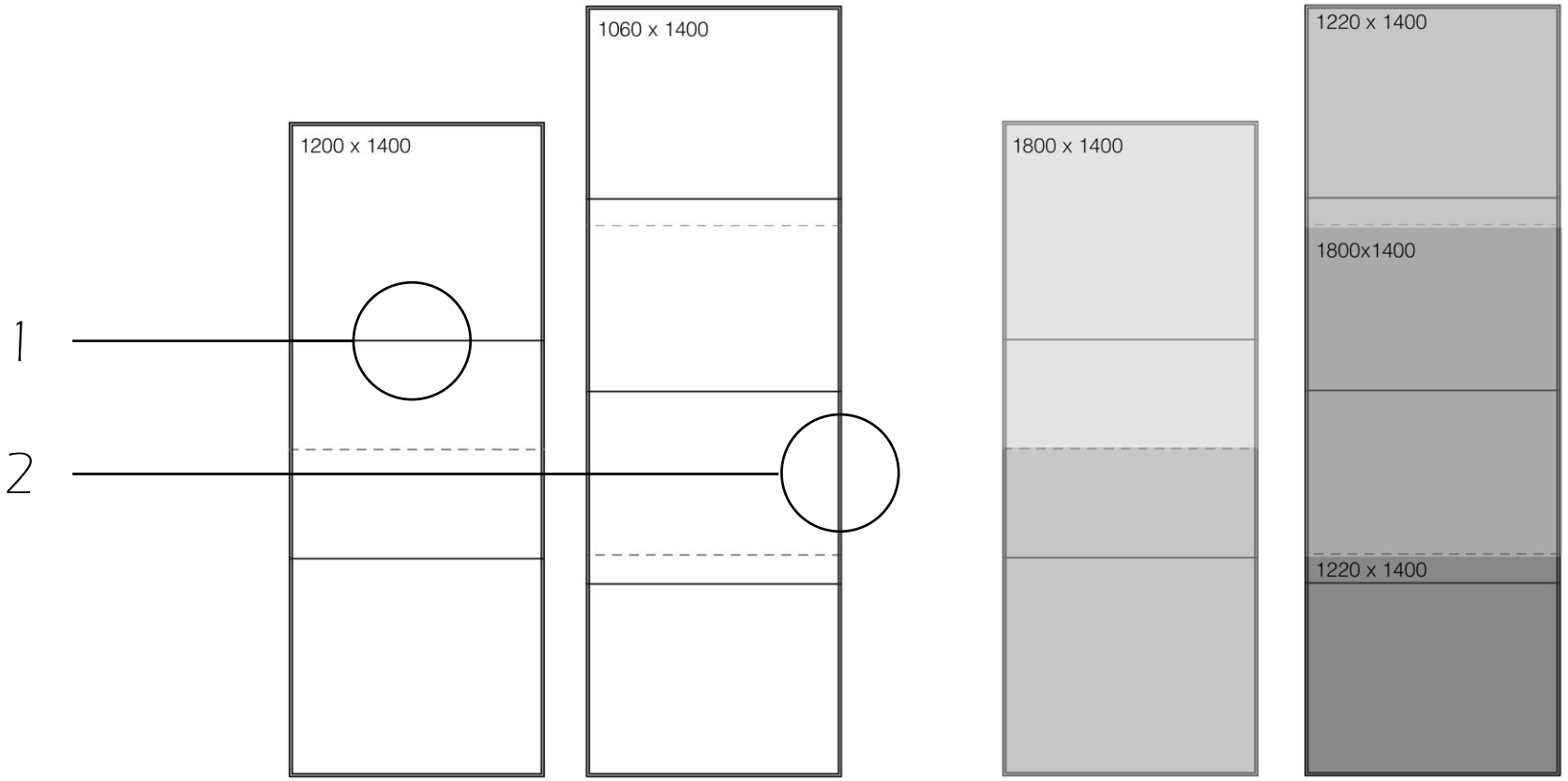
Facade



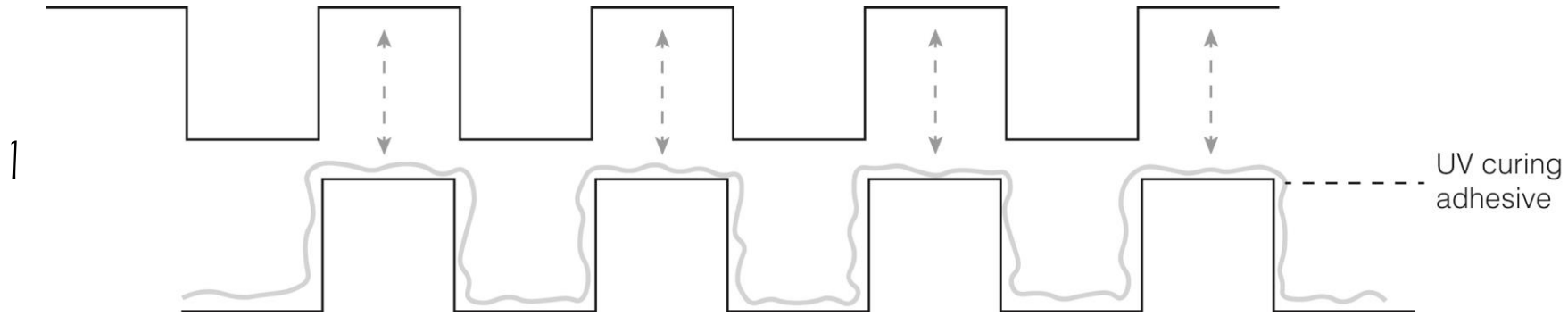
Production


1200 x 1400
1060 x 1400
1800 x 1400
1220 x 1400
1800x1400
1220 x 1400

Production

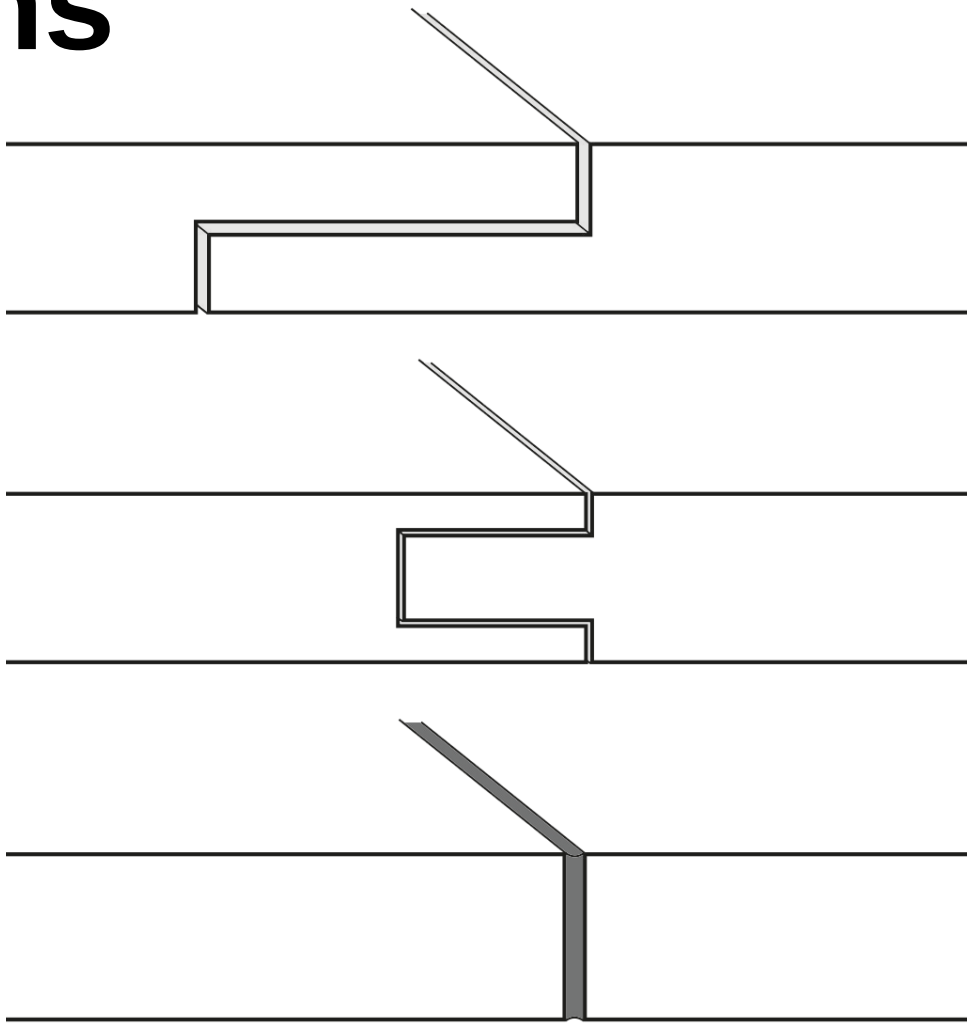

1060 x 1400
1200 x 1400
1800 x 1400
1220 x 1400
1800x1400
1220 x 1400
1
2

Connections

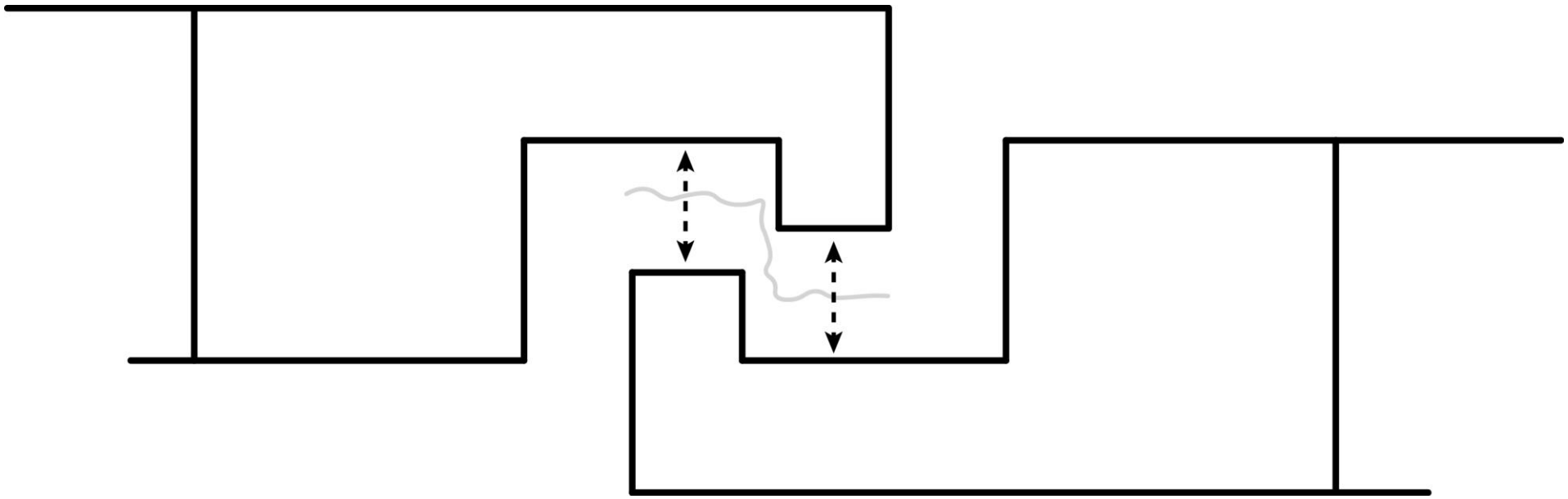


Connections

2



Connections



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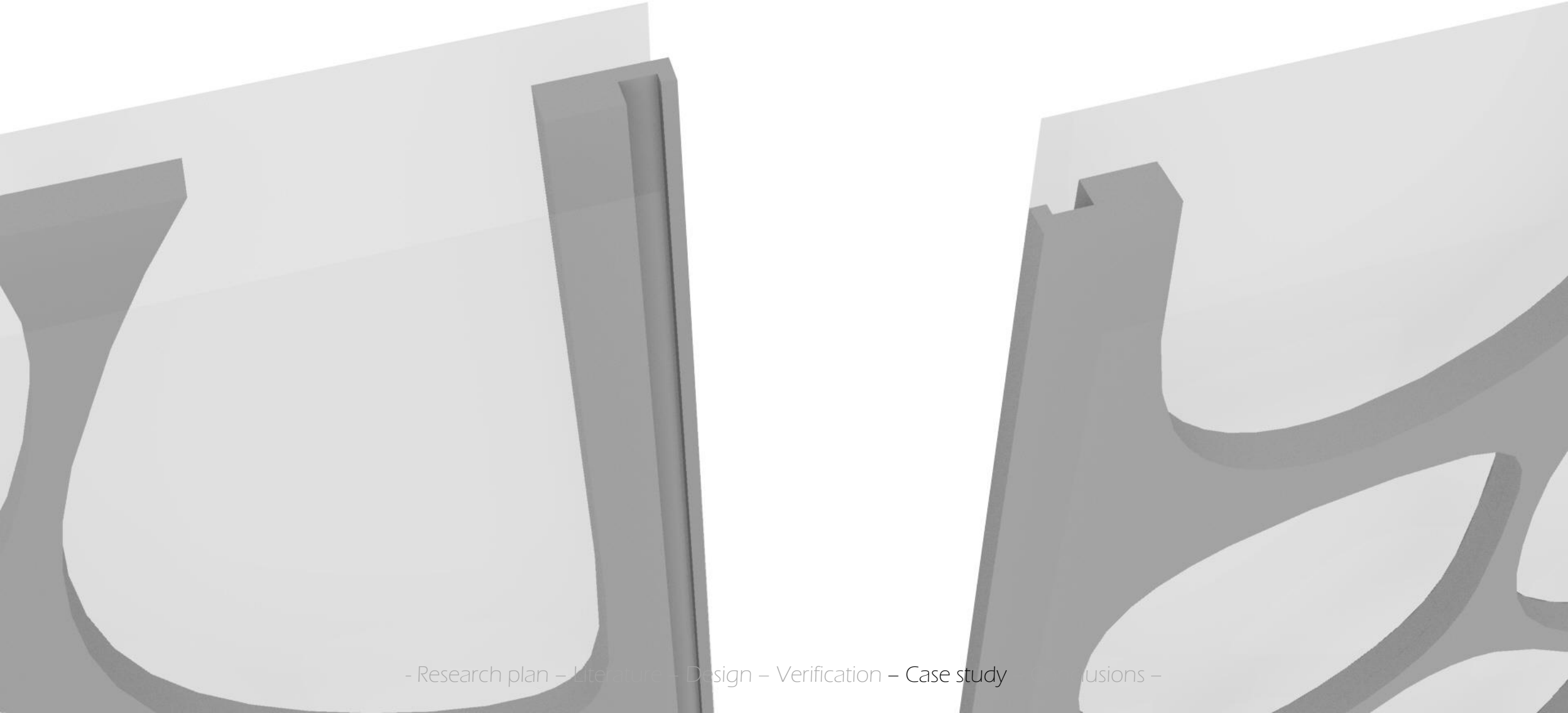

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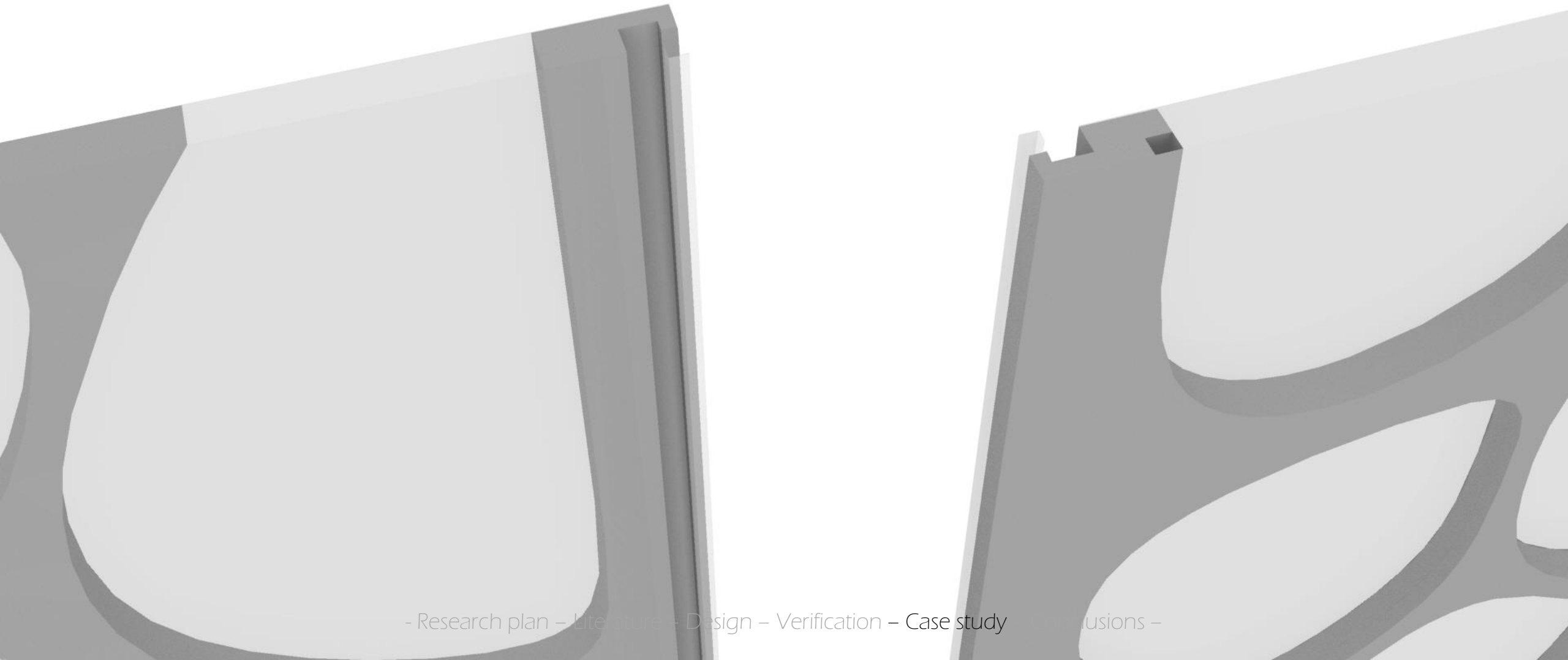
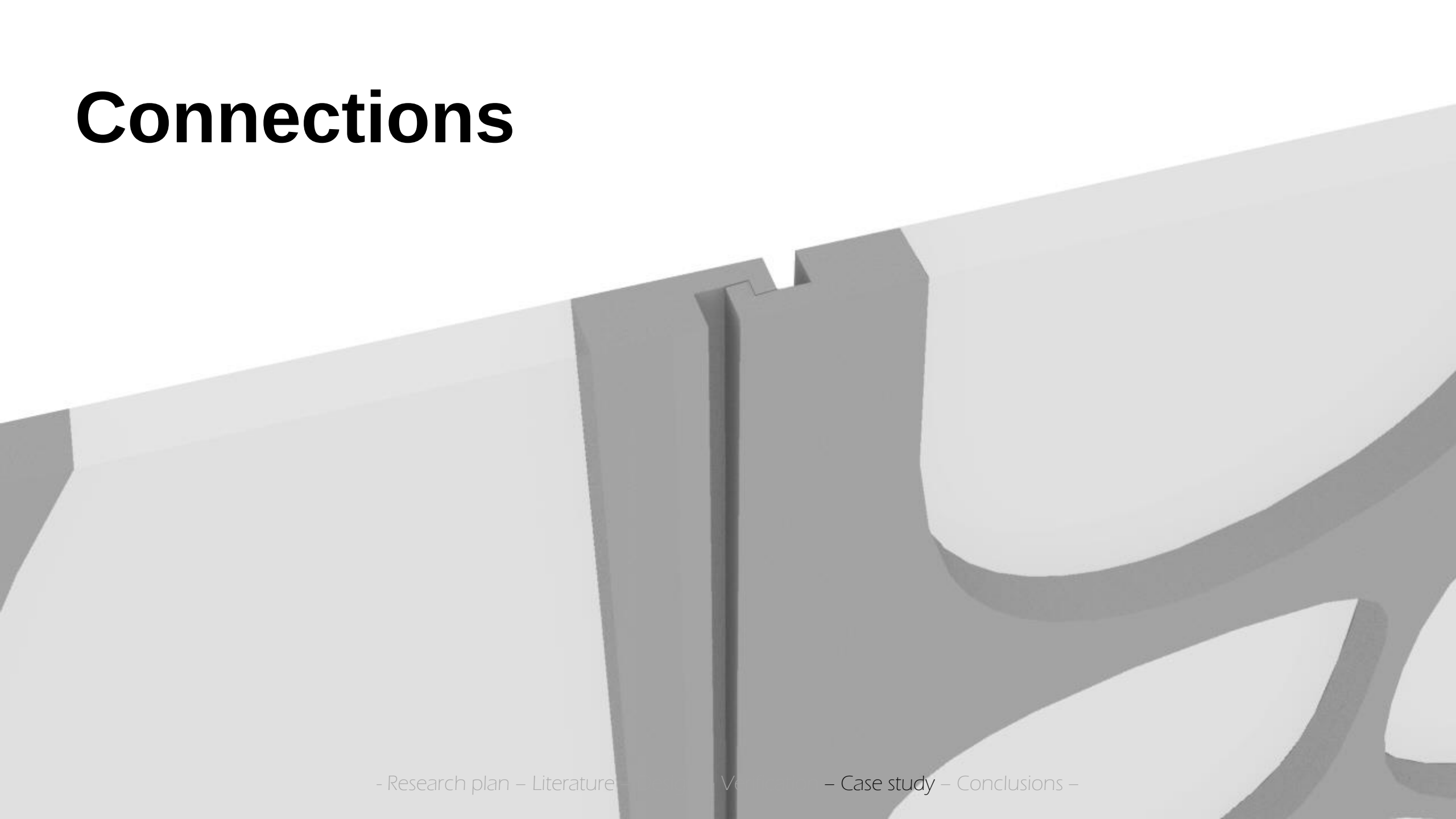


Connections



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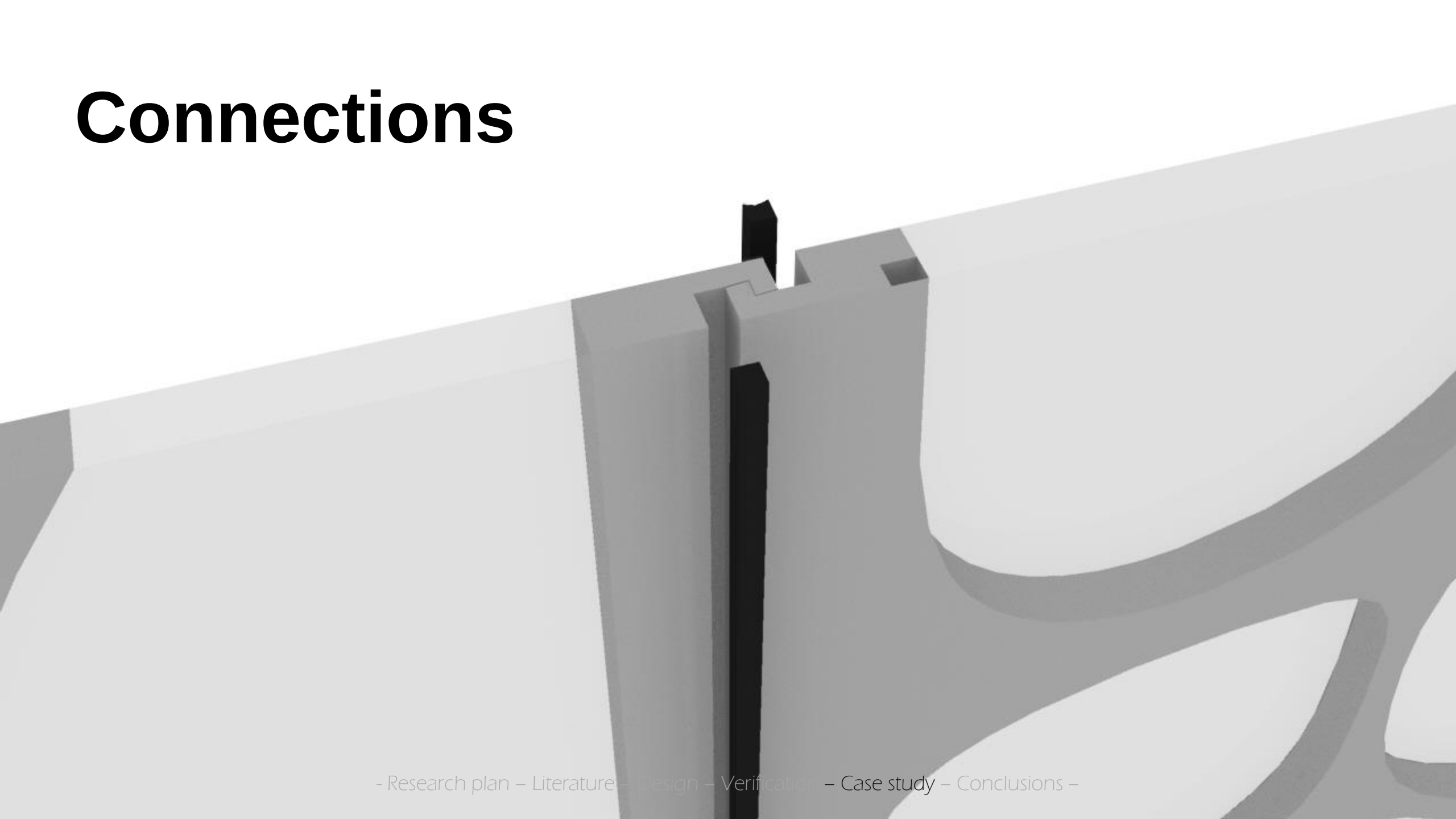
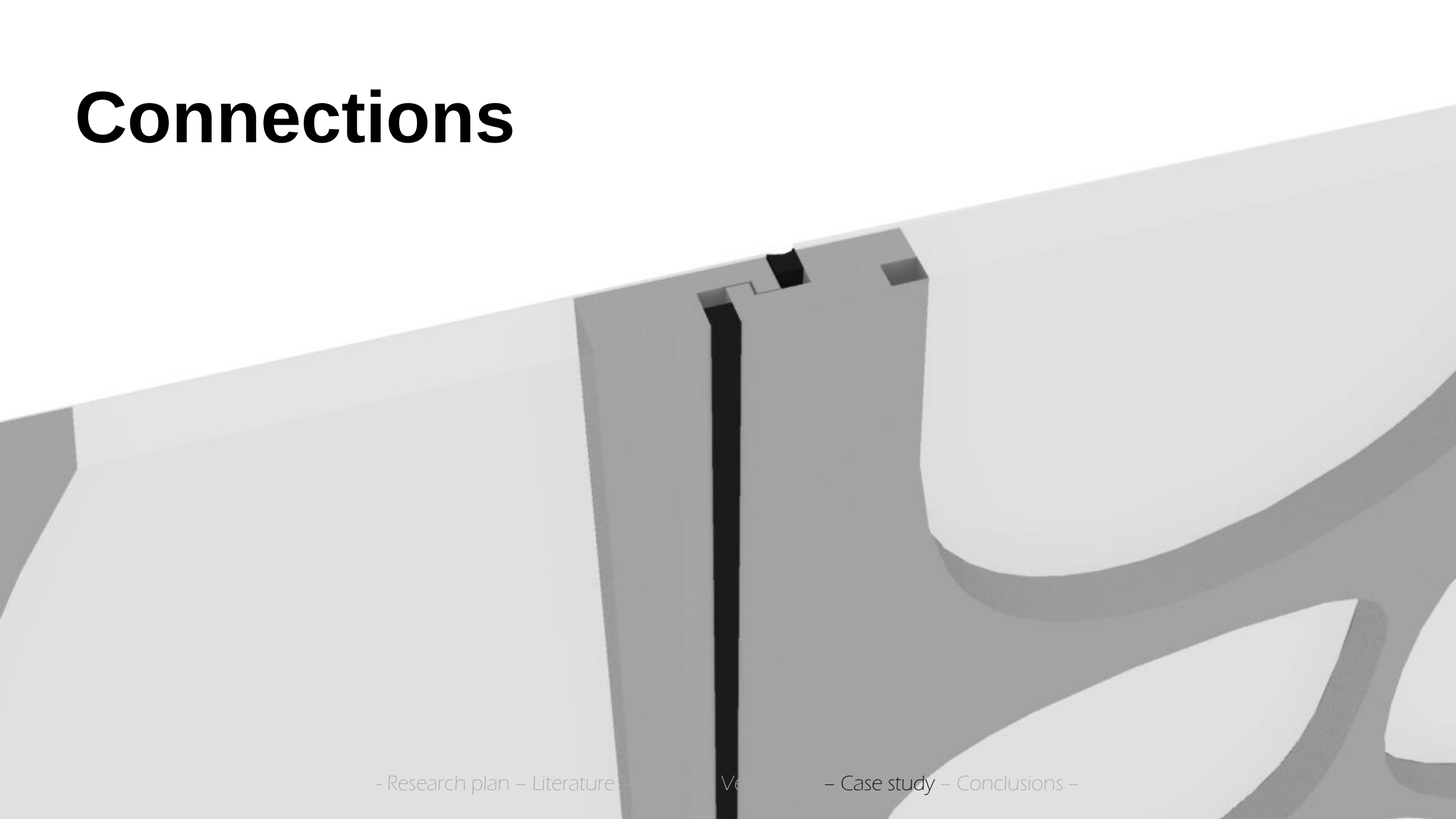
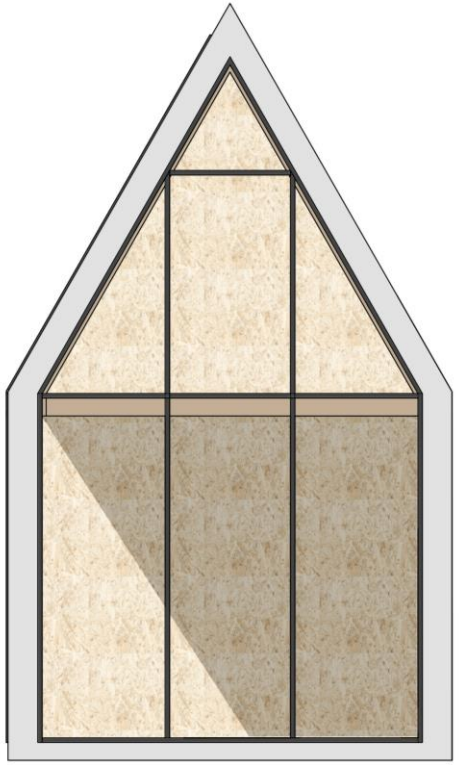
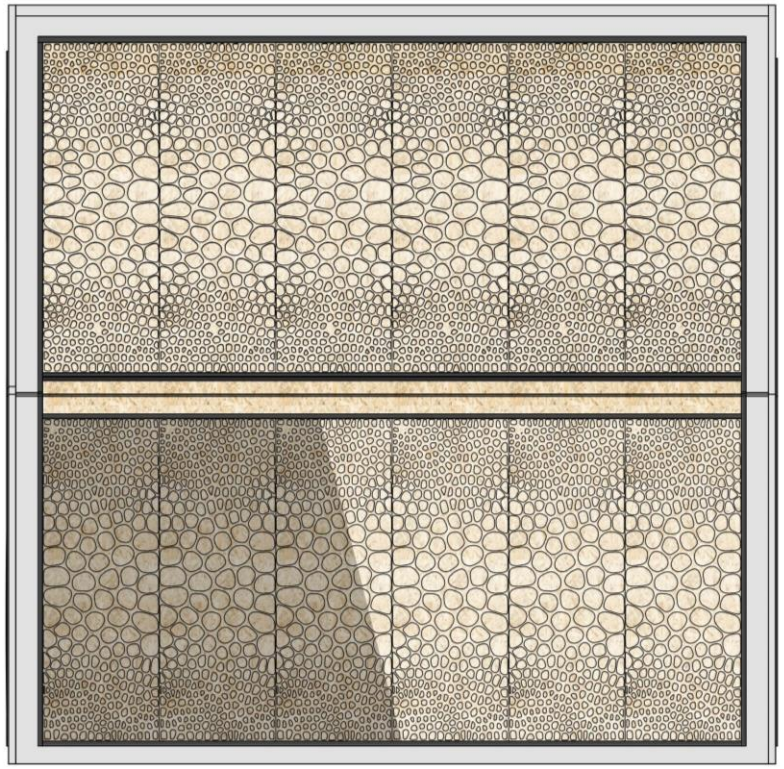


Connections

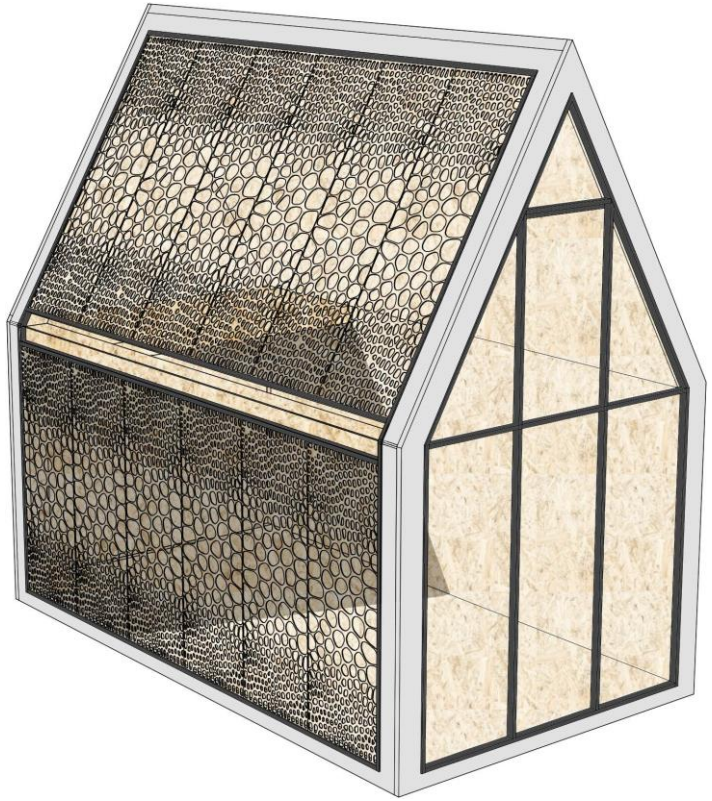


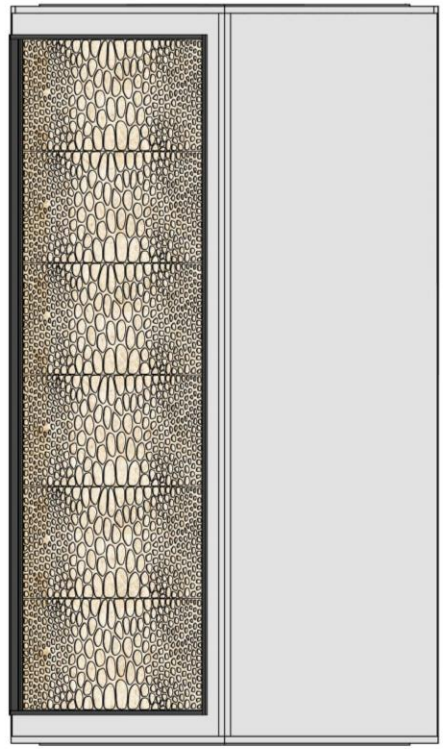
Final design





Final design





Final design

Final design

Conclusions

Conclusions

‘How can **thin glass** and a **3D printed spacer pattern** work together to create a **stiff** and **self supporting sandwich panel** which **increases the structural efficiency** of the material?’

Conclusions

‘How can thin glass and a 3D printed spacer pattern work together to create a stiff and self supporting sandwich panel which increases the structural efficiency of the material?’

- Result is one of many solutions
- Gradient mapping increases structural efficiency
- New window weight = 2,7 kg
- 85% weight reduction

Recommendations

- Optimizations
- Curved panels
- More open and light structure → FDM process
- Fire safety
- Thermal insulation

Thank You