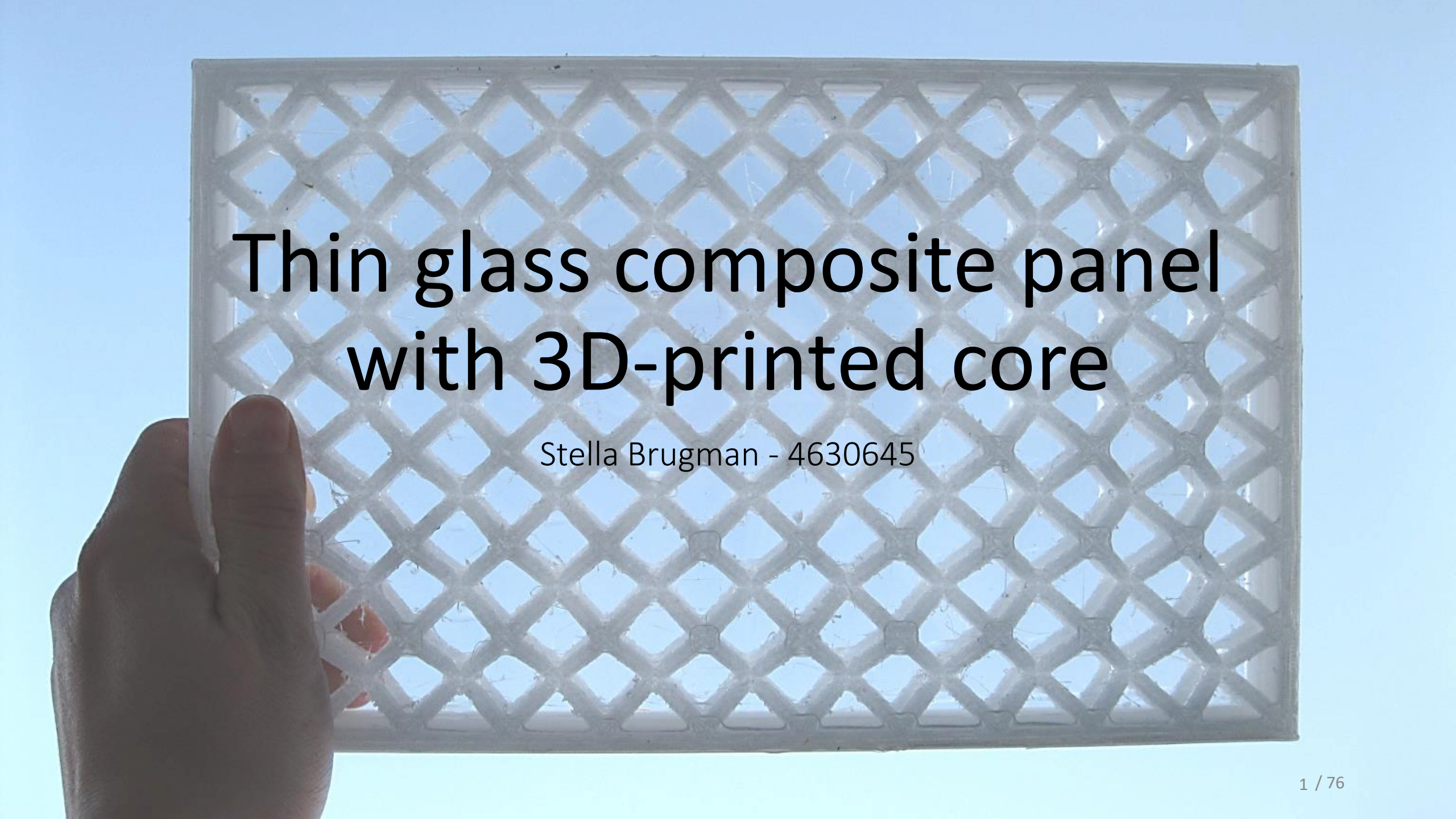


Thin glass composite panel with 3D-printed core

Stella Brugman - 4630645

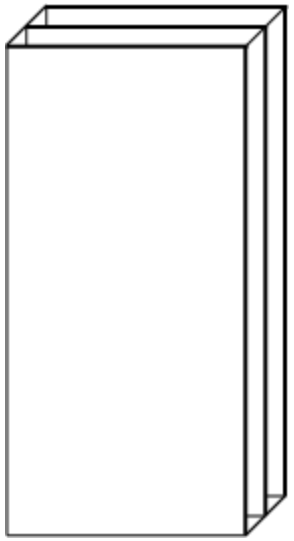
Content

- Introduction
- Literature study
  - Sandwich panels
  - (thin) glass
  - Additive manufacturing
  - Thermal insulation
  - Structural properties
- Prototype
- Preliminary design
- Design proposal
- Recommendations

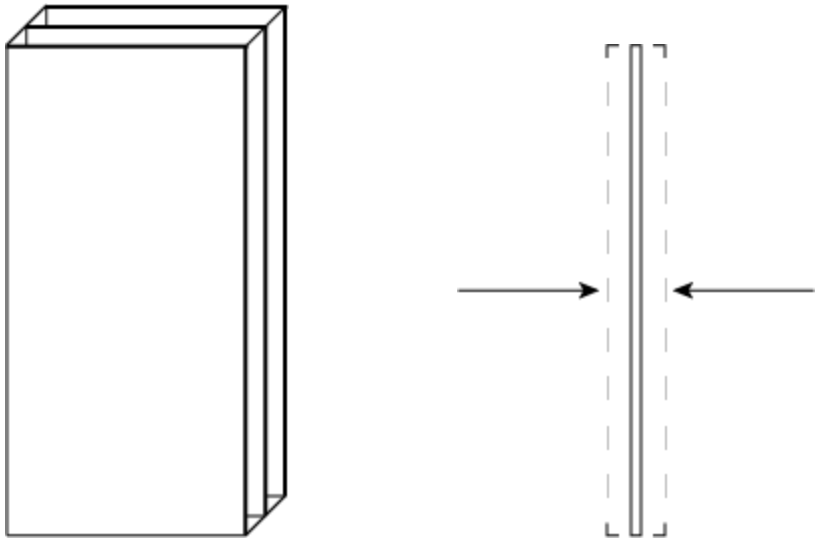
Thin glass. Photo: SCHOTT

Introduction

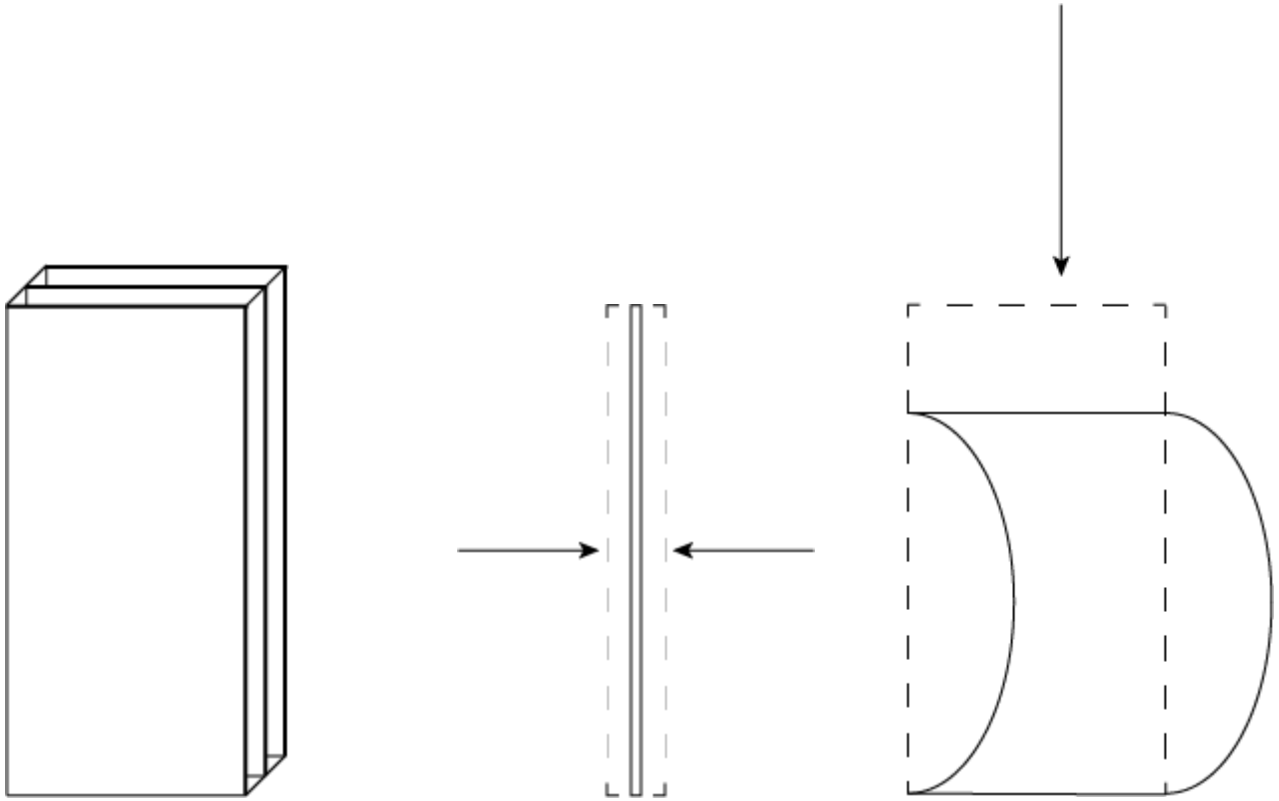
Problem



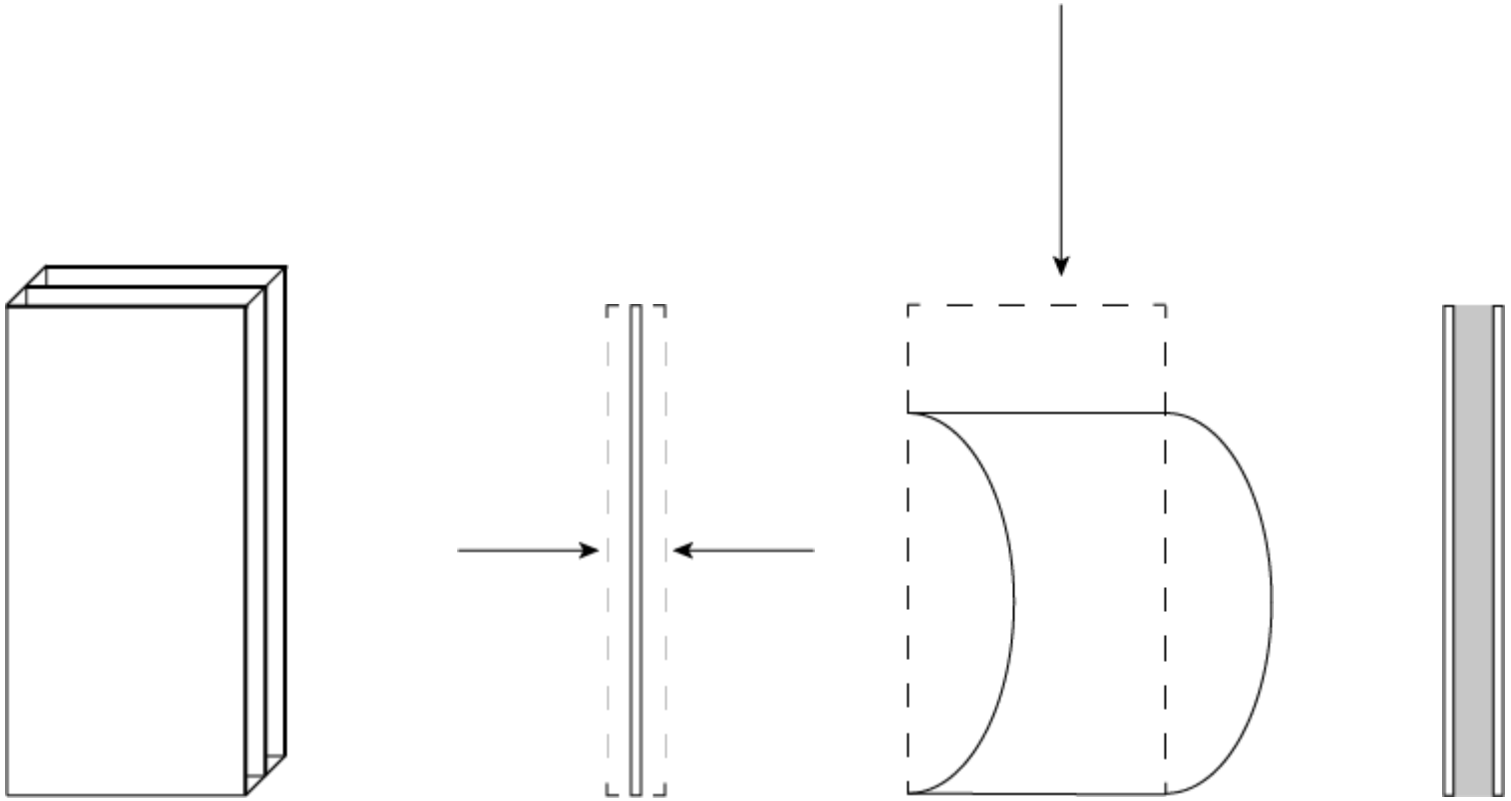
Problem



Problem



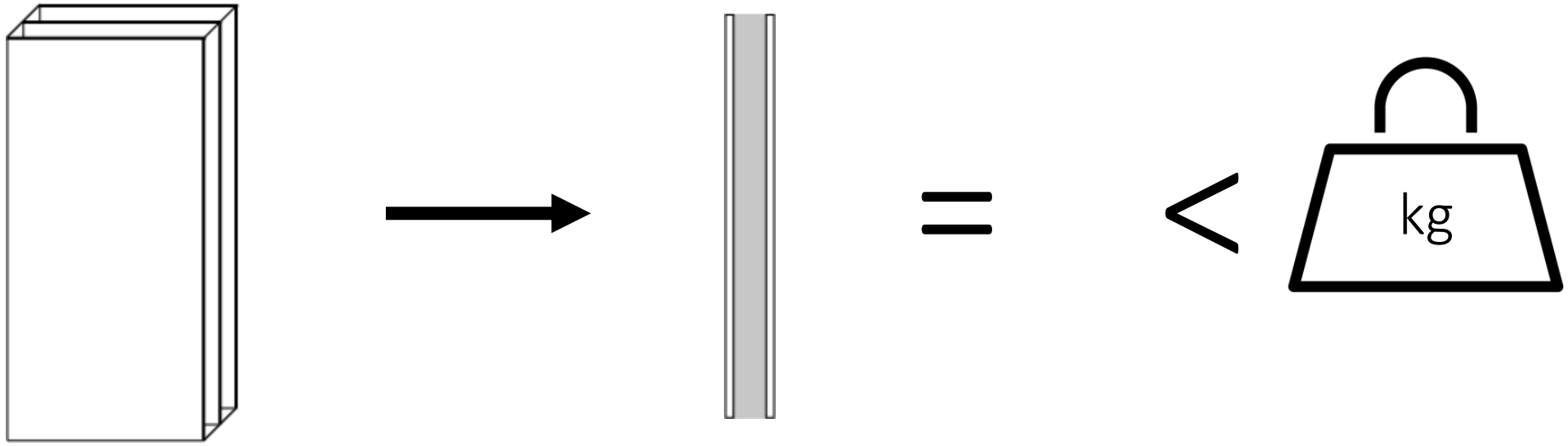
Problem



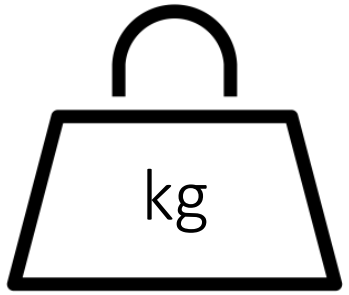
Context

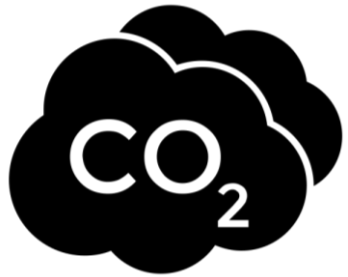
The Glass House, designed by Philip Johnson. Photo: Michael Biondo

Objective



Objective

< 

= < Energy demand & 

Objective

Panel needs to:

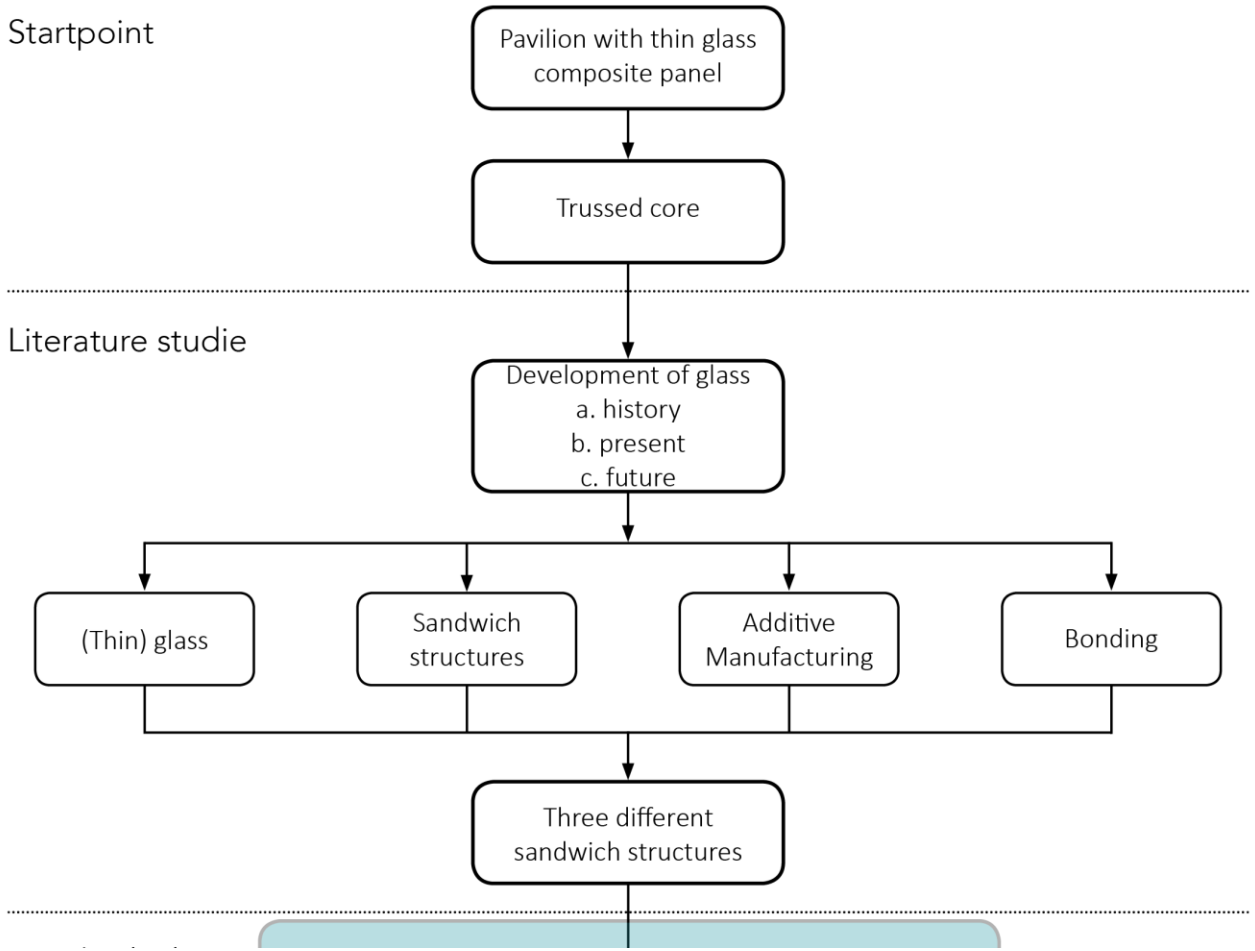
Meet current thermal insulation requirements

Be structurally safe

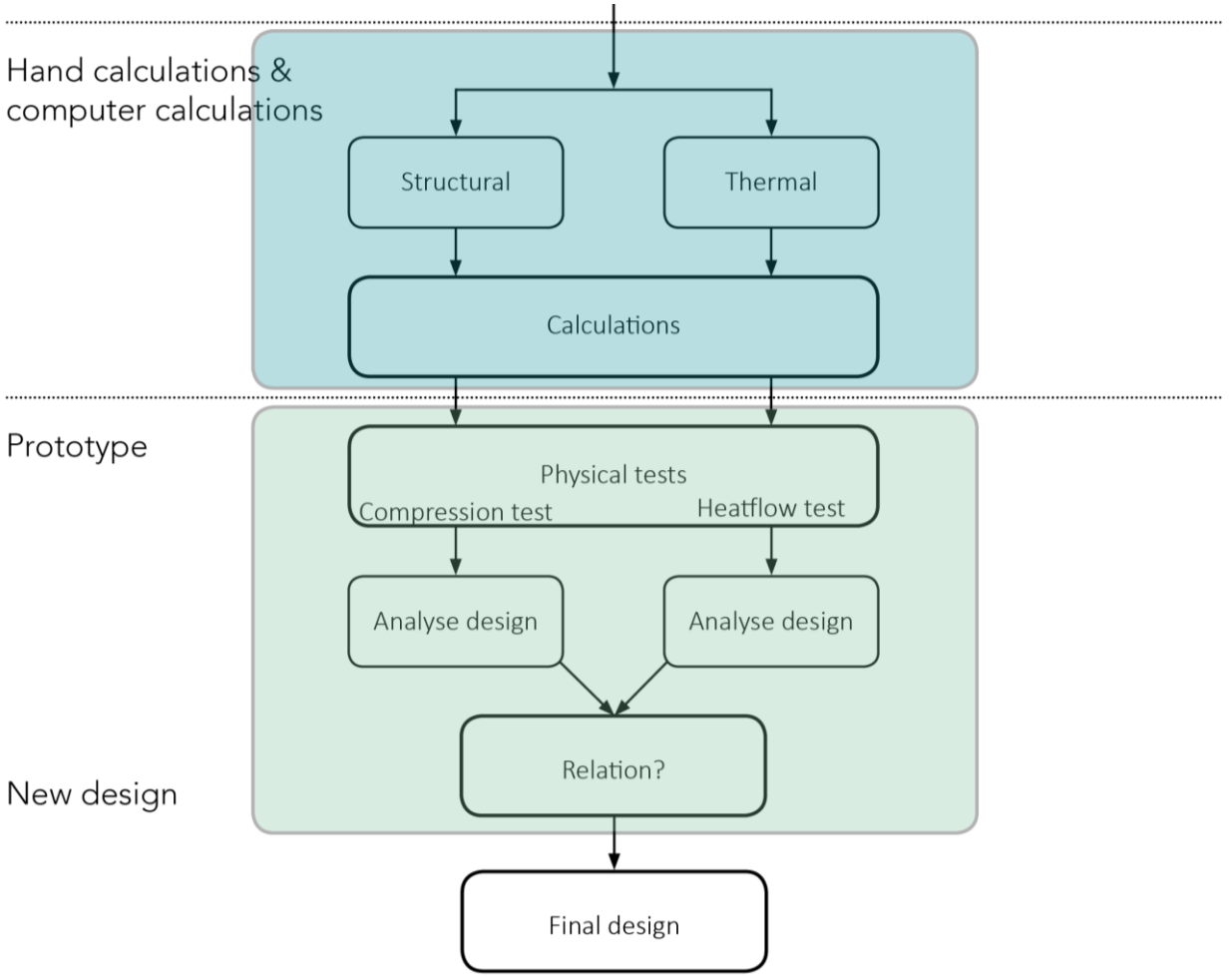
Main question

To what extent can a thin glass composite panel, with a polymeric 3D-printed trussed core, be improved to meet the thermal insulation and structural regulations of today, to be used as a façade element in the building industry?

Research framework

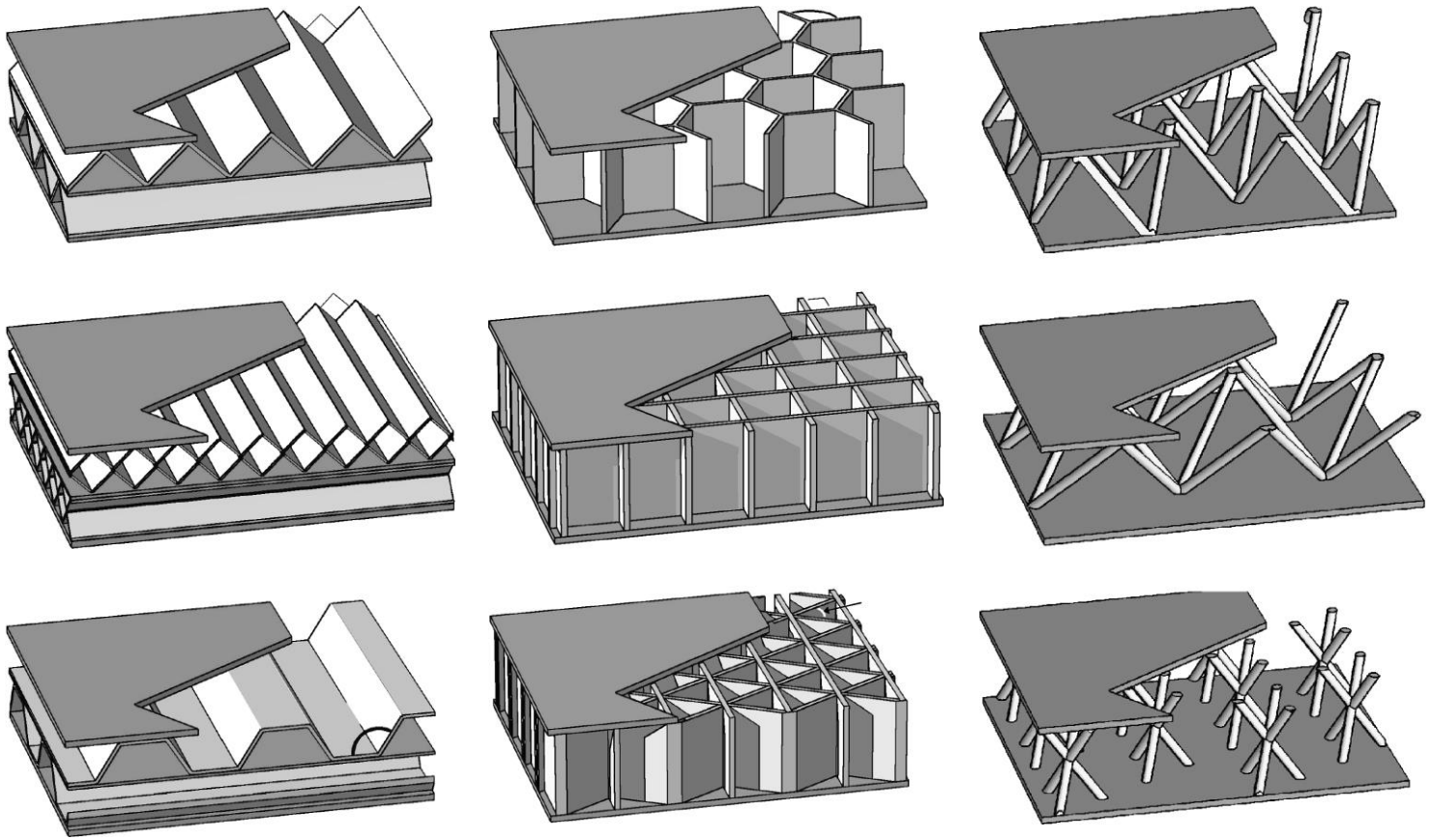


Research framework



Literature study

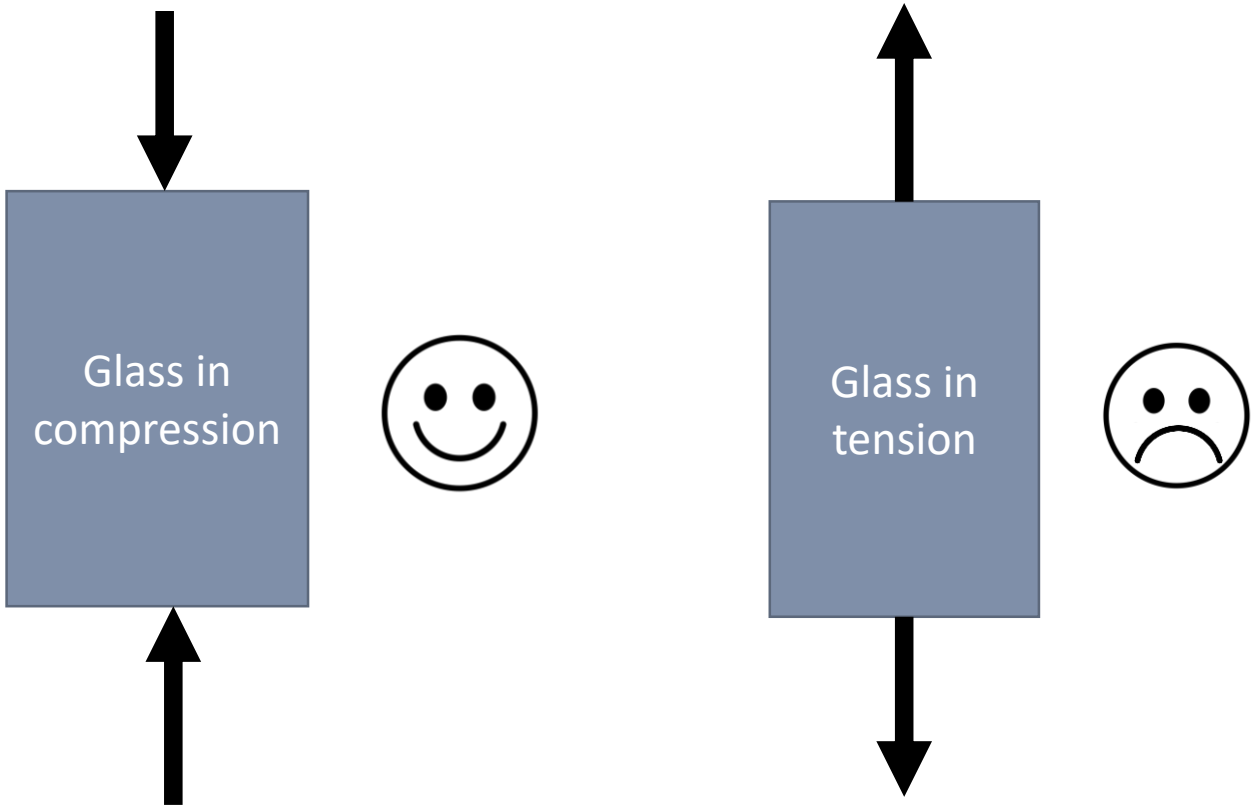
Sandwich structures



Different patterns in sandwich structures. Wadly, 2006.

(Thin) glass

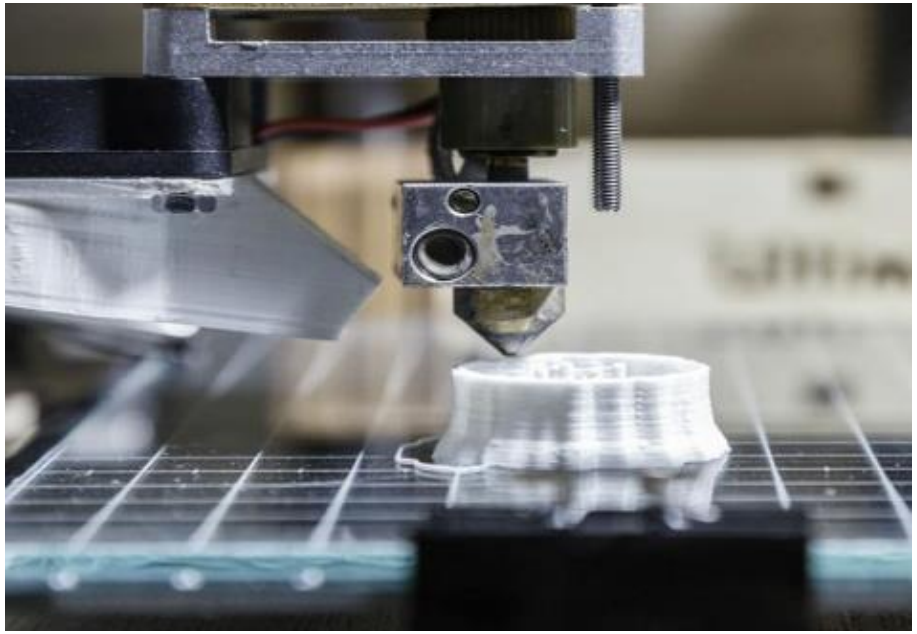
Wurm, 2017



Additive manufacturing

3D-printing

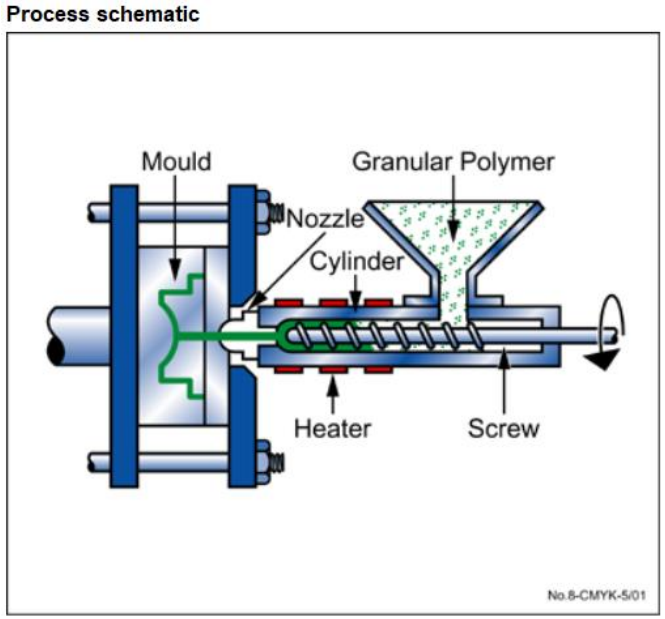
Rapid prototyping



FDM/ 3D printing. Image: Industry week.

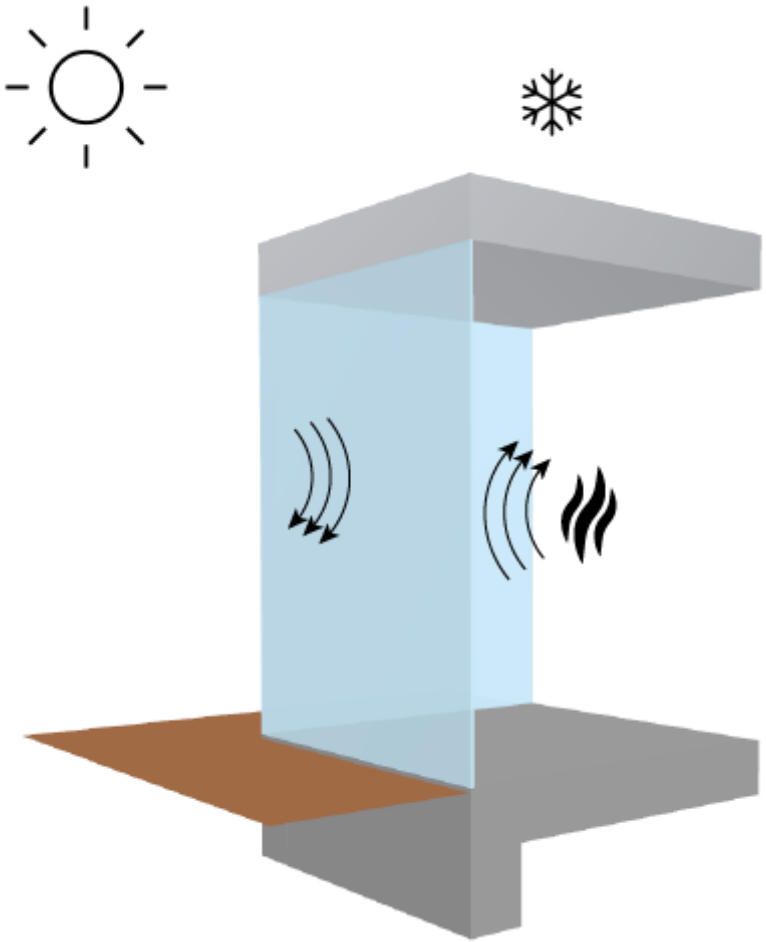
Injection molding

Mass production



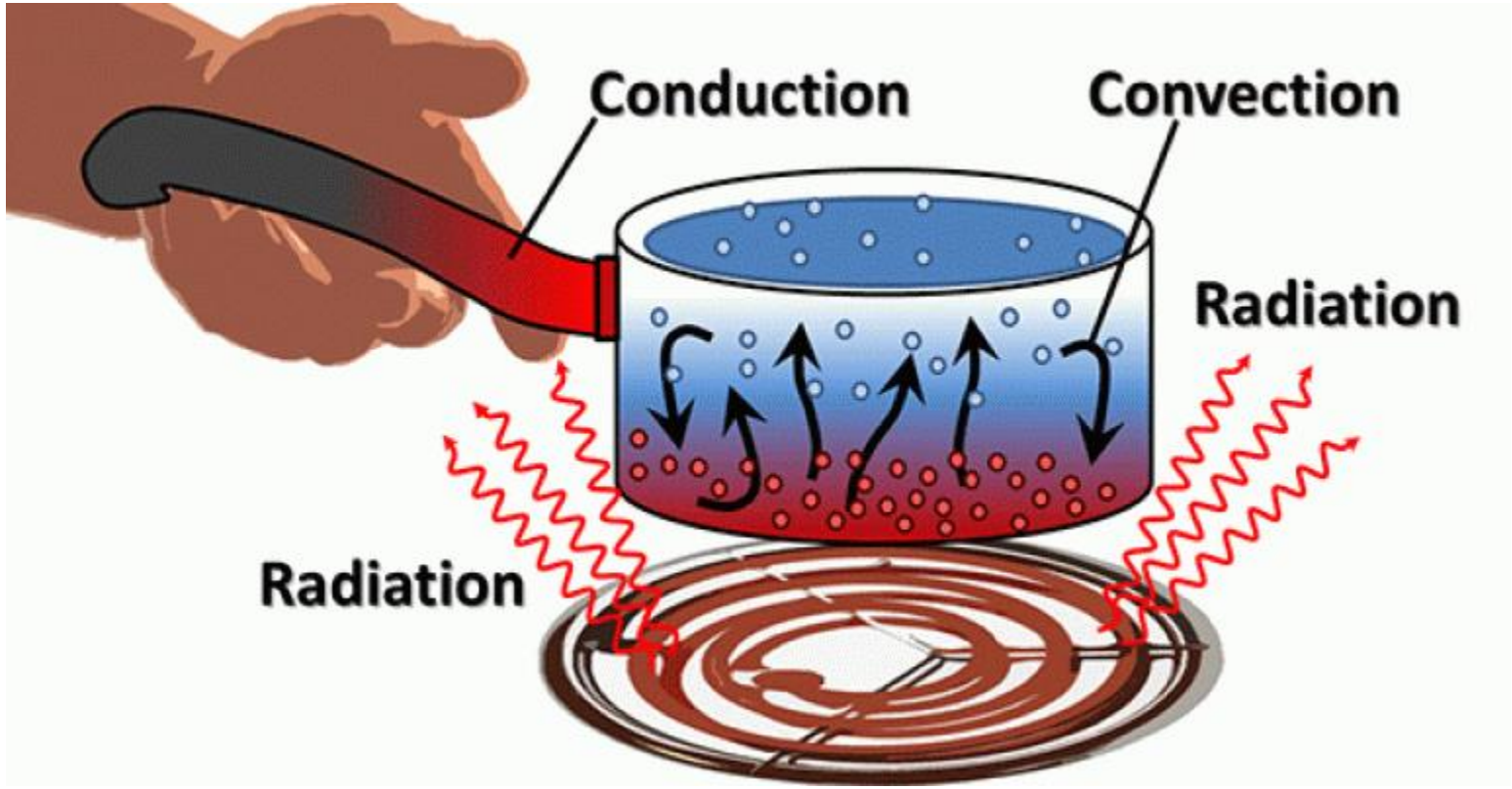
Scheme of injection molding. Image from CES EduPack 2018.

Façade criteria thermal insulation



Schematic visualisation of the function of the façade. Own image.

Thermal insulation

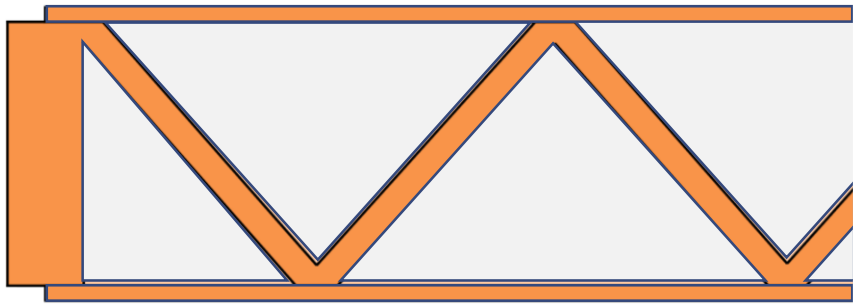


https://www.machinedesign.com/whats-difference-between/what-s-difference-between-conduction-convection-and-radiation

Thermal insulation

Heat transfer through conduction

- Glass (faces)
- PET (core)

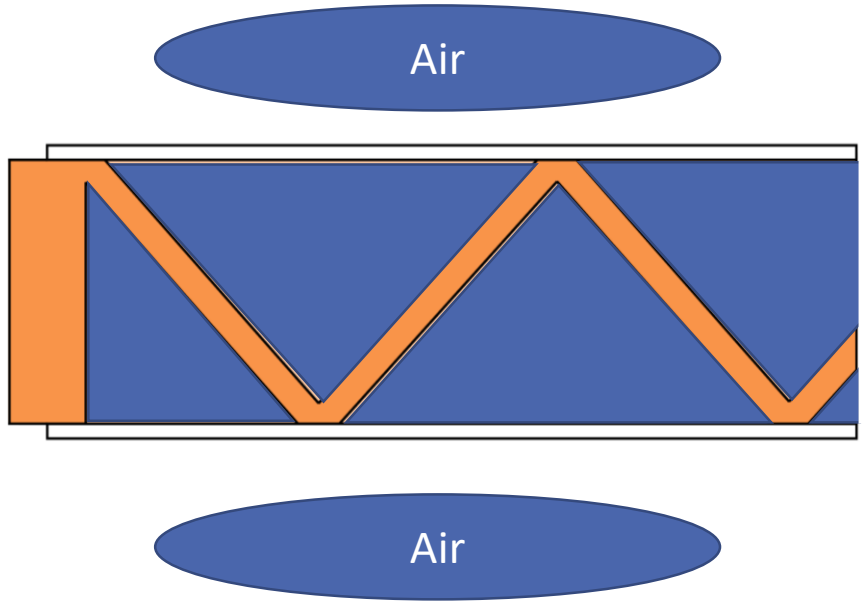


Schematic section of panel. Own image.

Thermal insulation

Heat transfer through conduction, convection

- Glass
- Spacer
- Air cavity
- Air layers surface

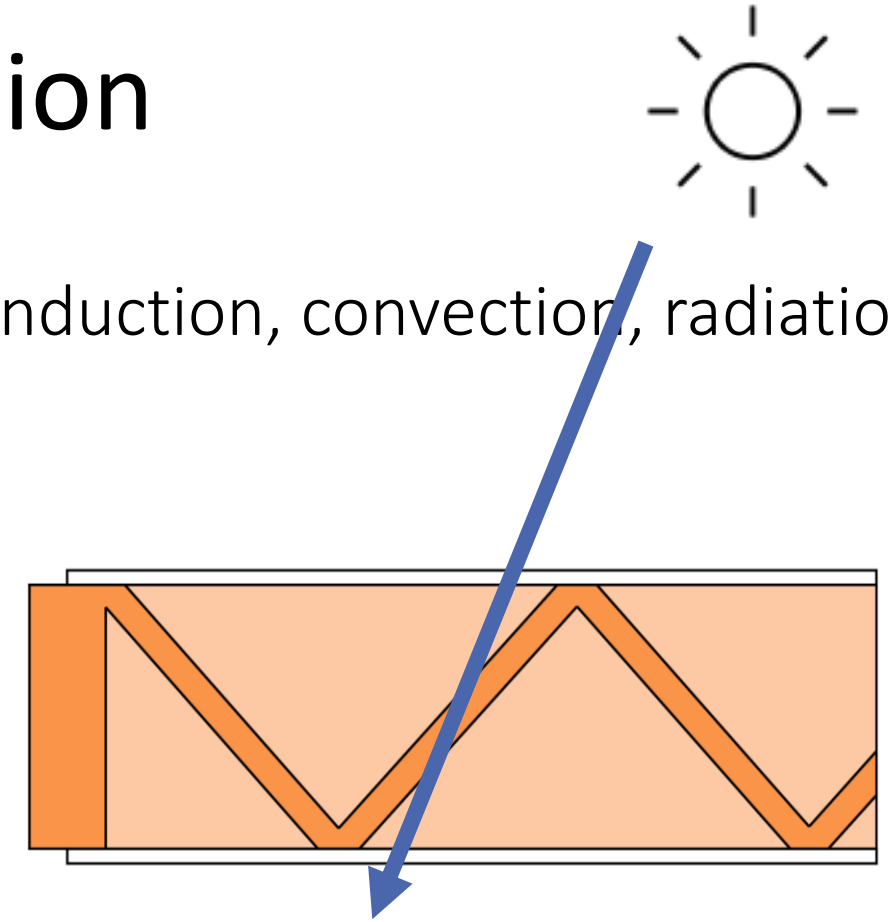


Schematic section of panel. Own image.

Thermal insulation

Heat transfer through conduction, convection, radiation

- Glass
- Spacer
- Air cavity
- Air layers surface



Schematic section of panel. Own image.

Structural properties

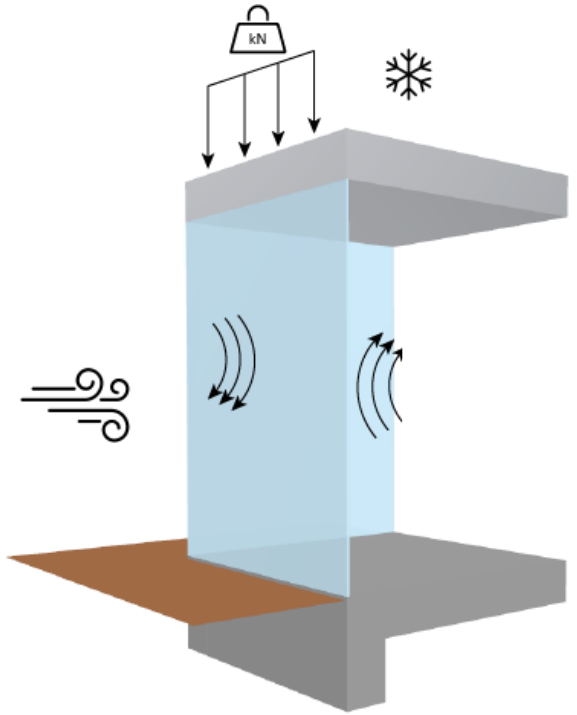
Permanent load

- Self-weight of the panel
- Weight of other structural elements

Variable load

- Snow load
- Wind load
- Life load

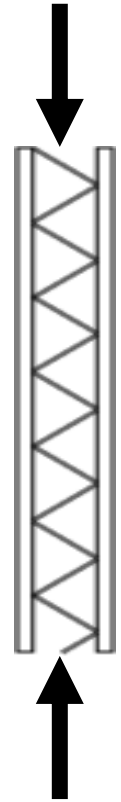
The safety factor is 1,5.

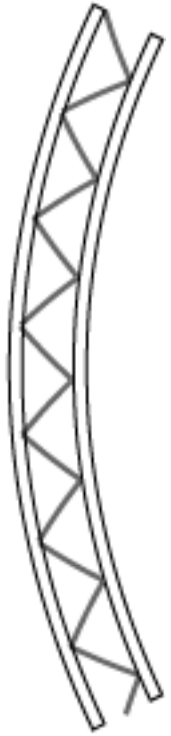


Schematic visualisation of the function of the façade. Own image.

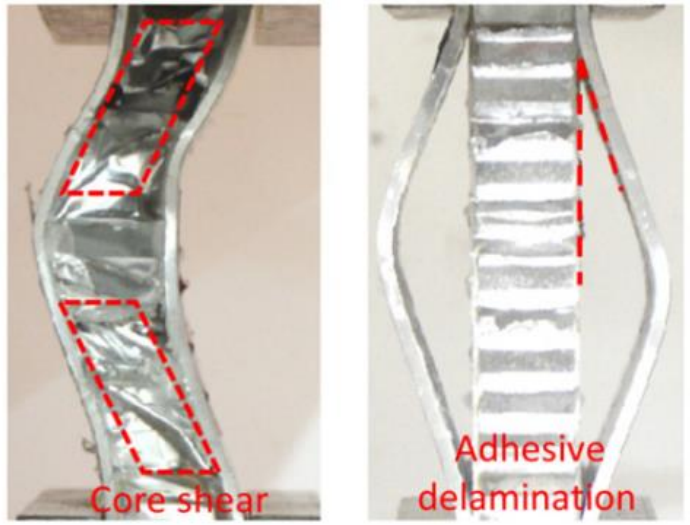
Sandwich structures

- Compression test





Buckling of a sandwich panel. Own image.

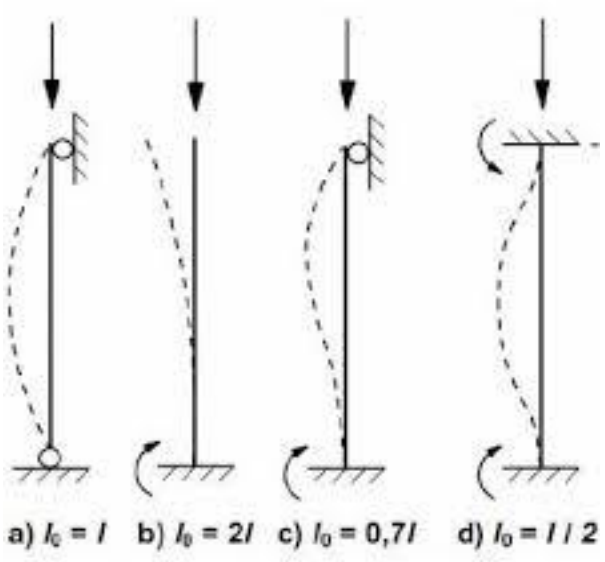


Failure modes aluminium sandwich panels with honeycomb core. Image by sun, Huo, Chen & Li, 2017.

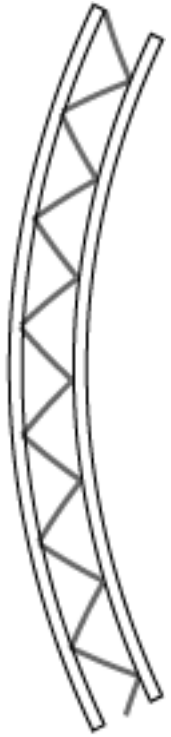
Sandwich structures

$$P_{cr} = \frac{\pi^2 \cdot E \cdot I}{L^2}$$

$$I = \frac{1}{12} b t^3$$



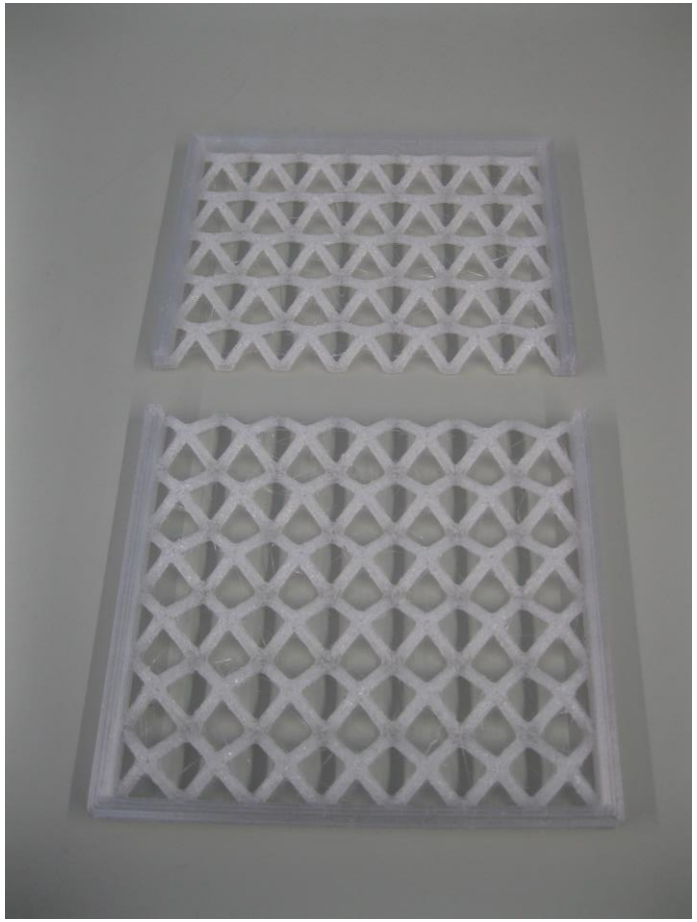
Effective length of column.



Buckling of a sandwich panel. Own image.

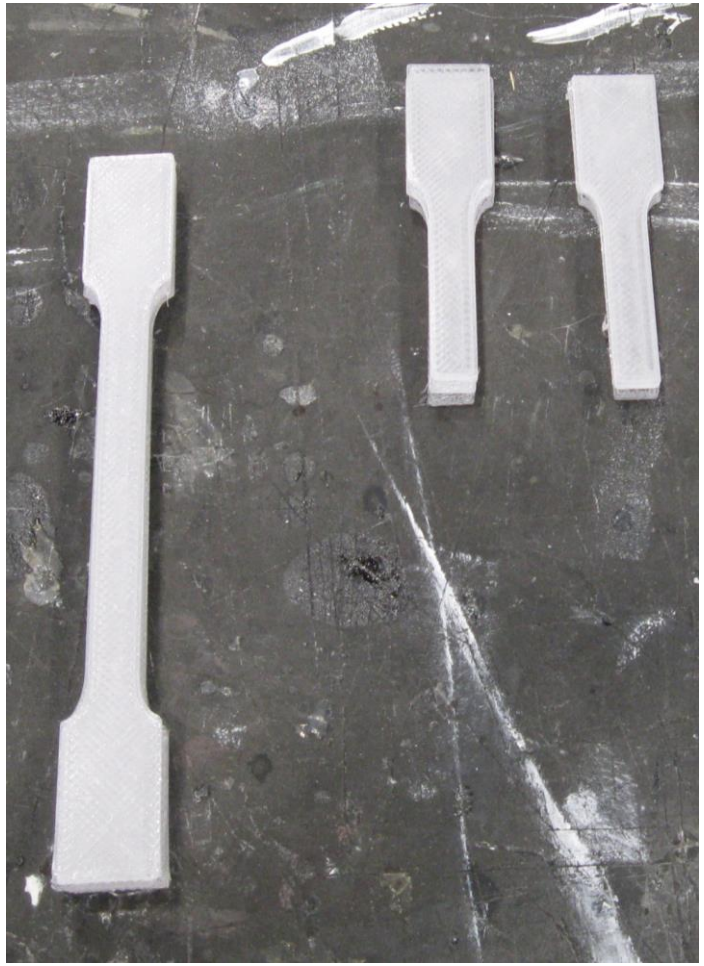
Prototype

Prototype

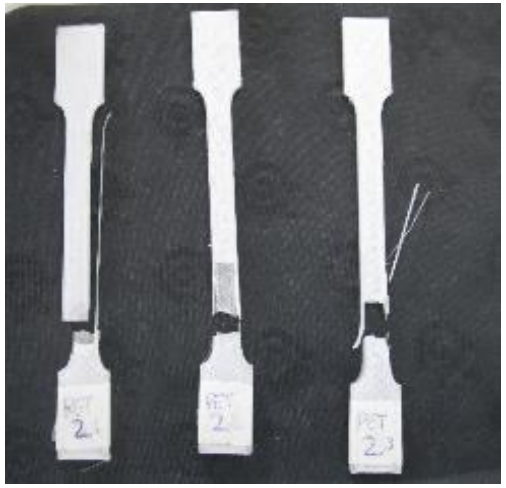


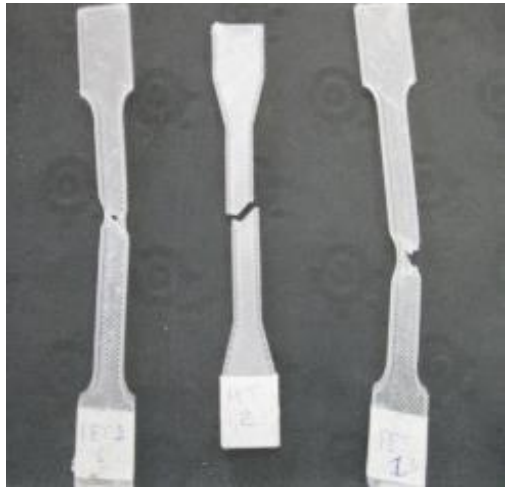
Prototype

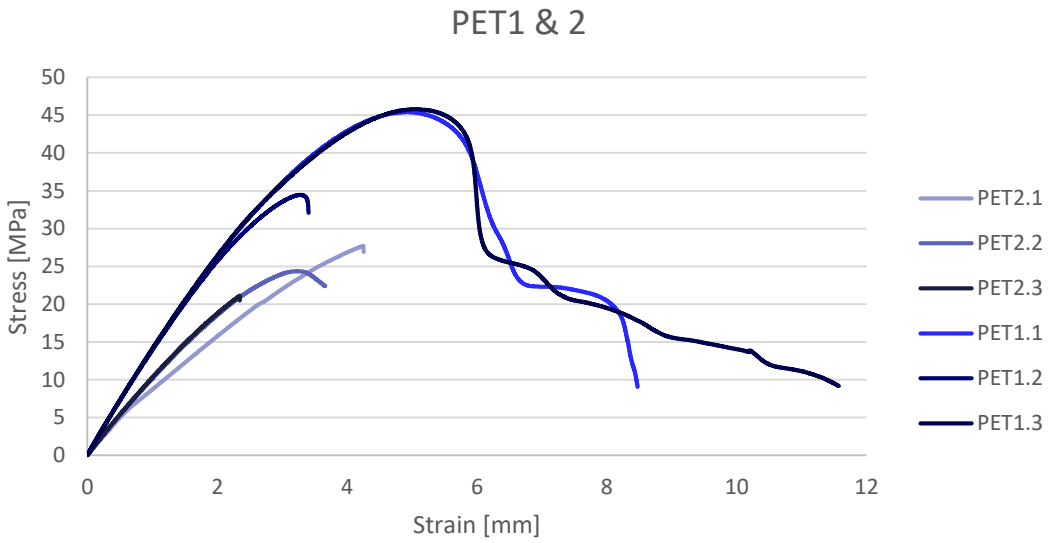
Prototype



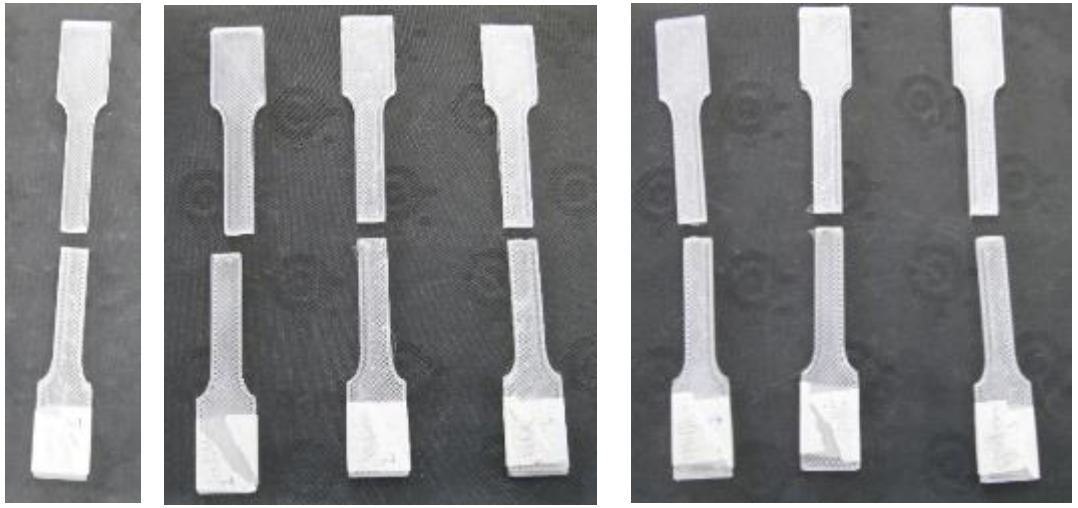
Prototype

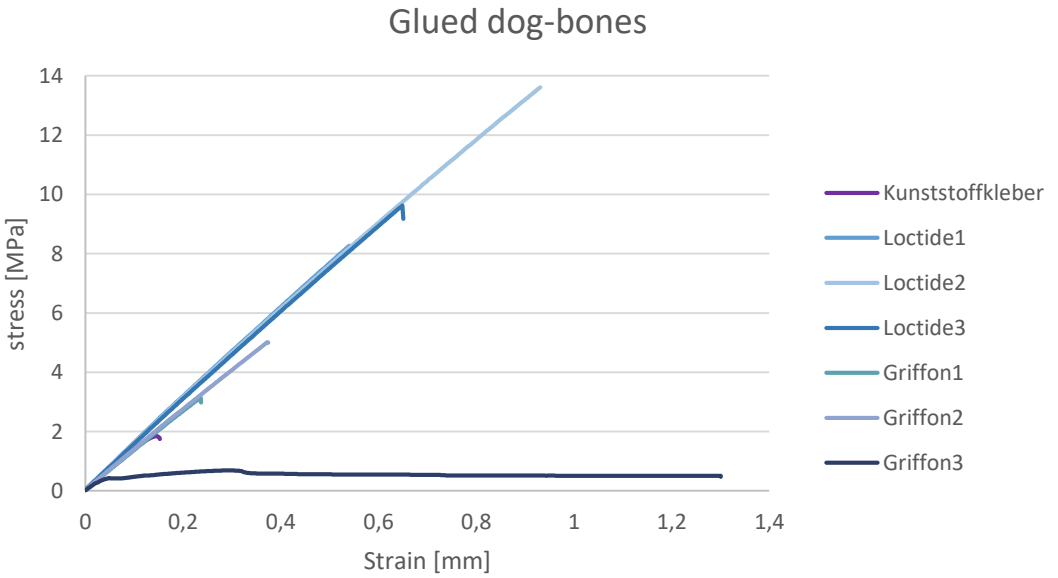




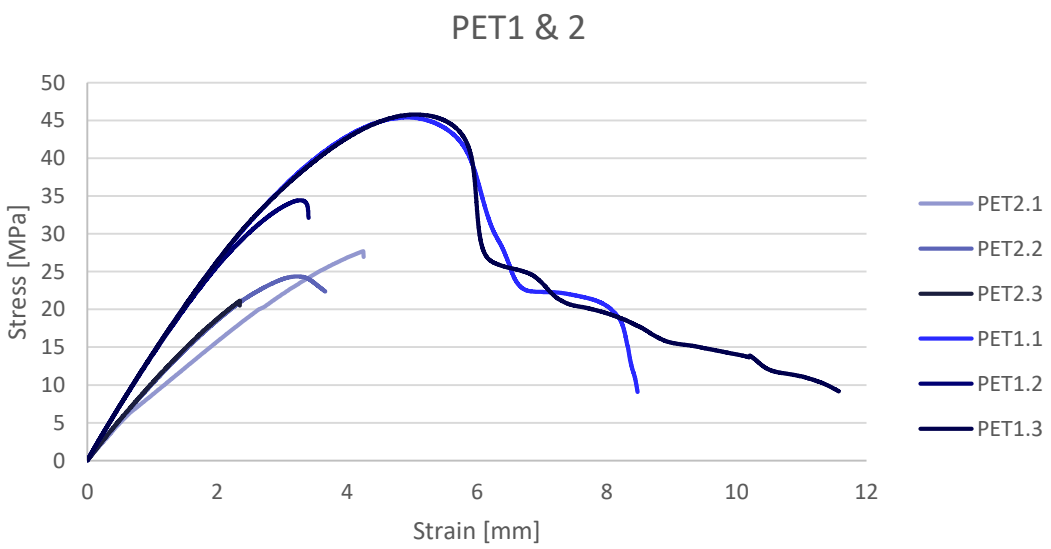

PET1 & 2
Stress [MPa]
Strain [mm]
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
PET2.1
PET2.2
PET2.3
PET1.1
PET1.2
PET1.3

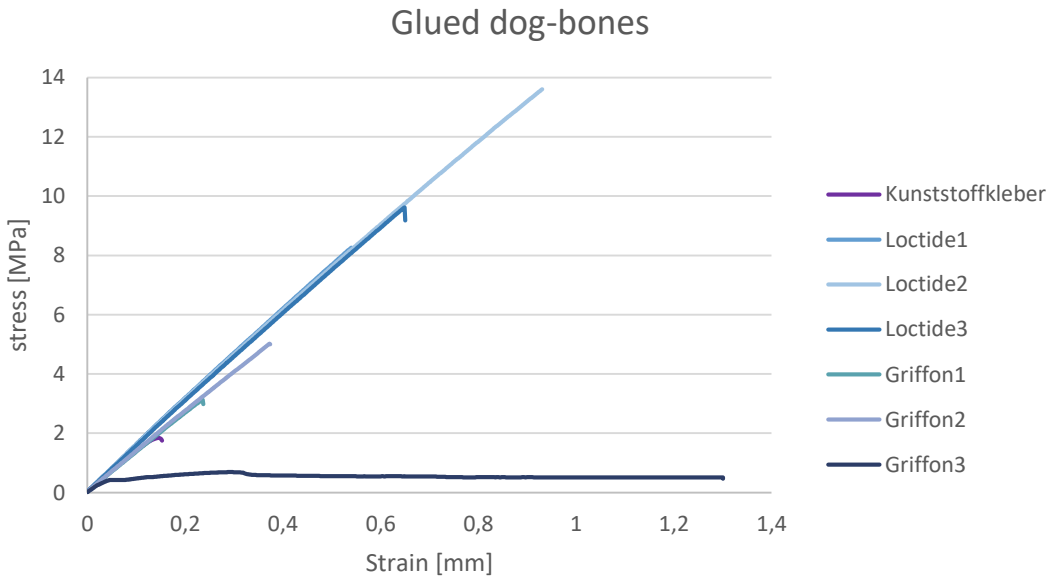
Prototype



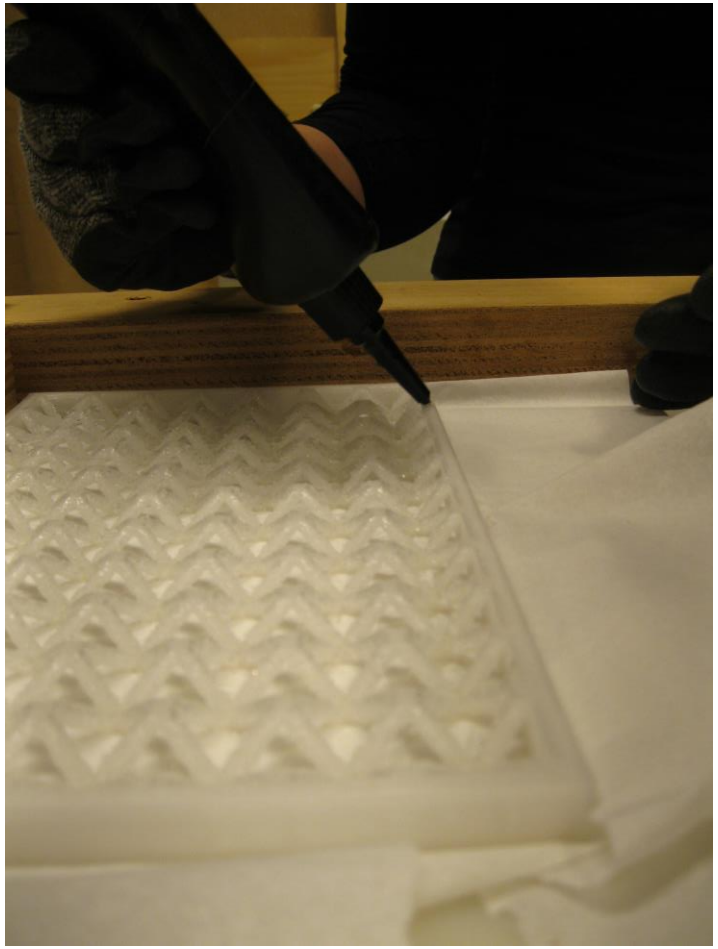

Glued dog-bones
stress [MPa]
14
12
10
8
6
4
2
0
0
0,2
0,4
0,6
0,8
1
1,2
1,4
Strain [mm]
Kunststoffkleber
Loctide1
Loctide2
Loctide3
Griffon1
Griffon2
Griffon3

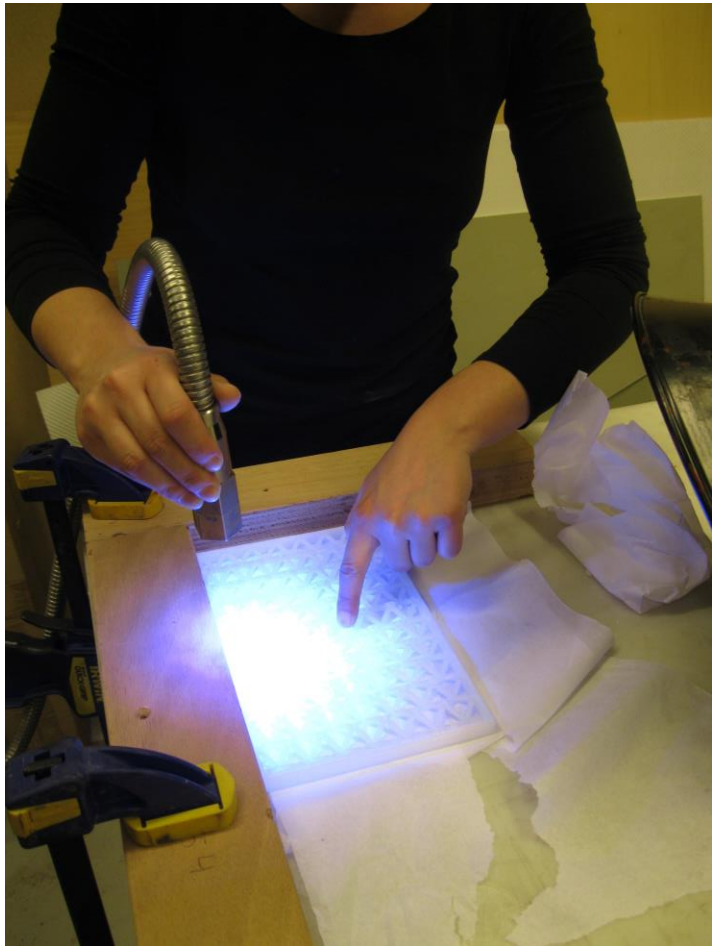
Prototype


PET1 & 2
Stress [MPa]
Strain [mm]
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
PET2.1
PET2.2
PET2.3
PET1.1
PET1.2
PET1.3


Glued dog-bones
stress [MPa]
Strain [mm]
0
2
4
6
8
10
12
14
0
0,2
0,4
0,6
0,8
1
1,2
1,4
Kunststoffkleber
Loctide1
Loctide2
Loctide3
Griffon1
Griffon2
Griffon3

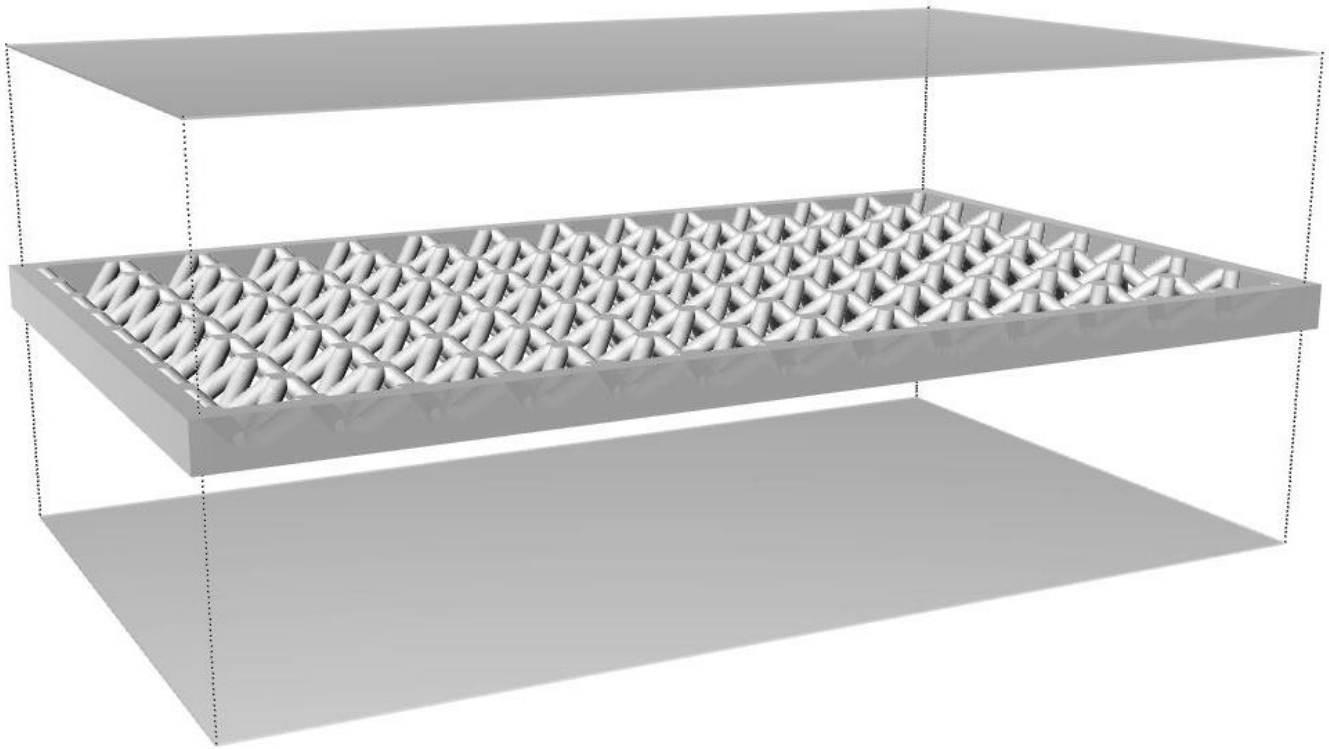
Panel bonding





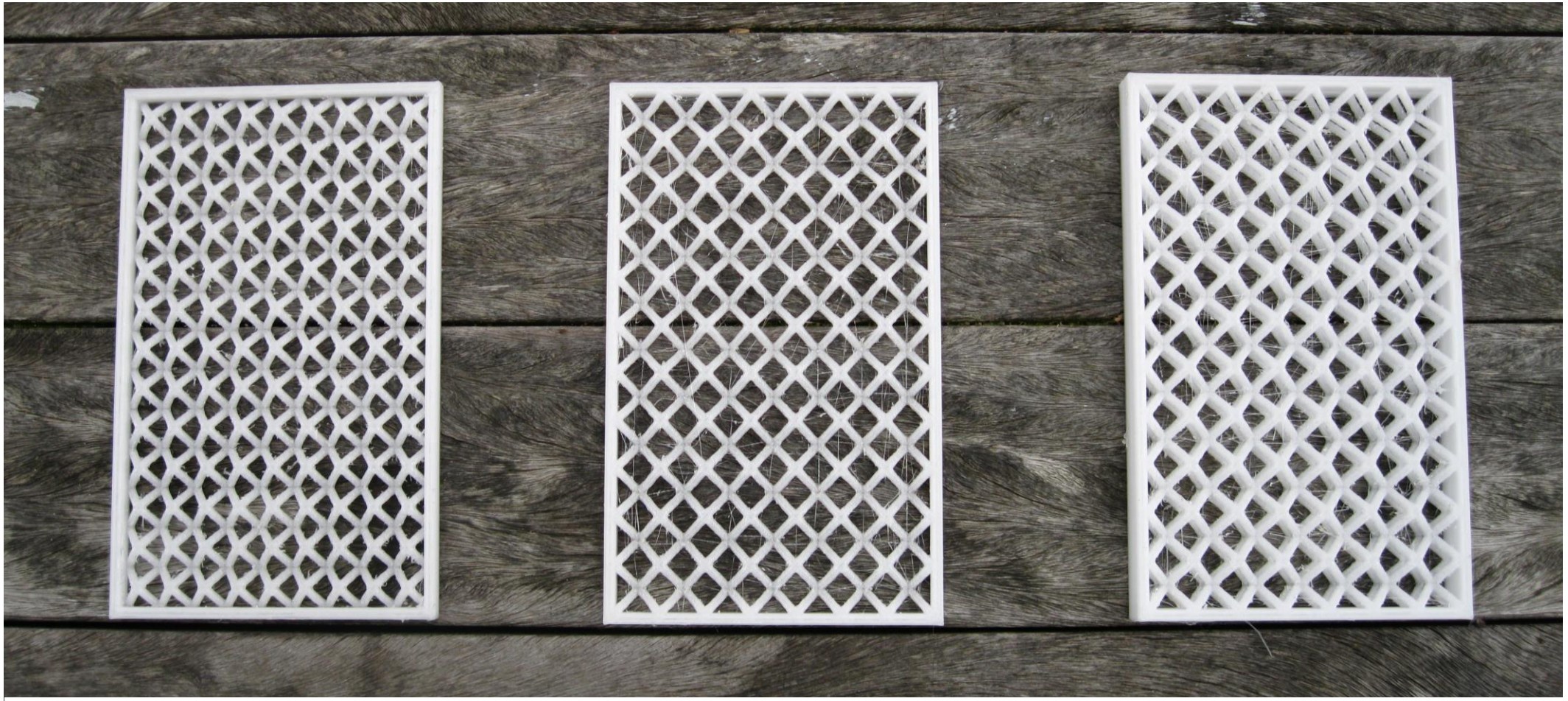
Preliminary design

Composite panel



3D exploded view of the panel. Own image.

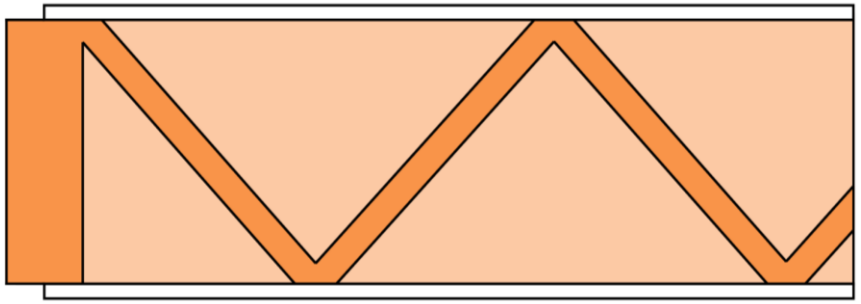
Composite panel



Overview of test specimen. Own image.

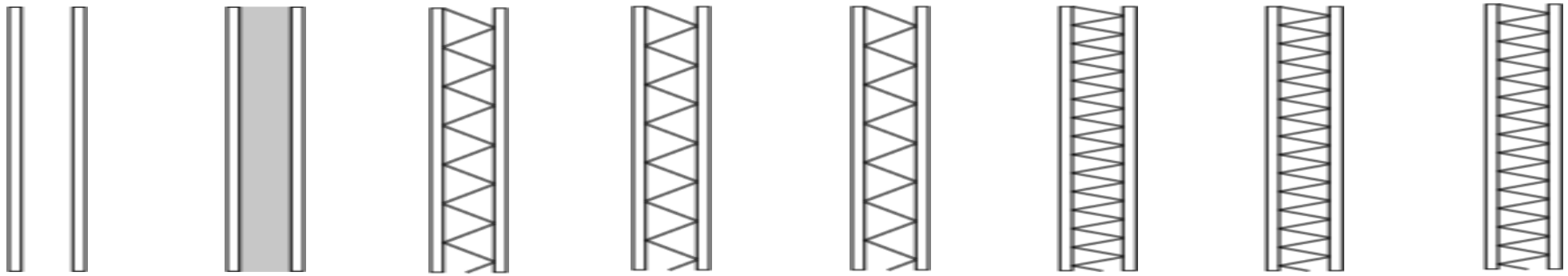
Thermal insulation

- PET
- Glass
- Air
- Sunlight radiation



Schematic section of panel. Own image.

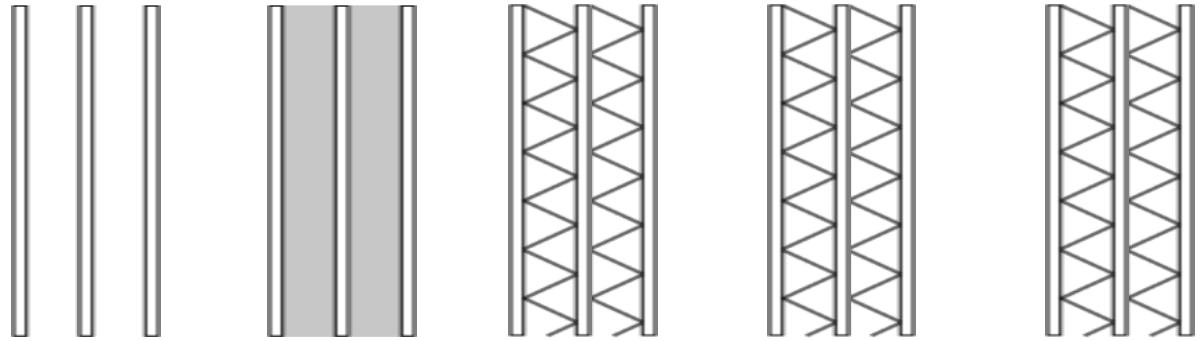
Thermal insulation



Visualisation thermal calculations. Own image.

Panel type	Reference	Reference	Standard	Standard	Standard	Dense	Dense	Dense
Characteristic	Air filled	PET filled	Optimistic	Pessimistic	Thermal bridge	optimistic	pessimistic	Thermal bridge
U [W/m²/K]	2,6	3,4	2,77	2,82	2,66	2,79	2,85	2,67

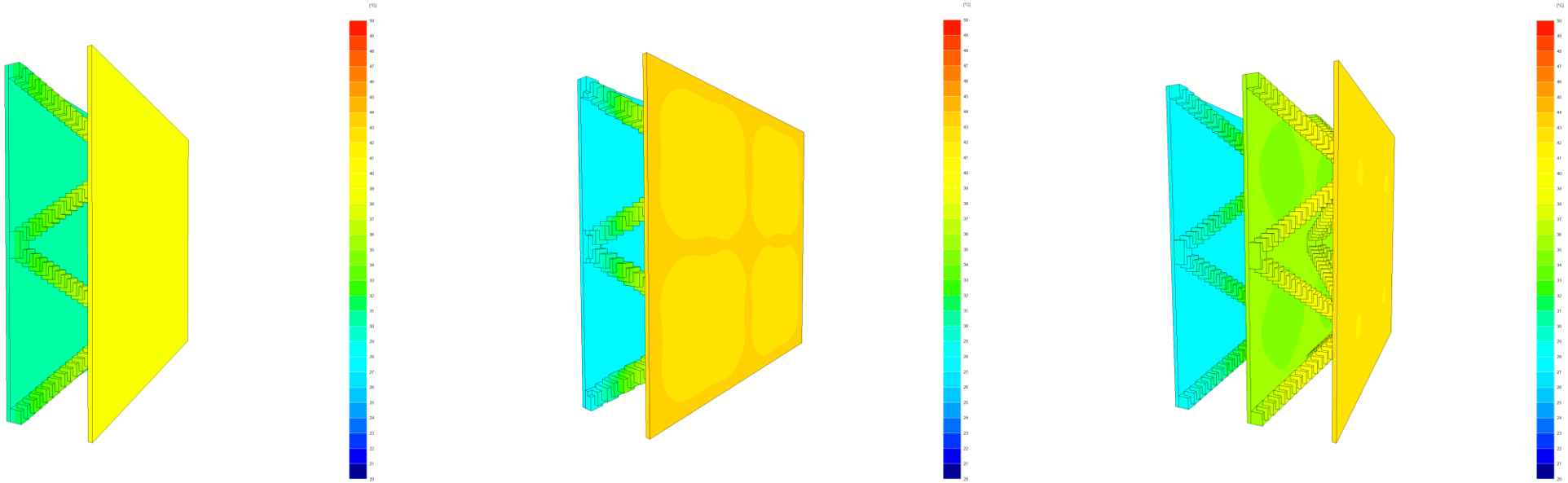
Thermal insulation



Visualisation thermal calculations. Own image.

Panel type	Reference	Reference	Standard	Standard	Standard
Characteristic	Air filled	PET filled	Optimistic	Pessimistic	Thermal bridge
U [W/m²/K]	1,90	3,00	2,19	2,22	2,040

Thermal insulation

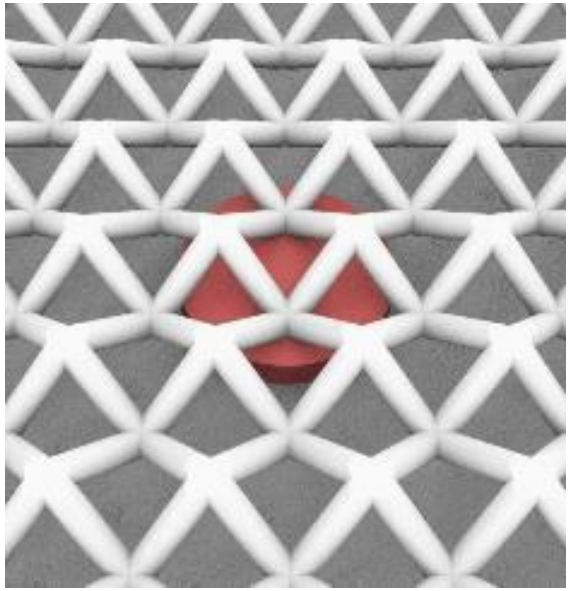


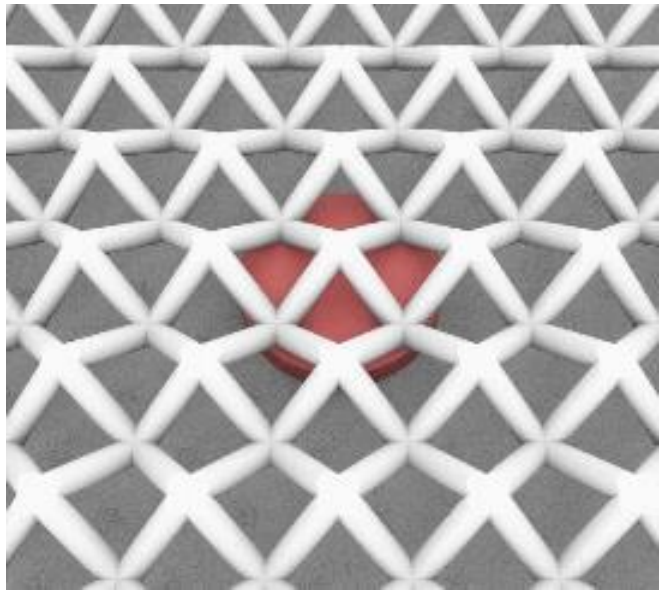
Trisco temperature range, standard truss. Own image.

Panel type	Standard	Standard	Standard
U [W/m²/K]	2,82	3,1	1,90

Thermal insulation

Photo of the complete test set-up. Own image.





Thermal insulation

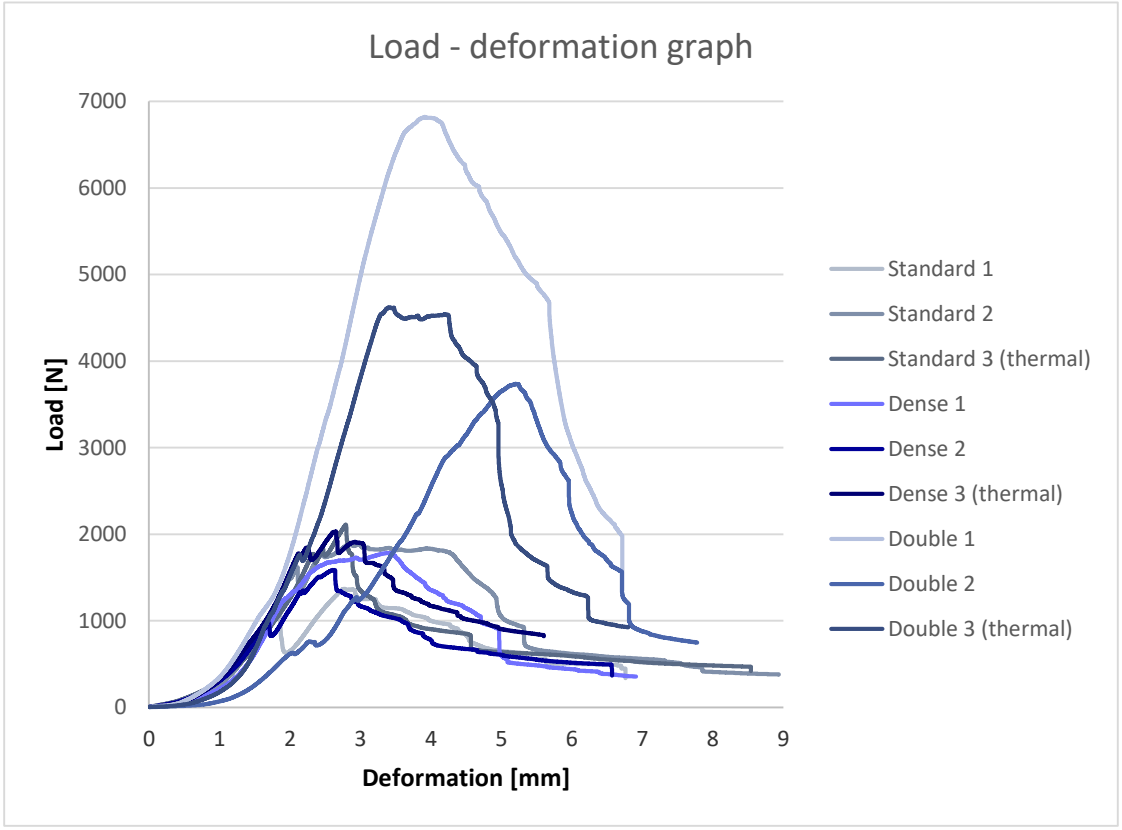
	Standard	Dense	Double
Optimistic	2,77	2,79	2,19
Pessimistic	2,82	2,85	2,22
Thermal bridge	2,66	2,67	2,04
Trisco	2,82	3,10	1,90
Test 1	2,37	2,39	1,90
Test 2	2,36	2,39	1,89

Structural properties

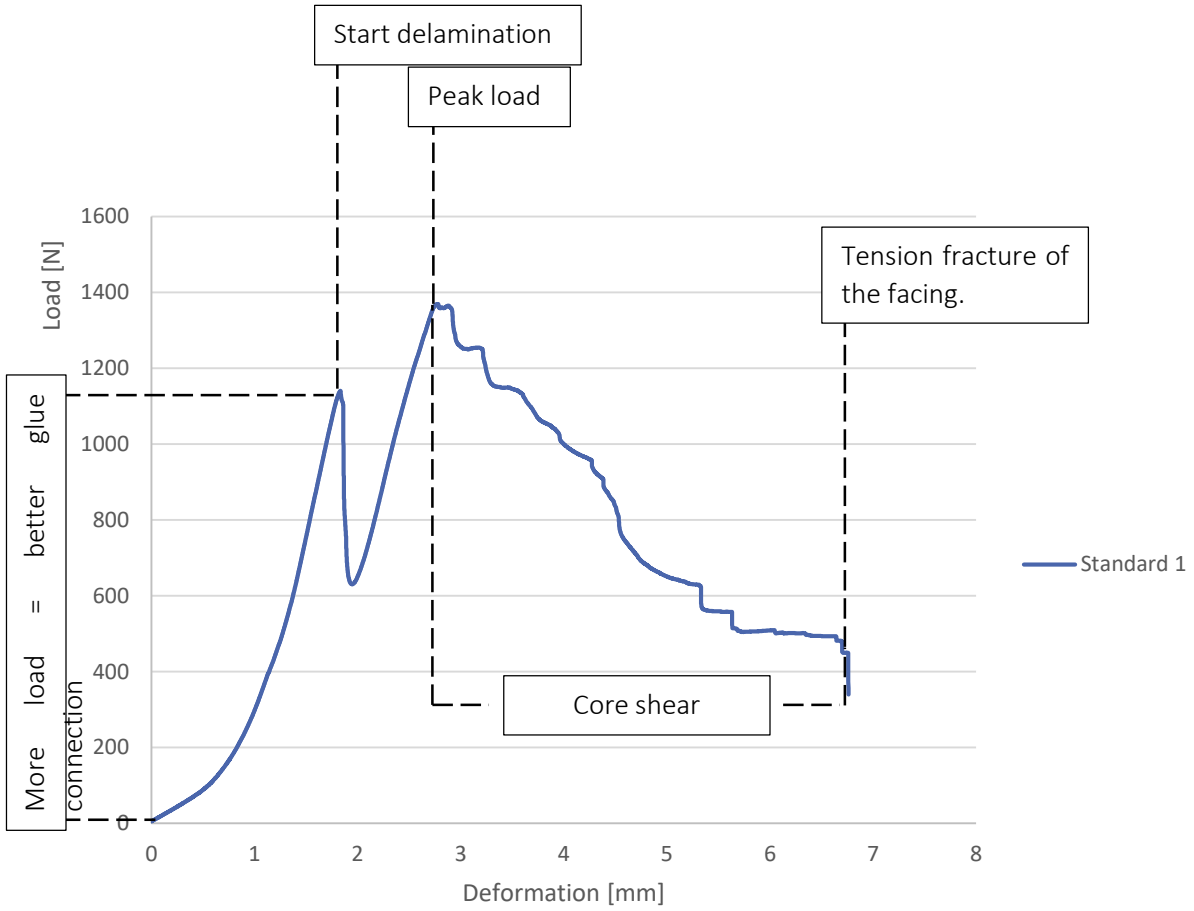
Structural properties

Maximum deformation. Own image.

Structural properties



Composite panel



Design proposal

Answer main question

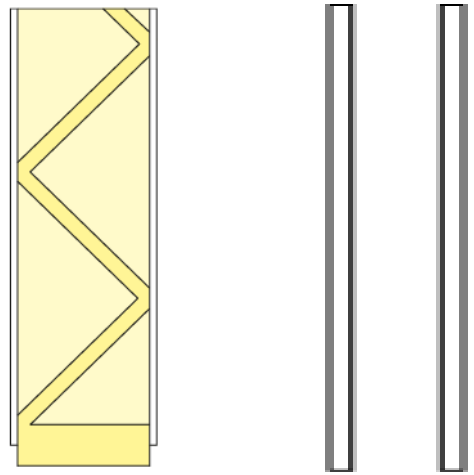
To what extent can a thin glass composite panel, with a polymeric 3D-printed trussed core, be improved to meet the thermal insulation and structural regulations of today, to be used as a façade element in the building industry?

Thermal improvements

- Decrease radiation and conduction
- Add more layers

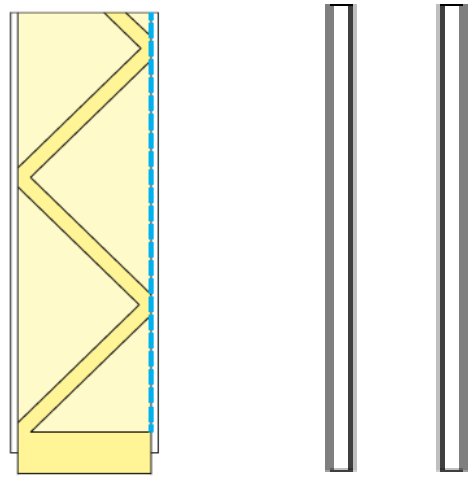
Thermal improvements

Improvement	Thin glass U [W/m²/K]	Normal U [W/m²/K]
Start point	2,66	2,58



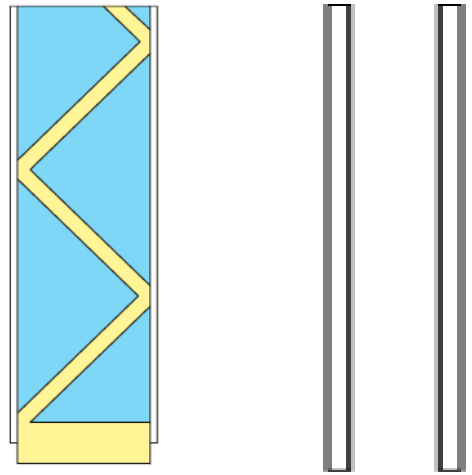
Thermal improvements

Improvement	Thin glass U [W/m²/K]	Normal U [W/m²/K]
Start point	2,66	2,58
Decrease radiation (ε = 0,2)	2,08	1,91



Thermal improvements

Improvement	Thin glass U [W/m²/K]	Normal U [W/m²/K]
Start point	2,66	2,58
Decrease radiation (ε = 0,2)	2,07	1,91
Krypton (λ = 0,009 W/m/K)	1,75	1,54



Thermal improvements

Improvement	Thin glass U [W/m²/K]	Normal U [W/m²/K]
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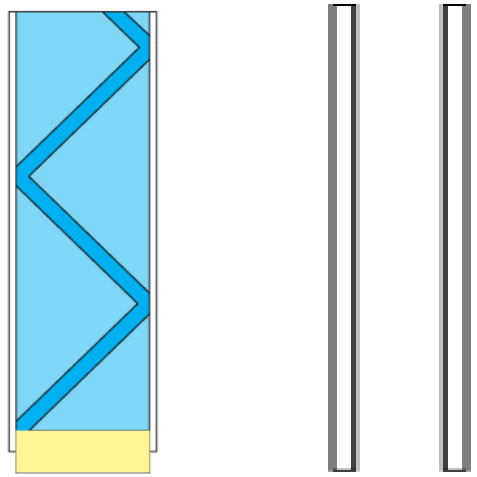

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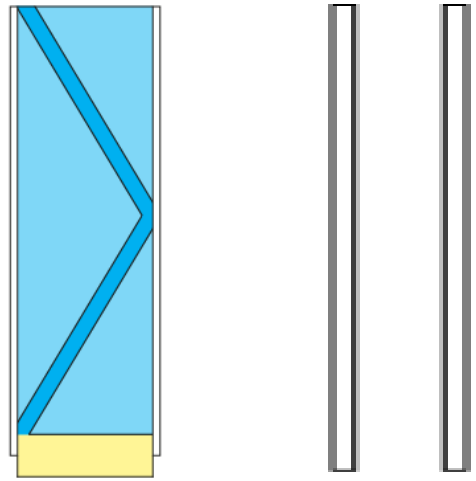
Wider grit (10%)	1,64	



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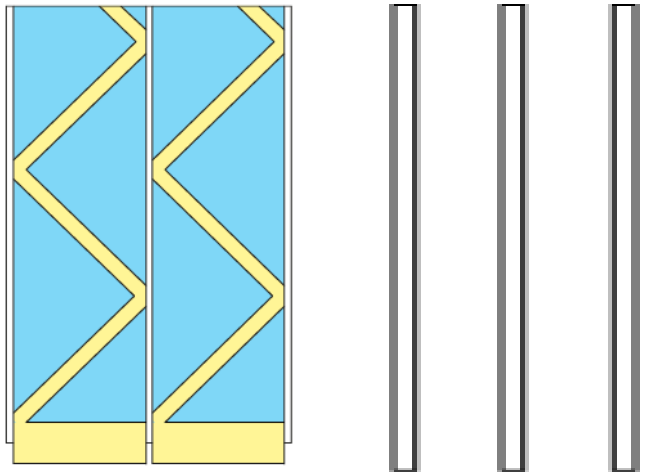
Add one layer	1,04	0,96



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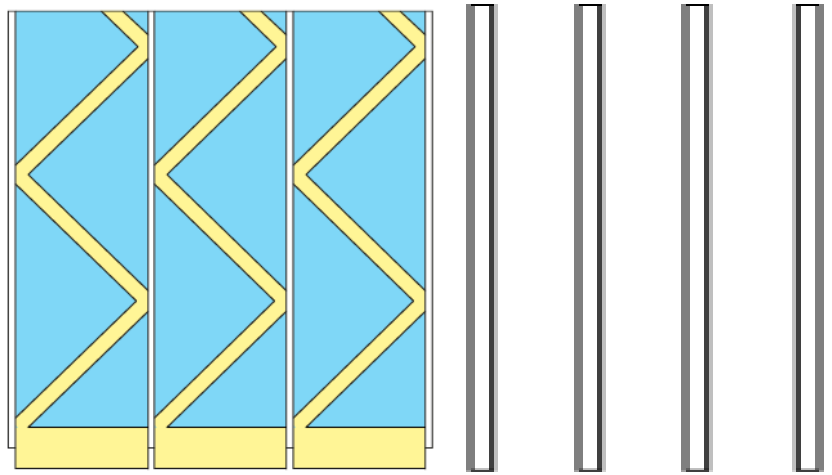
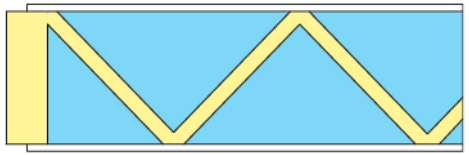
Wider grit (10%)	1,64	
Add one layer	1,04	0,96
Add two layers	0,76	0,70



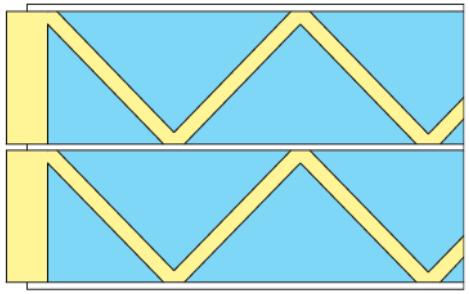
Thermal improvements

- No coating due to glue (only Krypton in cavity)

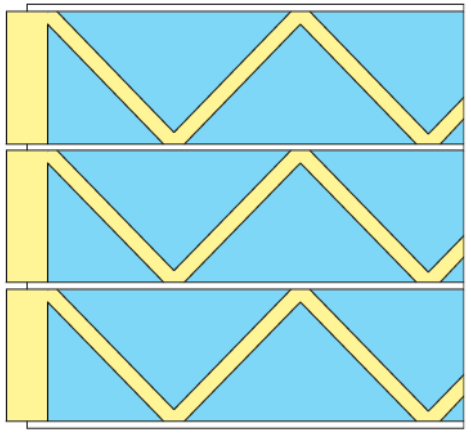
U = 2,53 W/m²/K



U = 1,88 W/m²/K



U = 1,50 W/m²/K

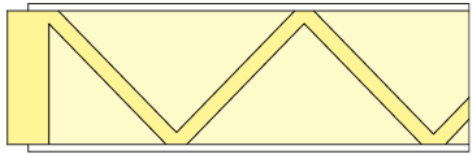


Structural improvements

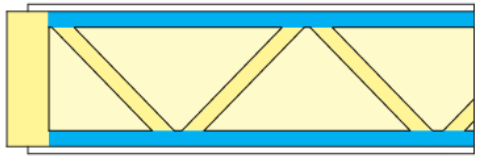
- Decrease delamination
- Decrease deformation
- Increase thickness of cross section

Structural improvements

1. Start point

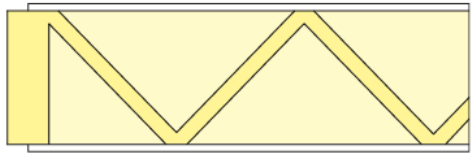


2. Extra beams

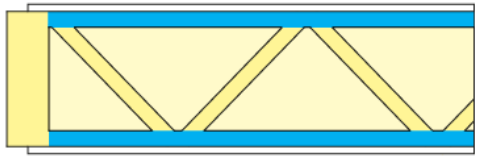


Structural improvements

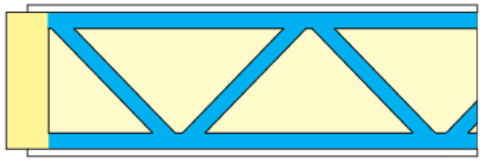
1. Start point



2. Extra beams



3. Change core material



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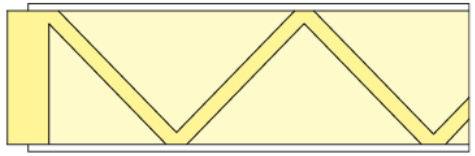

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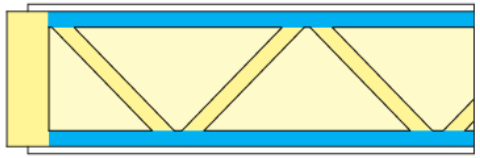

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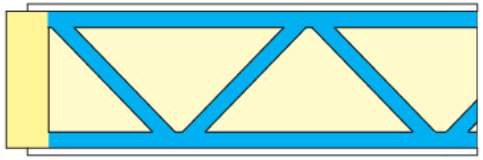
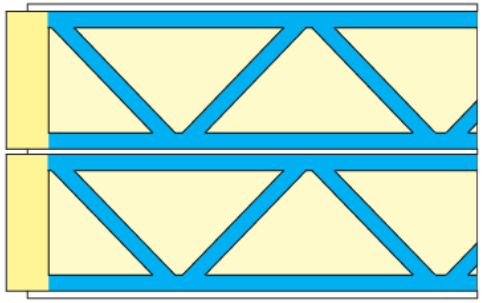


4. Add 1 layer max strength is tripled



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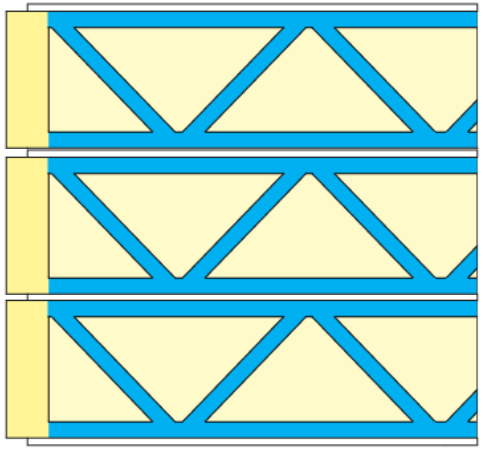

Answer main question

To what extent can a thin glass composite panel, with a polymeric 3D-printed trussed core, be improved to meet the thermal insulation and structural regulations of today, to be used as a façade element in the building industry?

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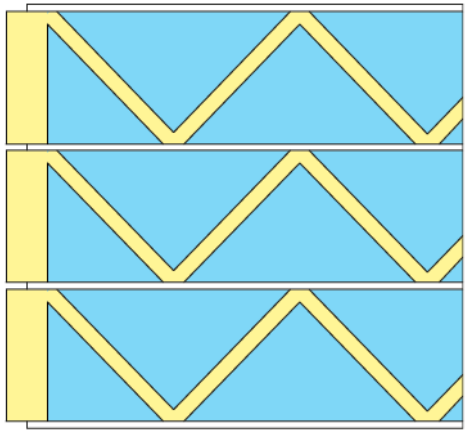


Thermal insulation:

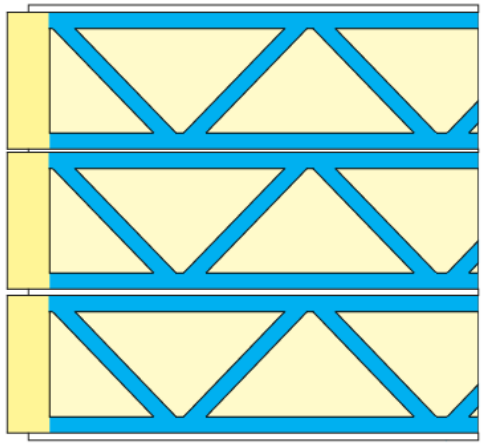
no core

Small panels

Big sheet:

extra beams

Lower thermal insulation



Design proposal

Design proposal

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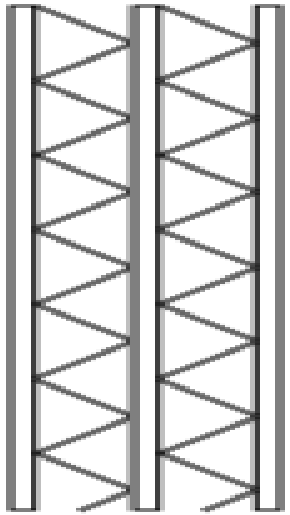
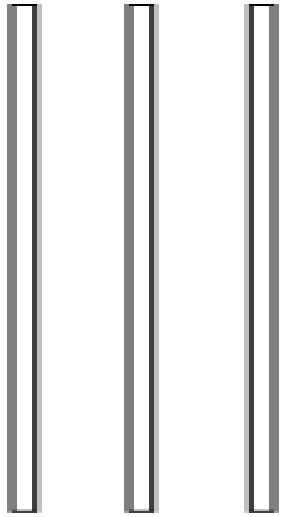


3x 0,5 mm glass + core =

18 kN/m²

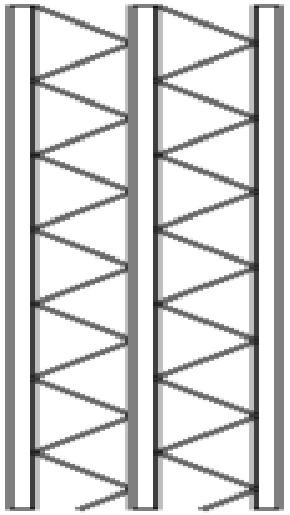


3x 4 mm glass =

29 kN/m²

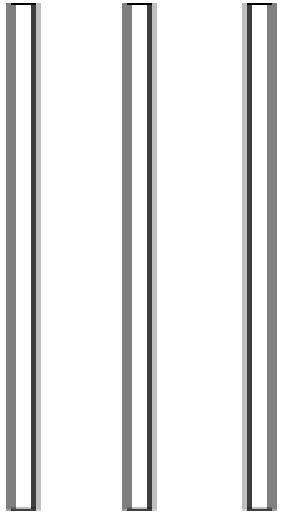
Design proposal

Dimensions: 3,2 x 1,245 m



3x 0,5 mm glass + core =

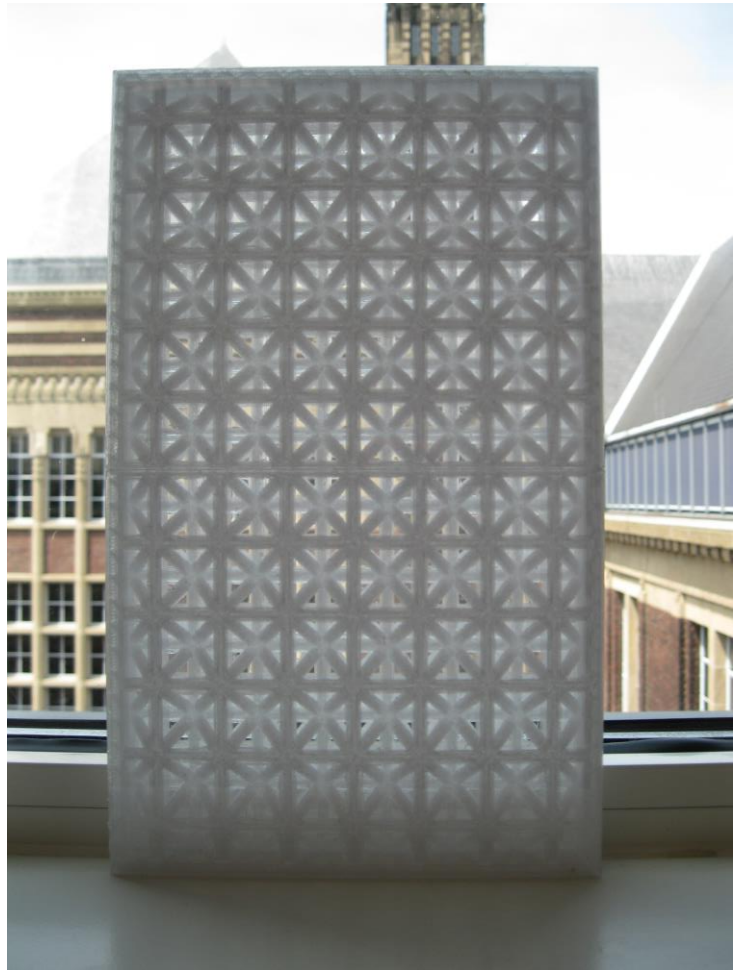
2171 MJ



3x 4 mm glass =

1845 MJ

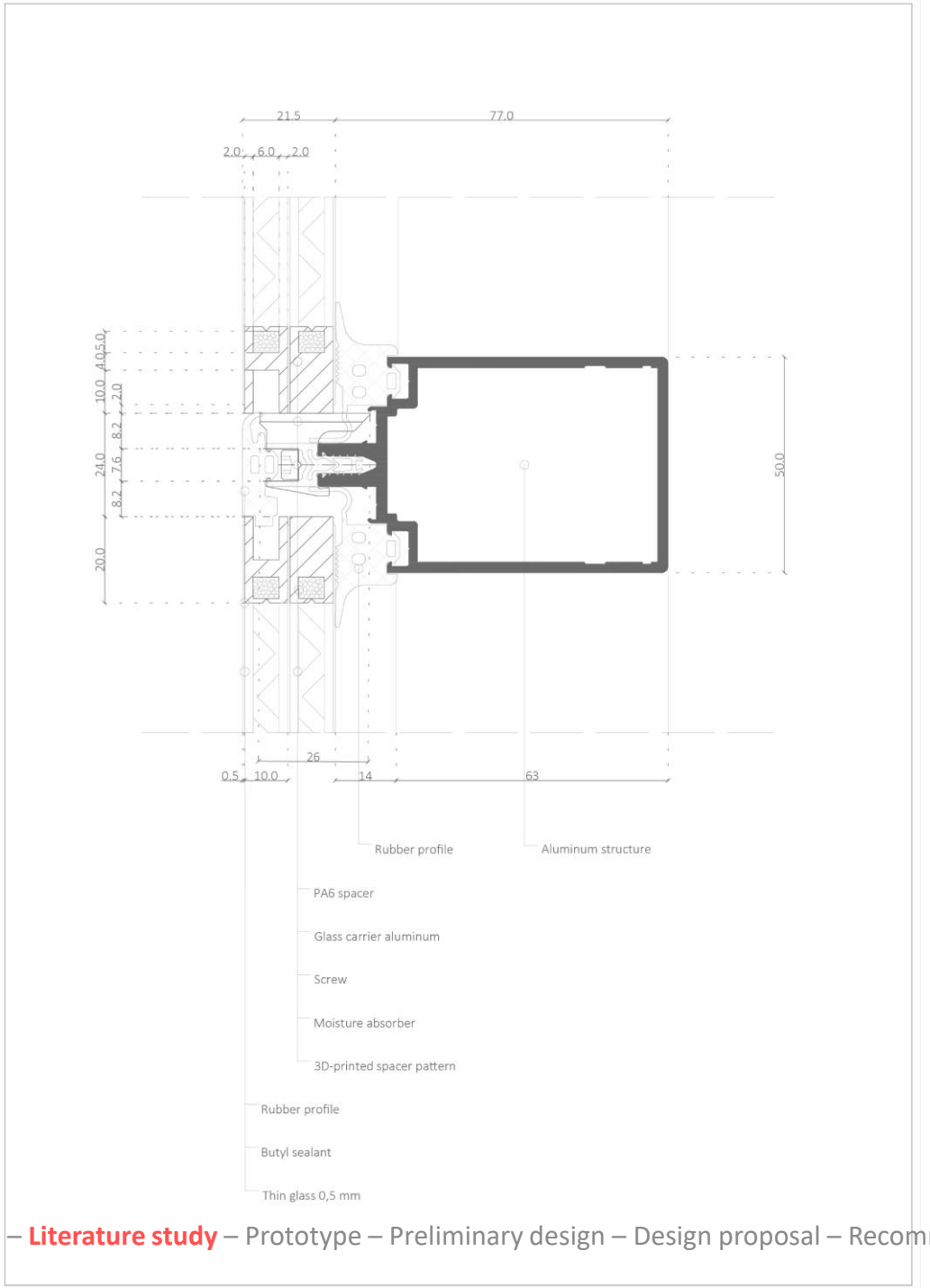
Design proposal



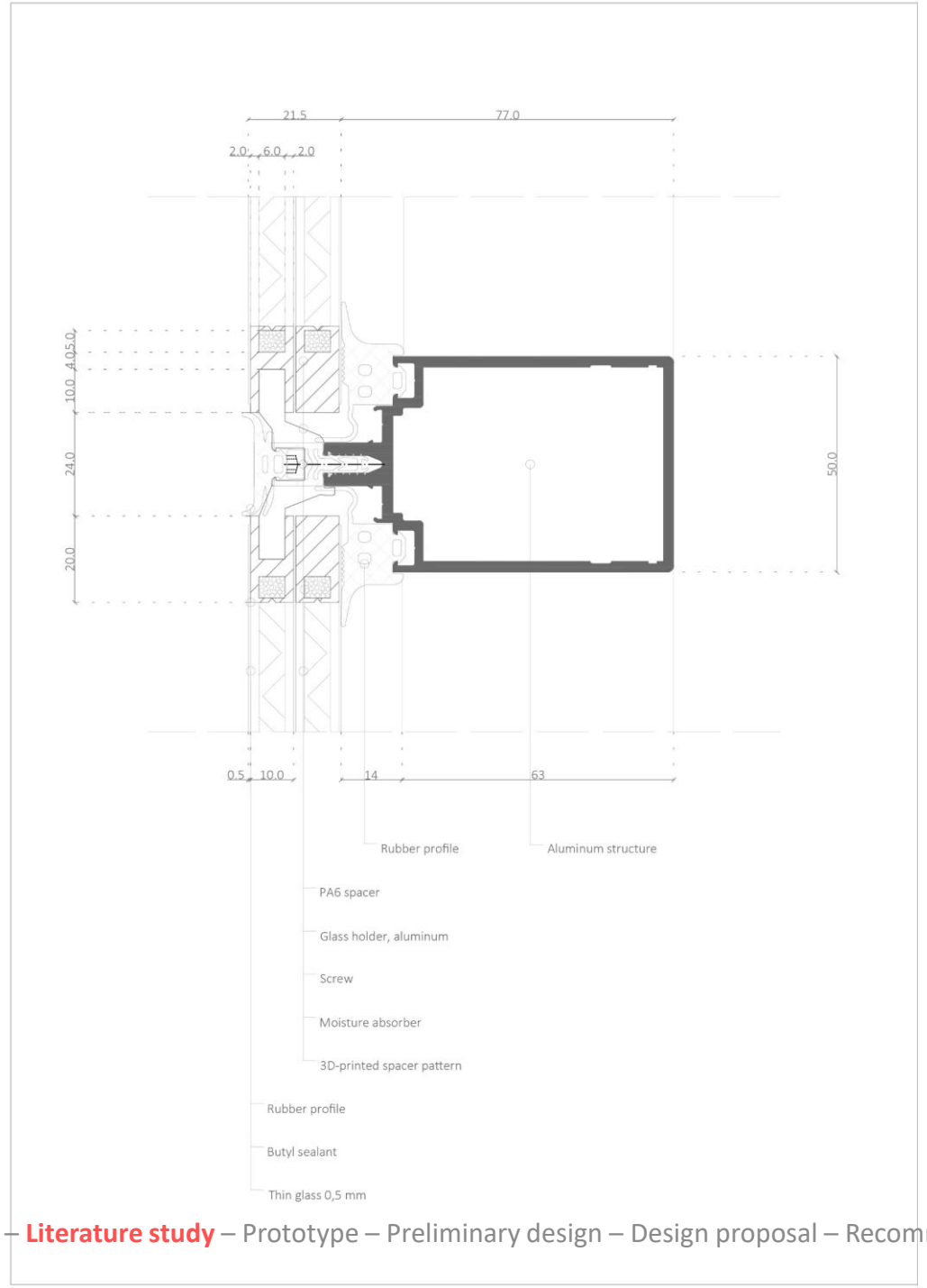
Dimensions 250 x 150 mm. Own image.

Full scale panel, 3,2 x 1,245 m. Own image.

Details

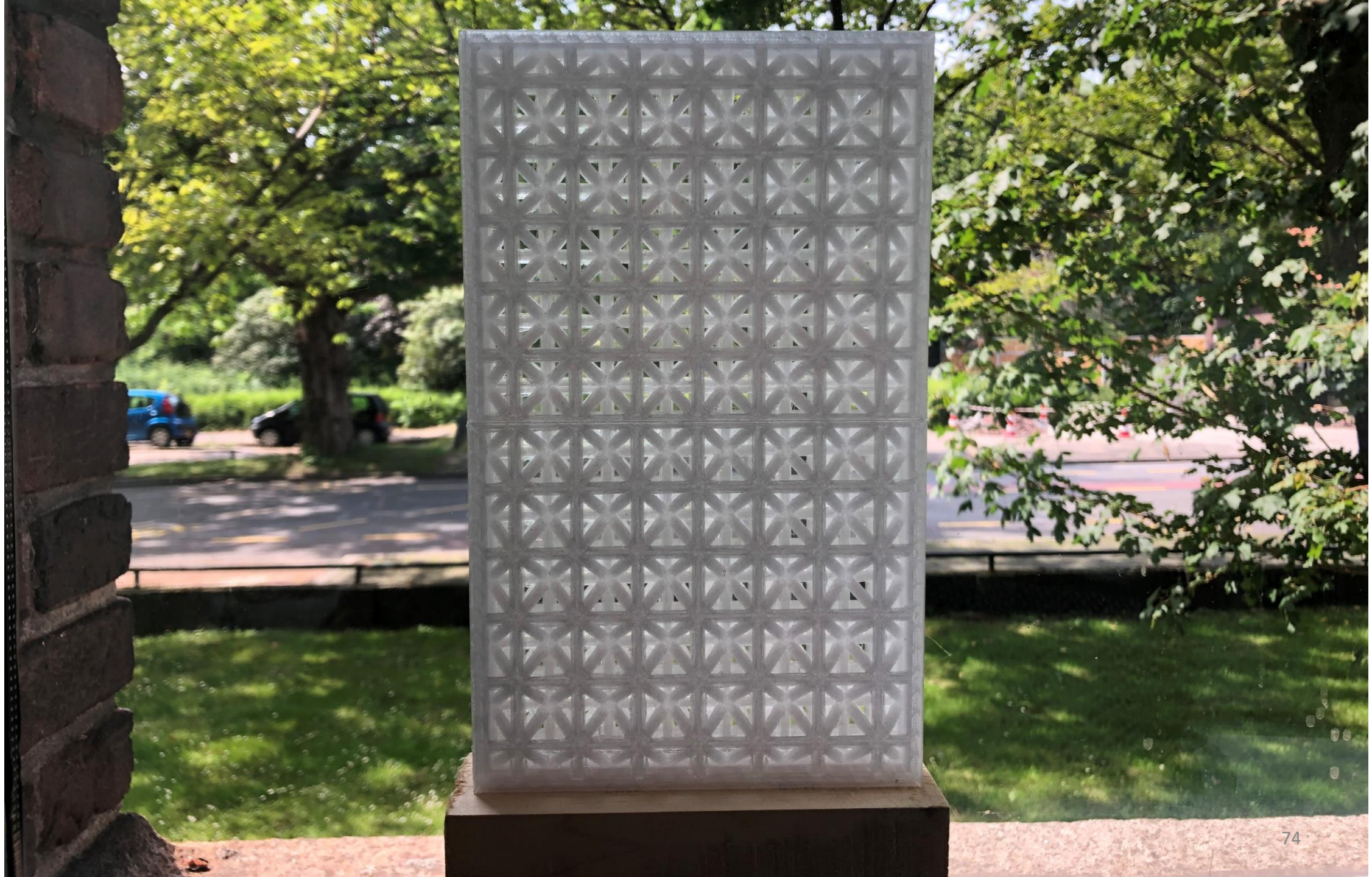

21.5
77.0
2.0
6.0
2.0
0.5
4.0
10.0
2.0
8.2
24.0
7.6
8.2
20.0
50.0
26
0.5
10.0
14
63
Rubber profile
Aluminum structure
PA6 spacer
Glass carrier aluminum
Screw
Moisture absorber
3D-printed spacer pattern
Rubber profile
Butyl sealant
Thin glass 0,5 mm

Details


21.5
77.0
2.0
6.0
2.0
10.0
4.0
5.0
24.0
20.0
50.0
0.5
10.0
14
63
Rubber profile
Aluminum structure
PA6 spacer
Glass holder, aluminum
Screw
Moisture absorber
3D-printed spacer pattern
Rubber profile
Butyl sealant
Thin glass 0,5 mm

Recommendations

- Different pattern for:
  - Improvement 3D-printing
- Tests with other core materials (woodfill or corkfill) and coatings for better thermal insulation
- Design and test spacer at edge of panel for gas
- Other bonding methods (lamination -> different core material)
- Leave out the glue/ change geometry of panel




Thank you!
Questions?

(Thin) glass

- Float glass