A CIRCULAR BIOBASED COMPOSITE FACADE

Reseach on a high performance and circular application of biobased composite on a facade

First mentor: Ir. A. Bergsma
Second mentor: Ir. R. Gkaidatzis
External mentor: Ir. C. de Wolf

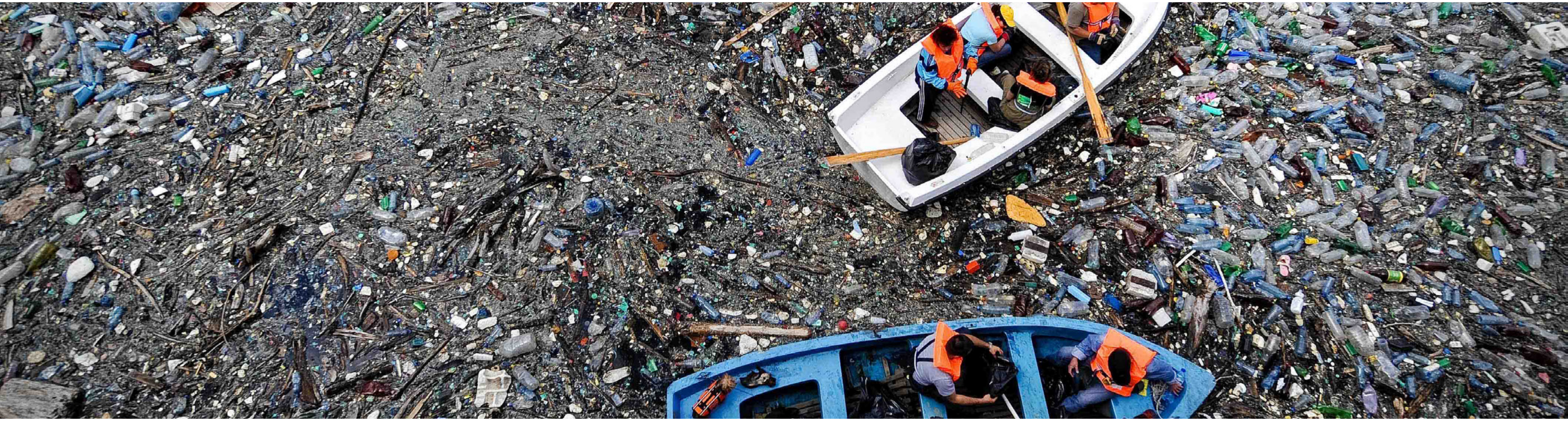
DGMR Bouw
TU DELFT Building Technology

Marijn Flore Verlinde 4076982

INTRODUCTION

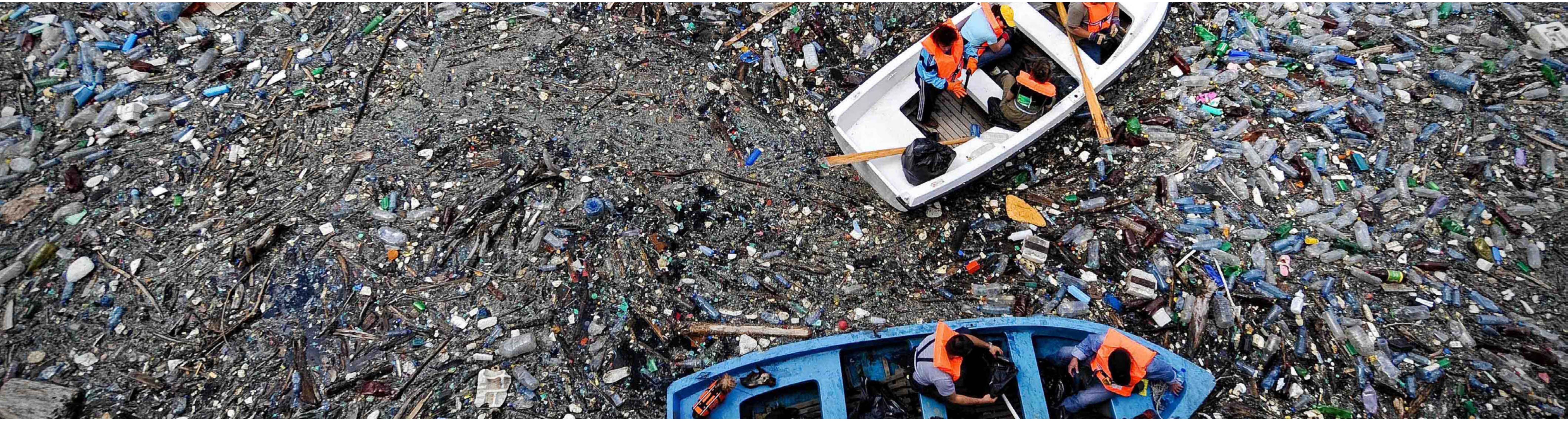
INTRODUCTION | Problem statement

"The building industry produces annually twice as much waste as all the Dutch households together"



INTRODUCTION | Problem statement

"Most construction waste goes into landfills, increasing the burden of landfill loading and operation"



Material scarcity

Copper	Lead	Zinc	Aluminum
38 years	8 years	34 years	510 years



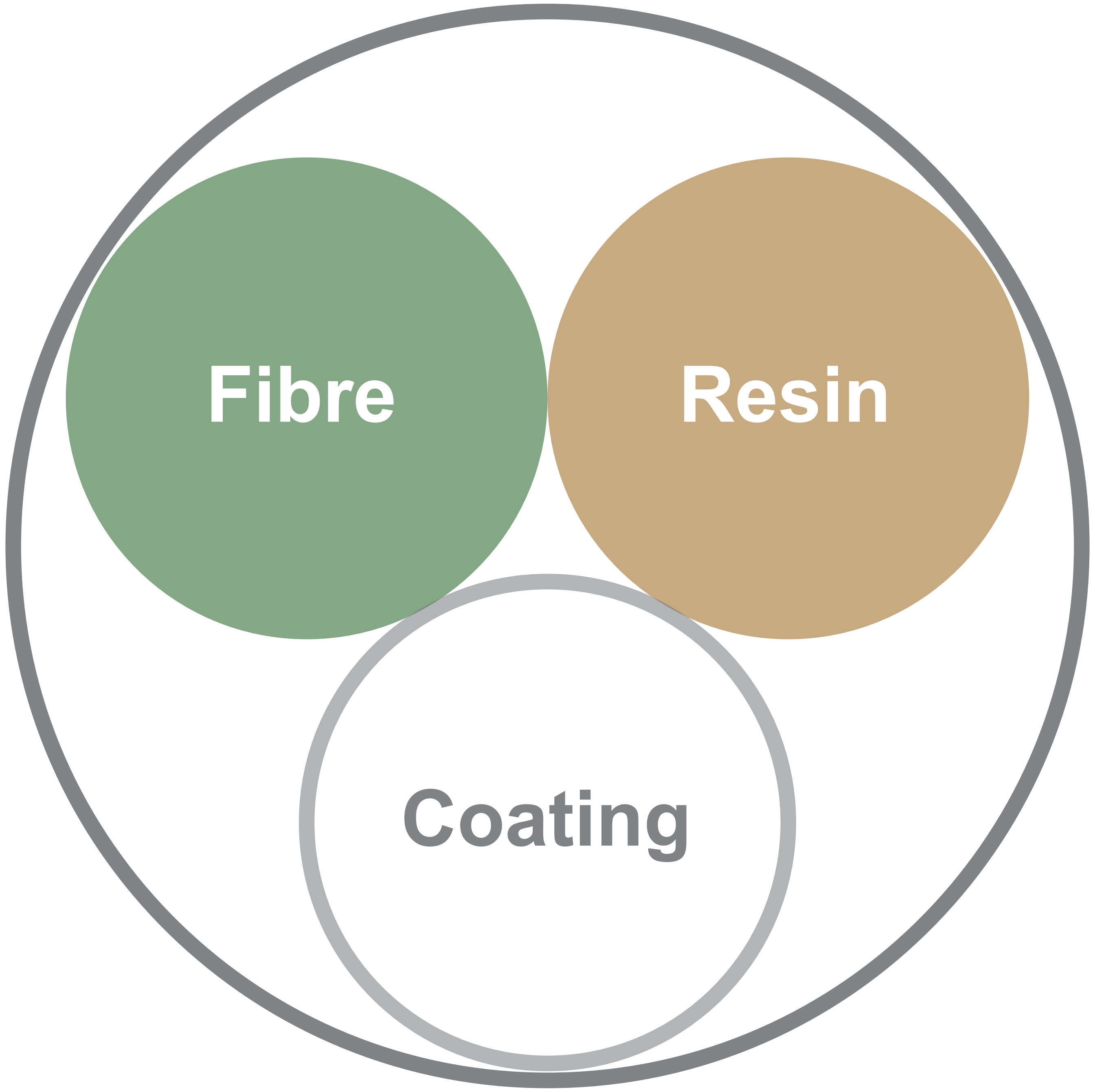

Explore whether a more environmental friendly composite material could be offered to designers while retaining the same design options current materials offer

"What is possible with biobased composite when used for a circular facade design?"

dGmR

BIOBASED COMPOSITE

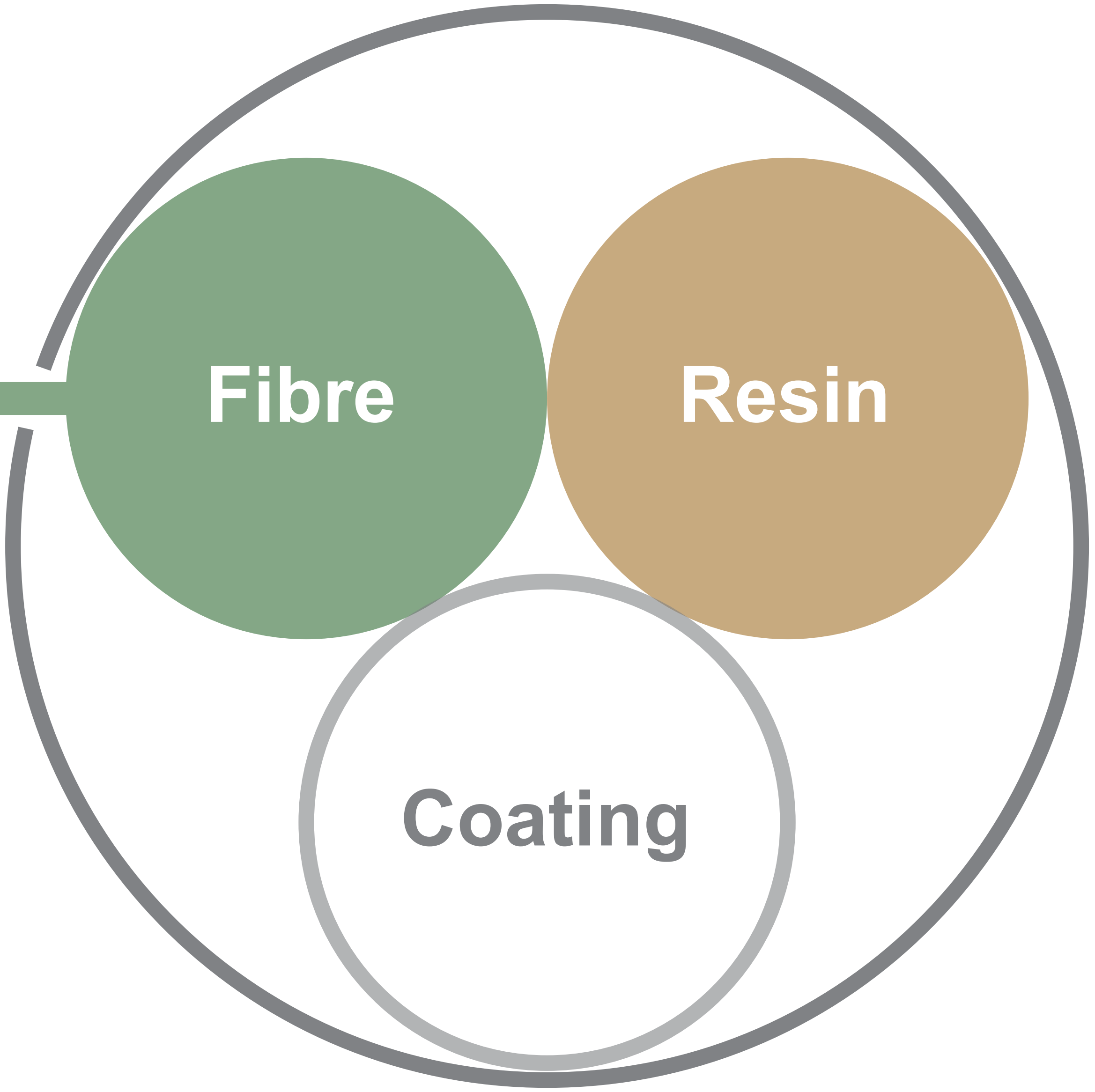
INTRODUCTION | Biobased Composite



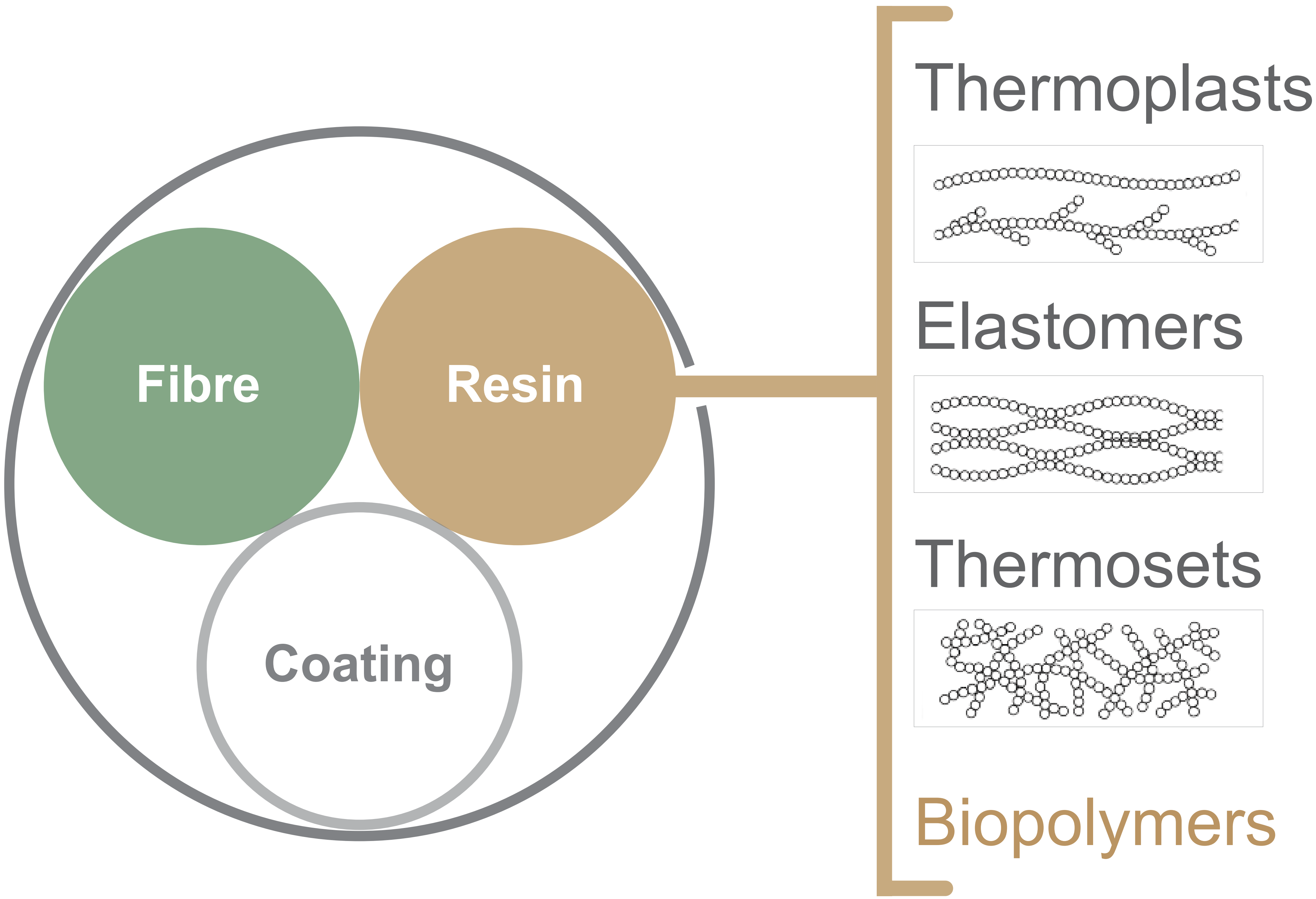
INTRODUCTION | Biobased Composite

Natural fibres
Flax
Hemp
Jute
Abaca

Fabrics
Random
Directional
Uni-directional
Bi-/ Tri-/ Multi-axial



INTRODUCTION | Biobased Composite



dGm[R]

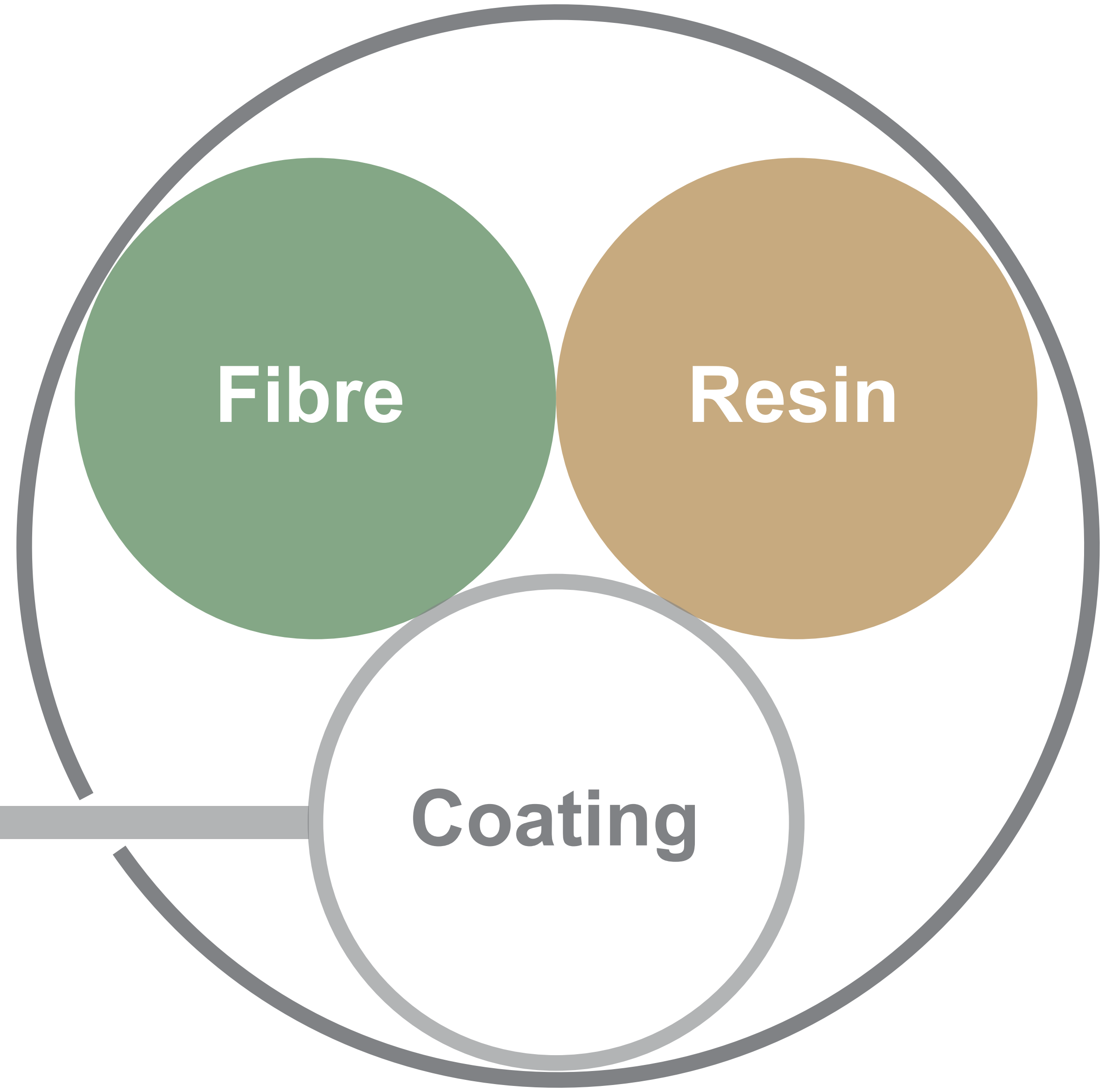
INTRODUCTION | Biobased Composite

Pigment, solvent, binder

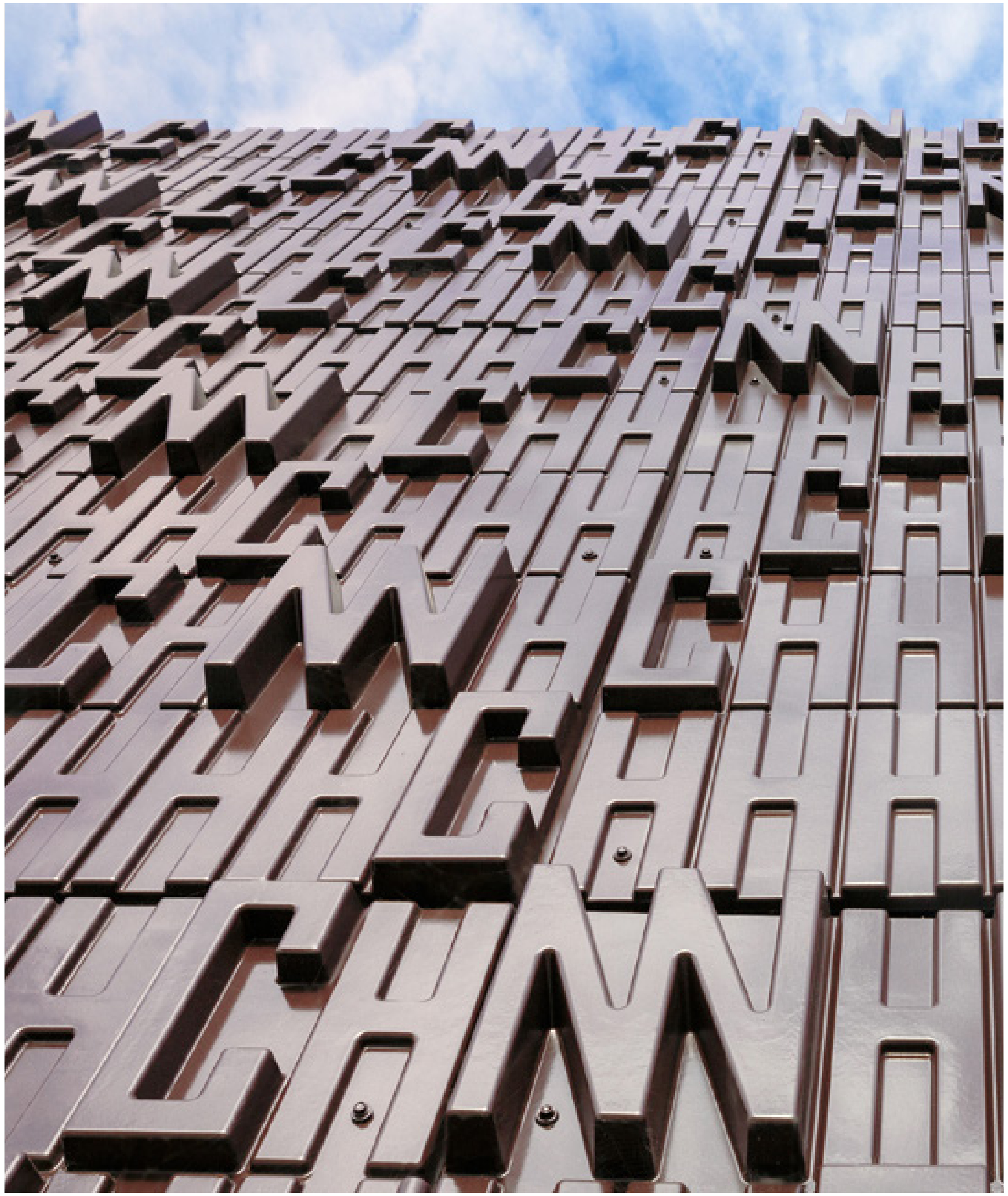
Organic

Protective
UV-radiation
Water
Fire

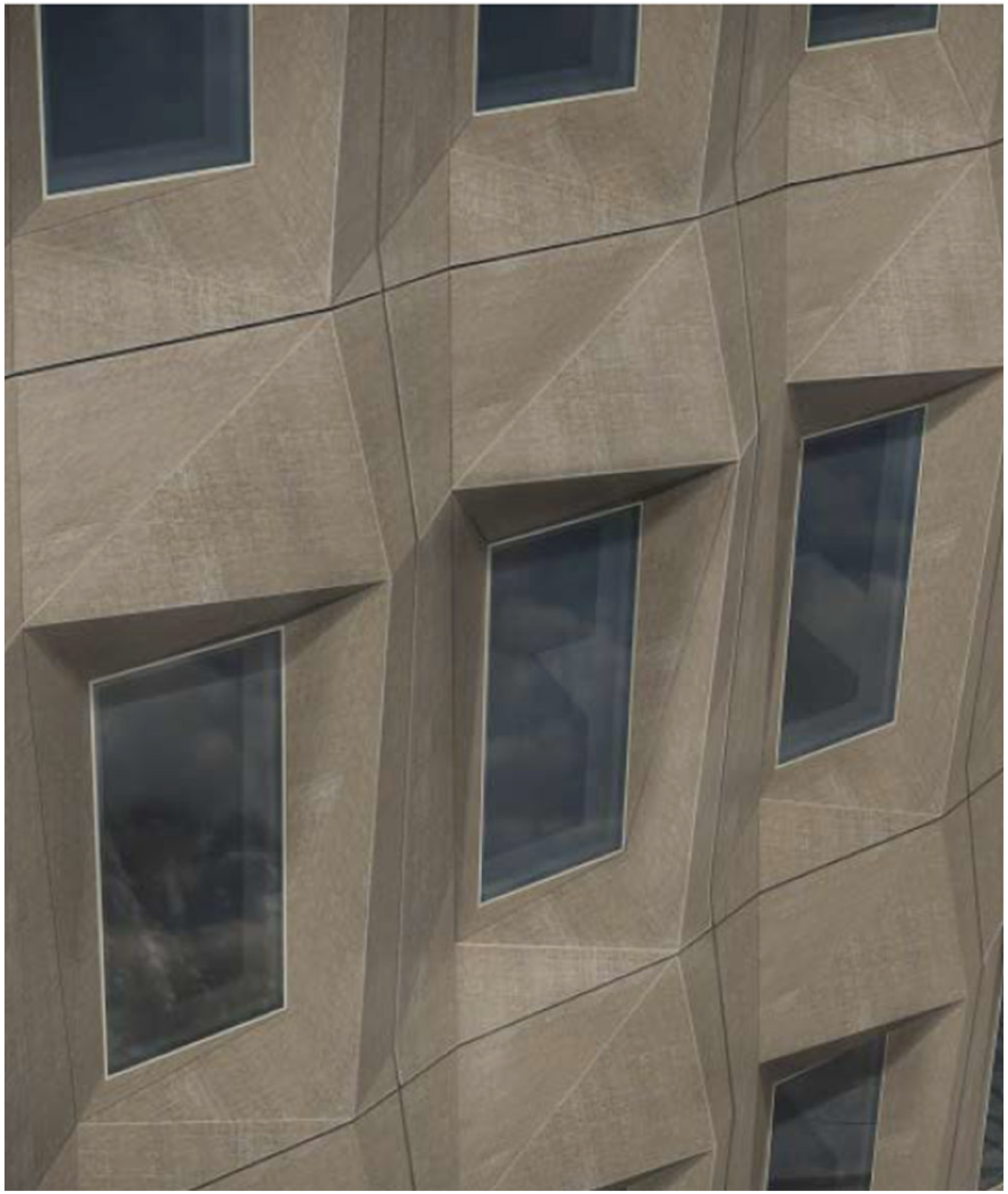
Decorative
Paint
Laquer



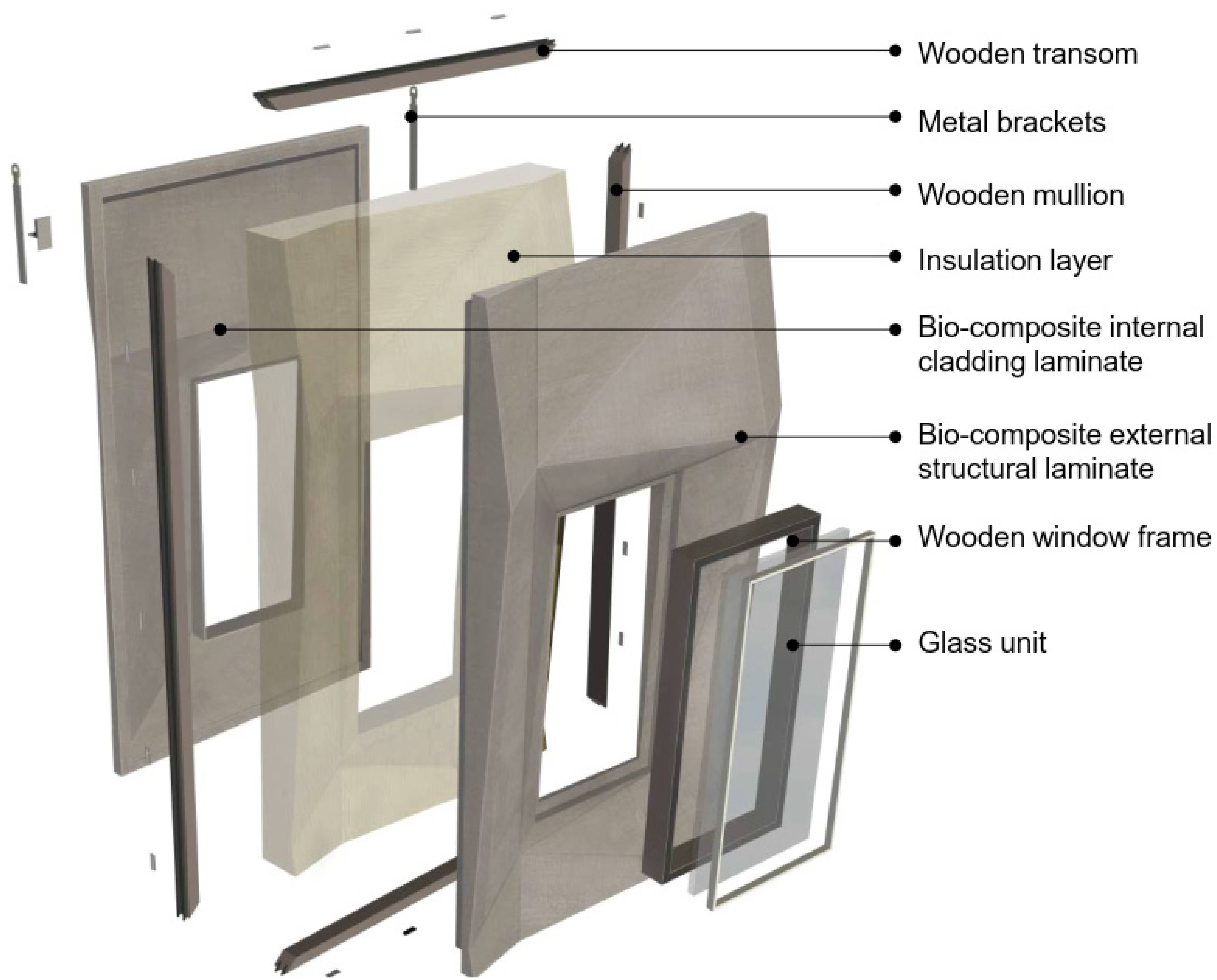
FORMER PROJECTS | WORLDS FIRST BIOBASED COMPOSITE FACADE

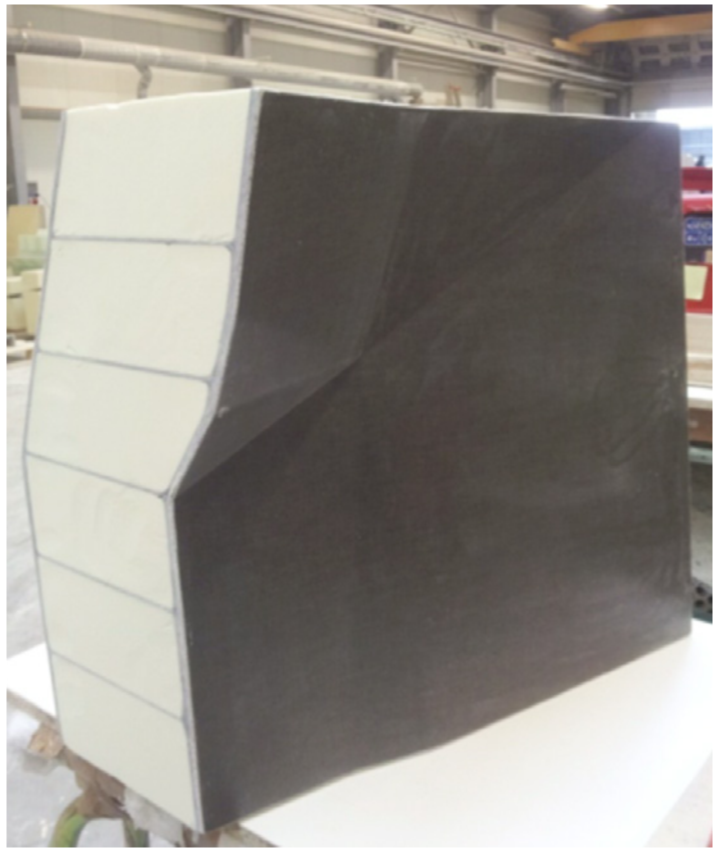


FORMER PROJECTS | EXTERNAL WALL PANEL - THE BIOBUILD PROJECT



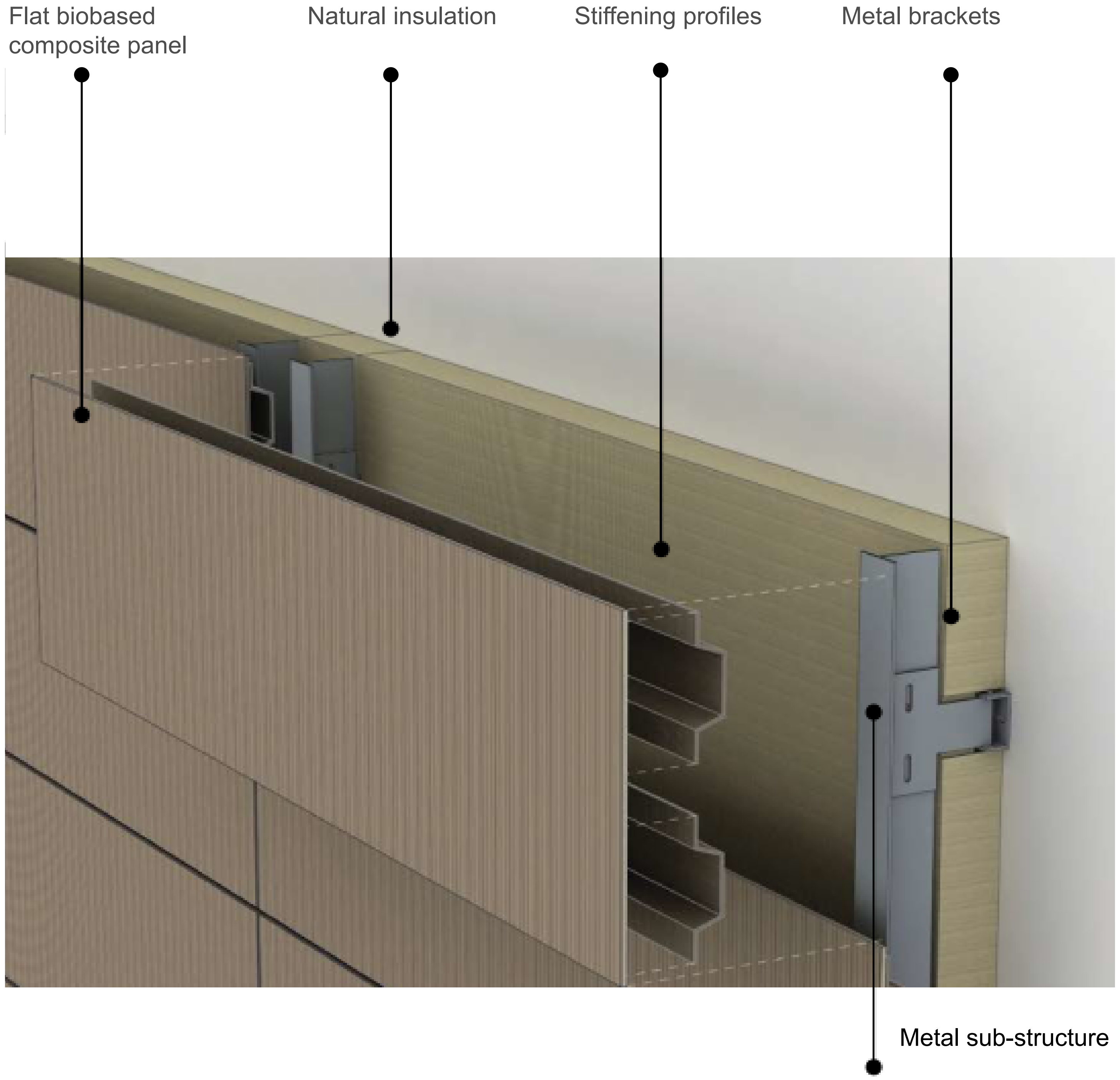
FORMER PROJECTS | EXTERNAL WALL PANEL - THE BIOBUILD PROJECT

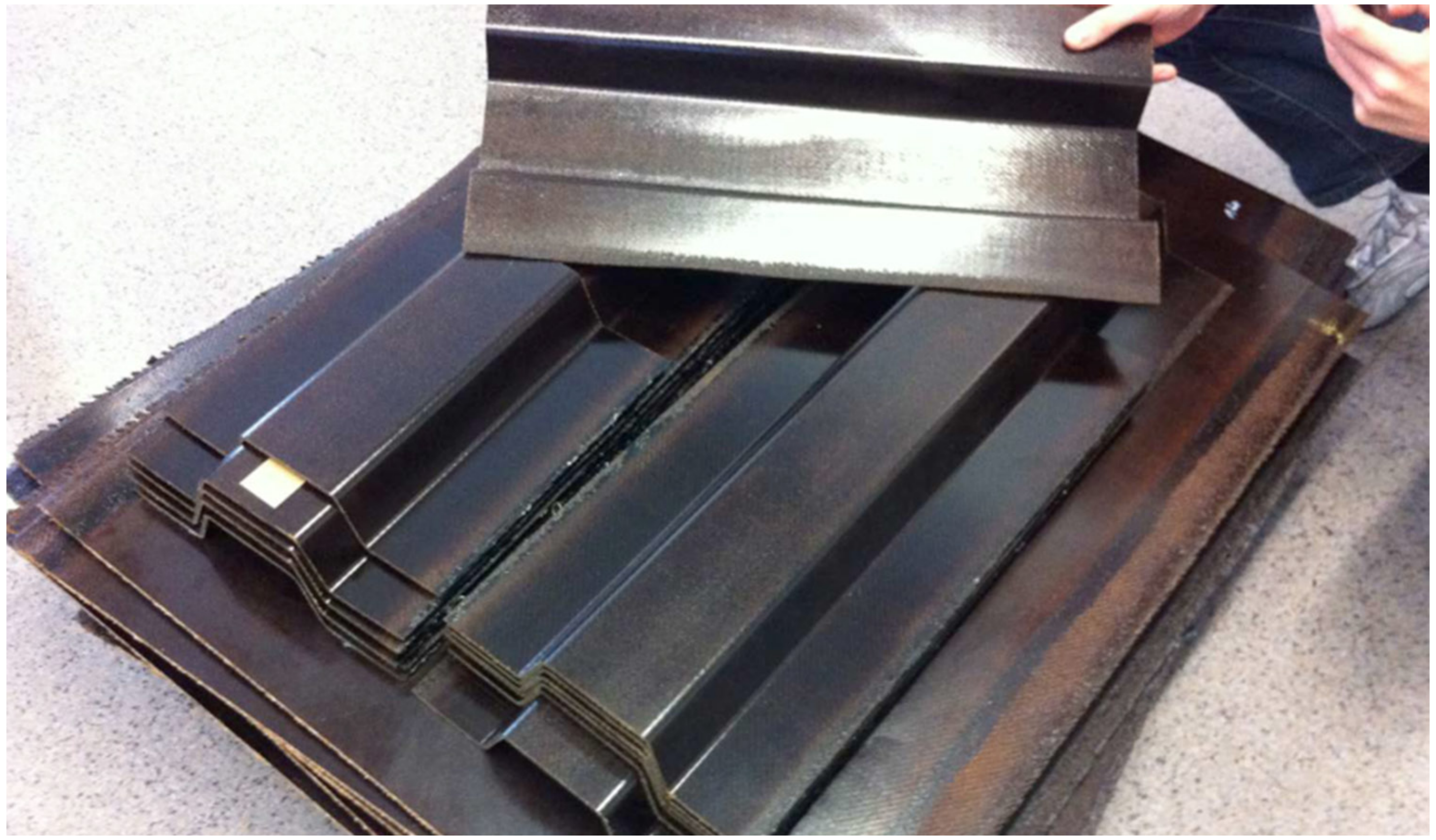


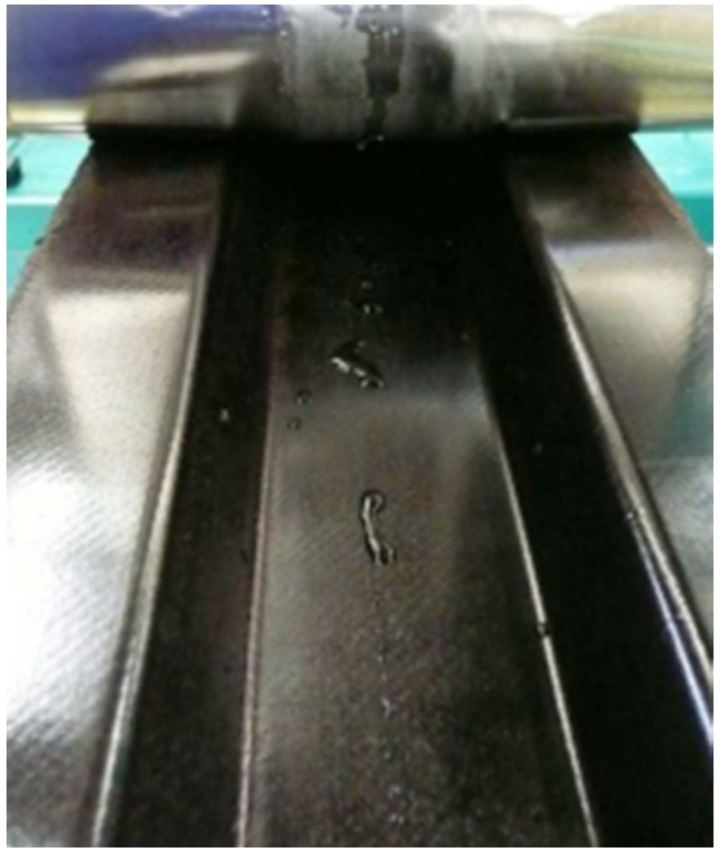


dGm[R]

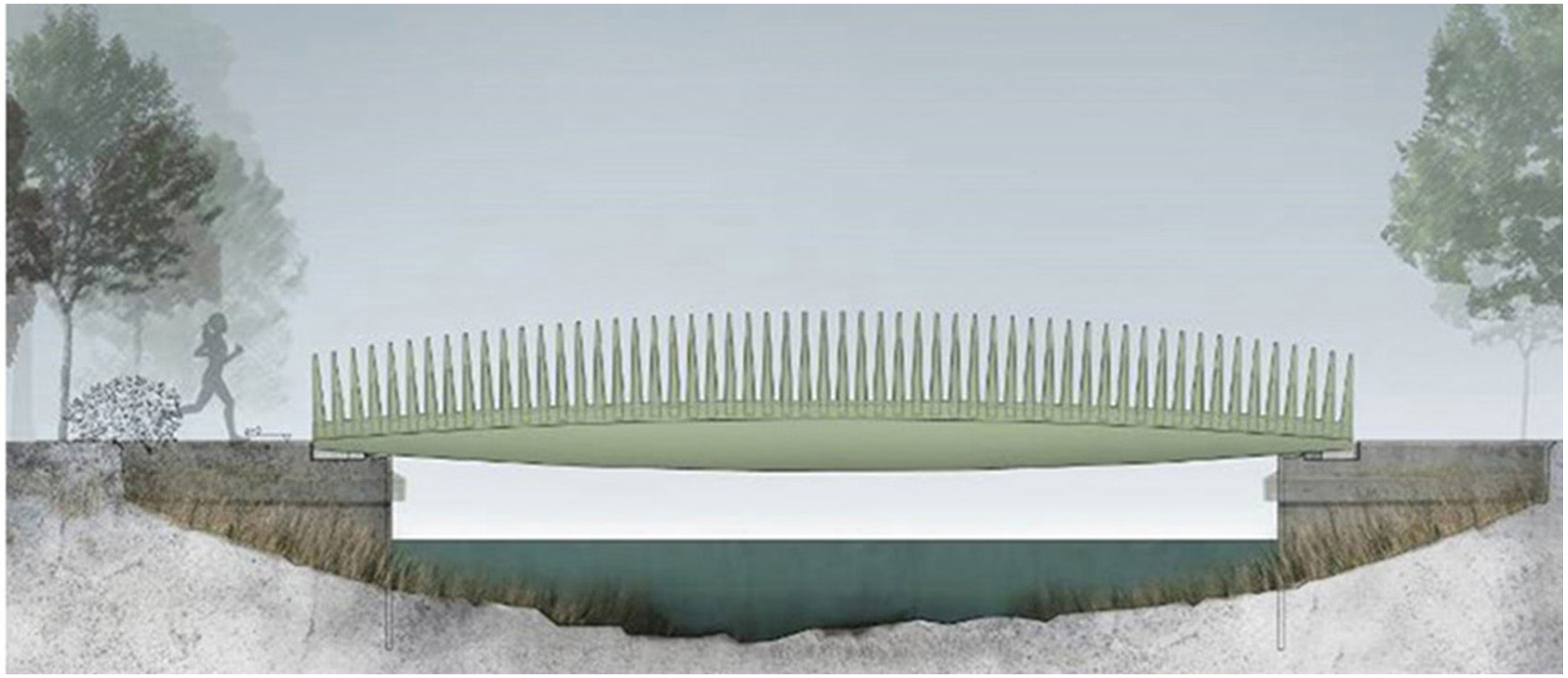
FORMER PROJECTS | EXTERNAL CLADDING KIT - THE BIOBUILD PROJECT







FORMER PROJECTS | BIOBASED COMPOSITE PEDESTRIAN BRIDGE



a circular biobased composite facade

CIRCULARITY

"At this moment, in the Netherlands 50% of the national raw material consumption is caused by the construction industry and 40% of this amount refers to demolition waste"

CIRCULARITY | Introduction

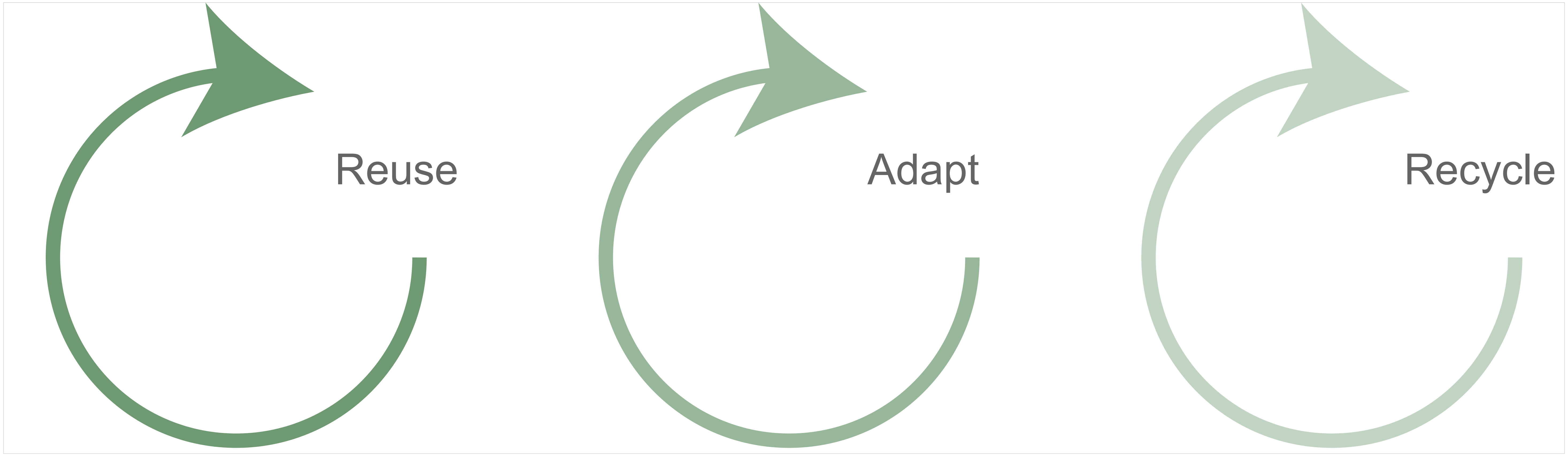
1. Reduce resources
2. Reuse resources
3. Circular solutions

CIRCULARITY | Approach

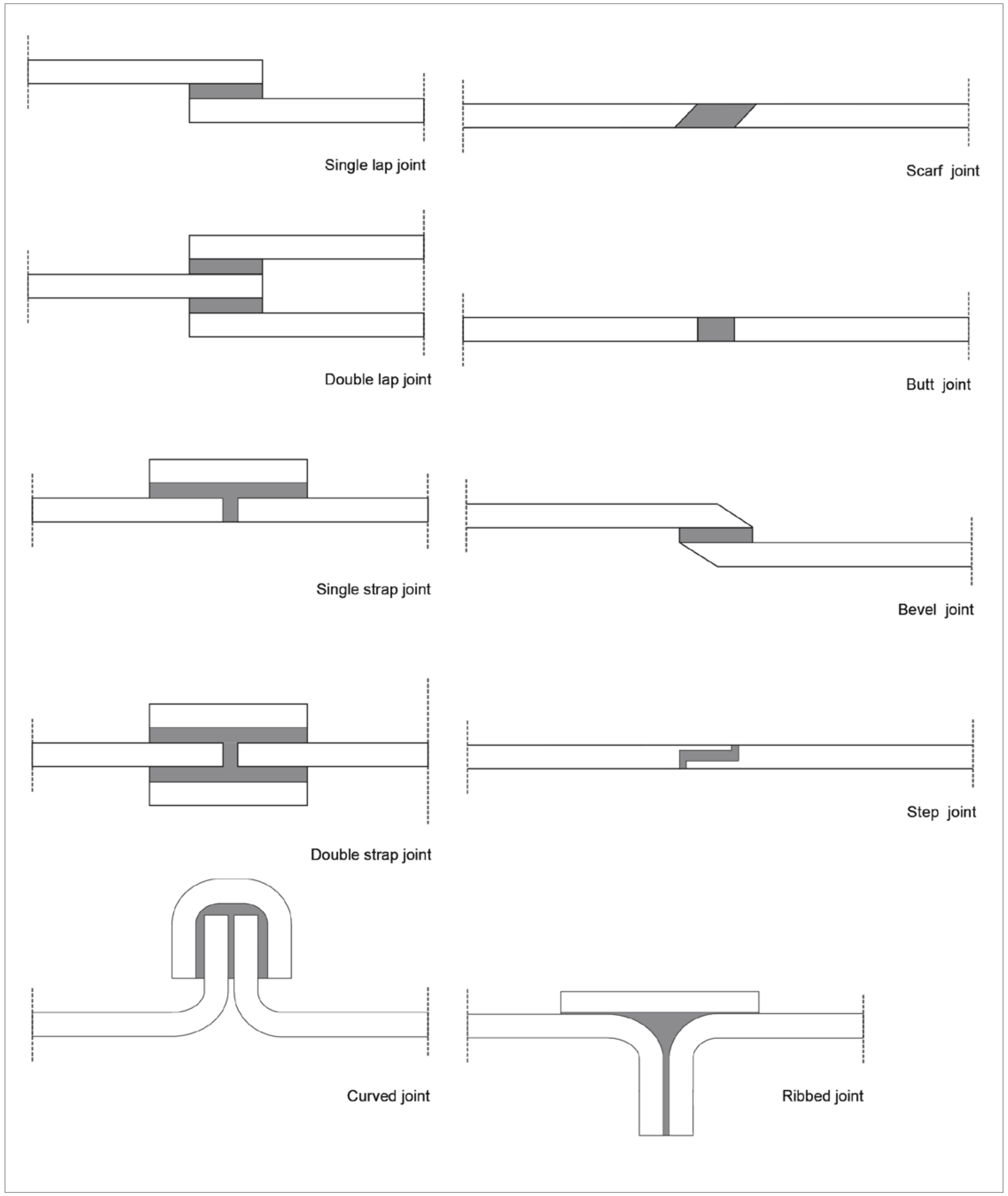
"Keep materials performing as long as possible"

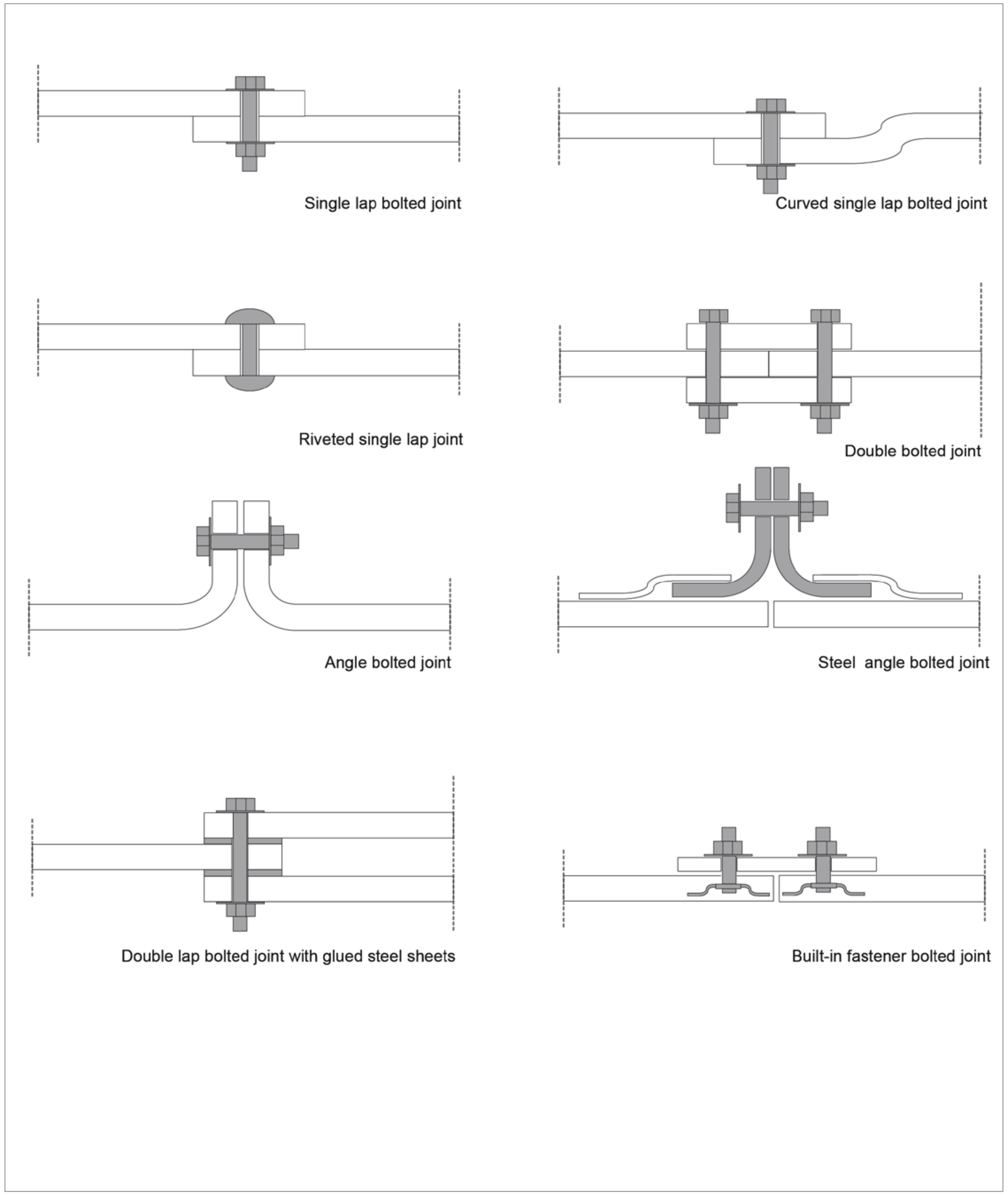
"Avoid waste"

"Regard waste as resource"

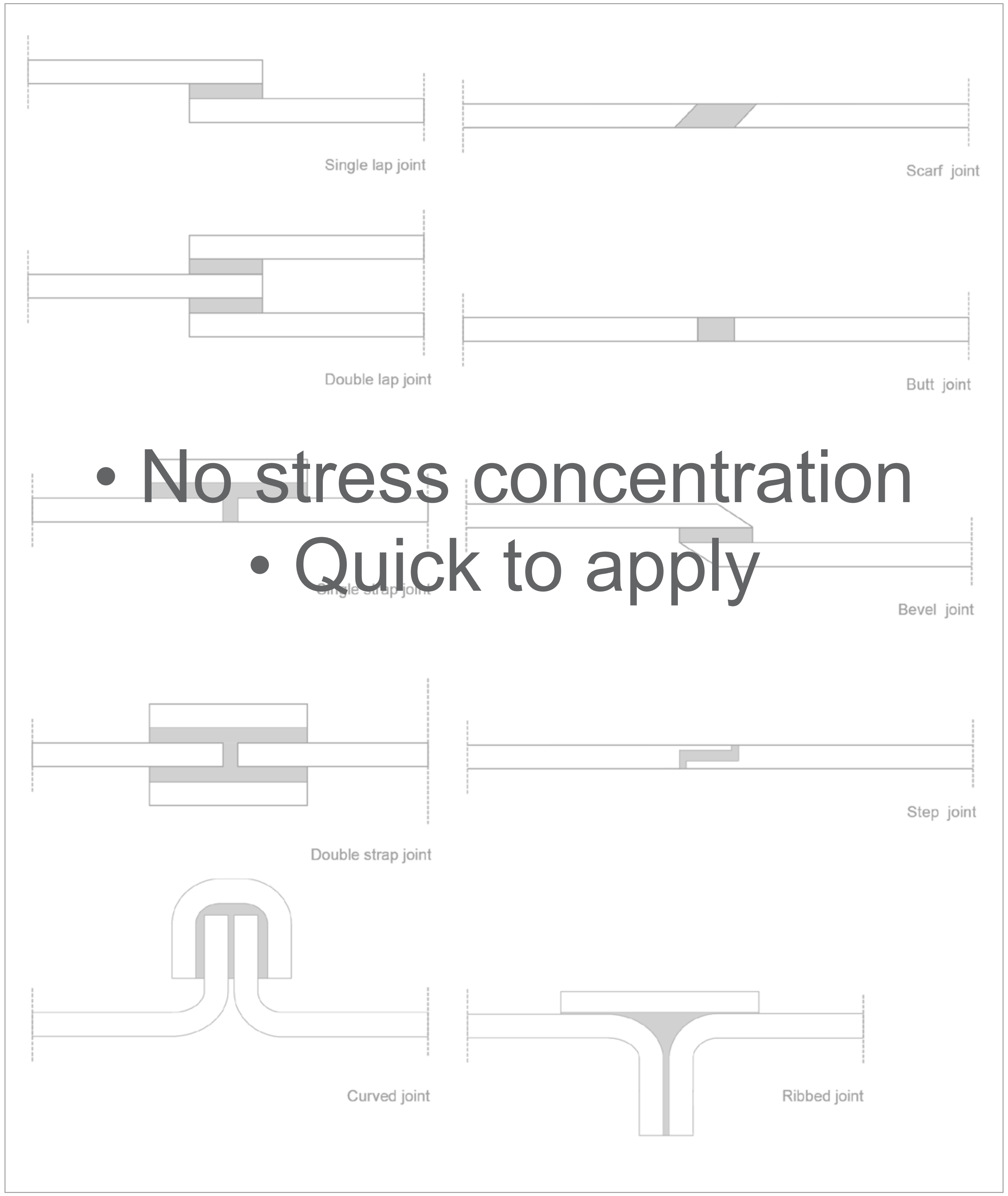


CIRCULARITY | Connections

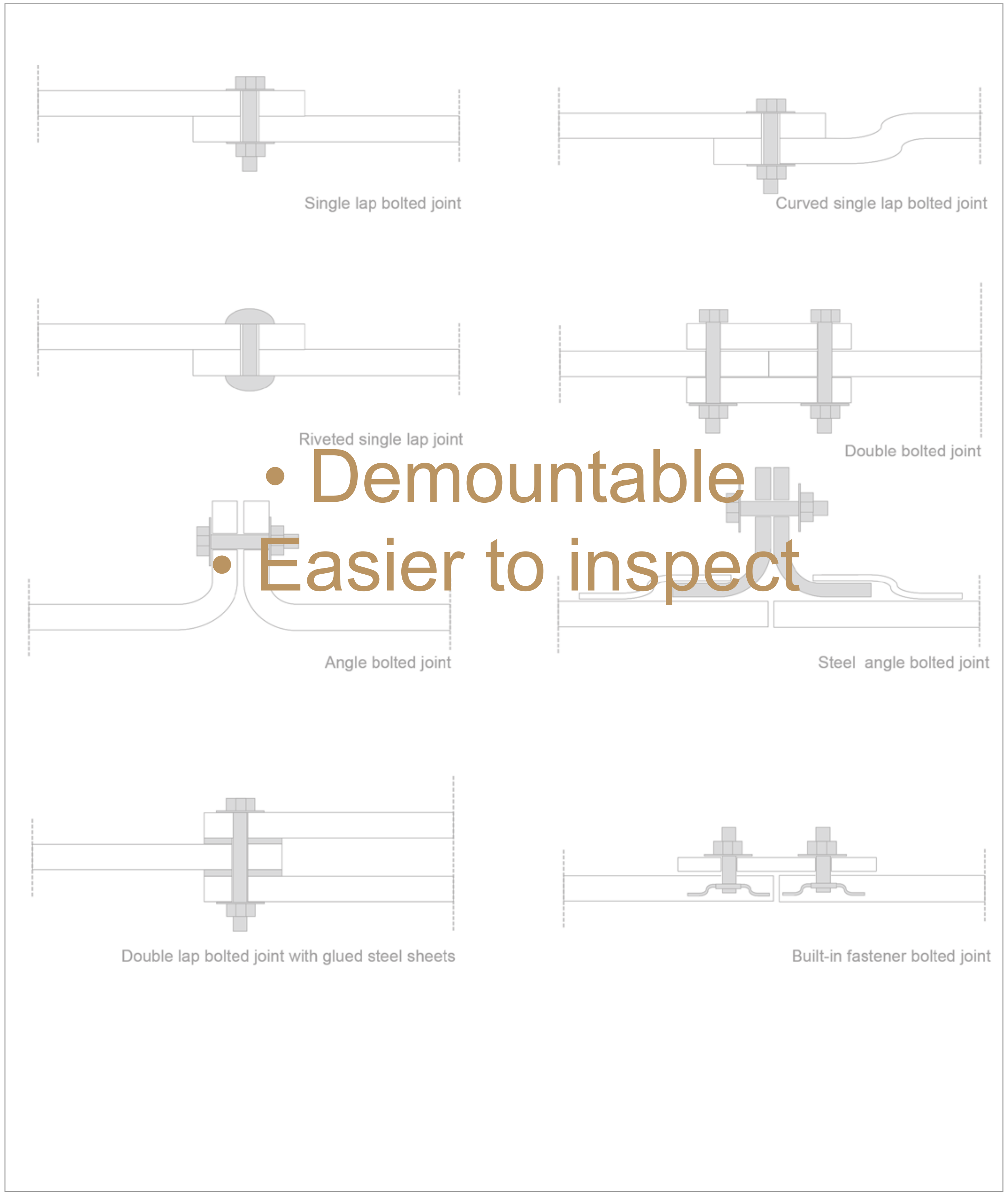




CIRCULARITY | Connections

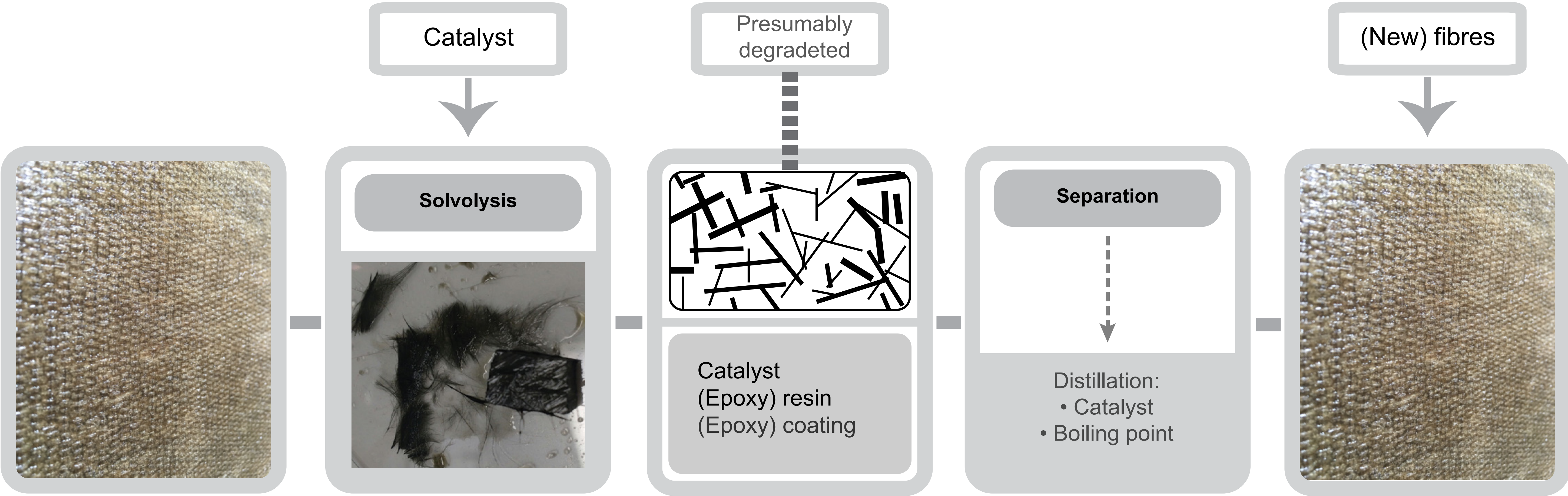


- No stress concentration
- Quick to apply



- Demountable
- Easier to inspect

CIRCULARITY | Recycling

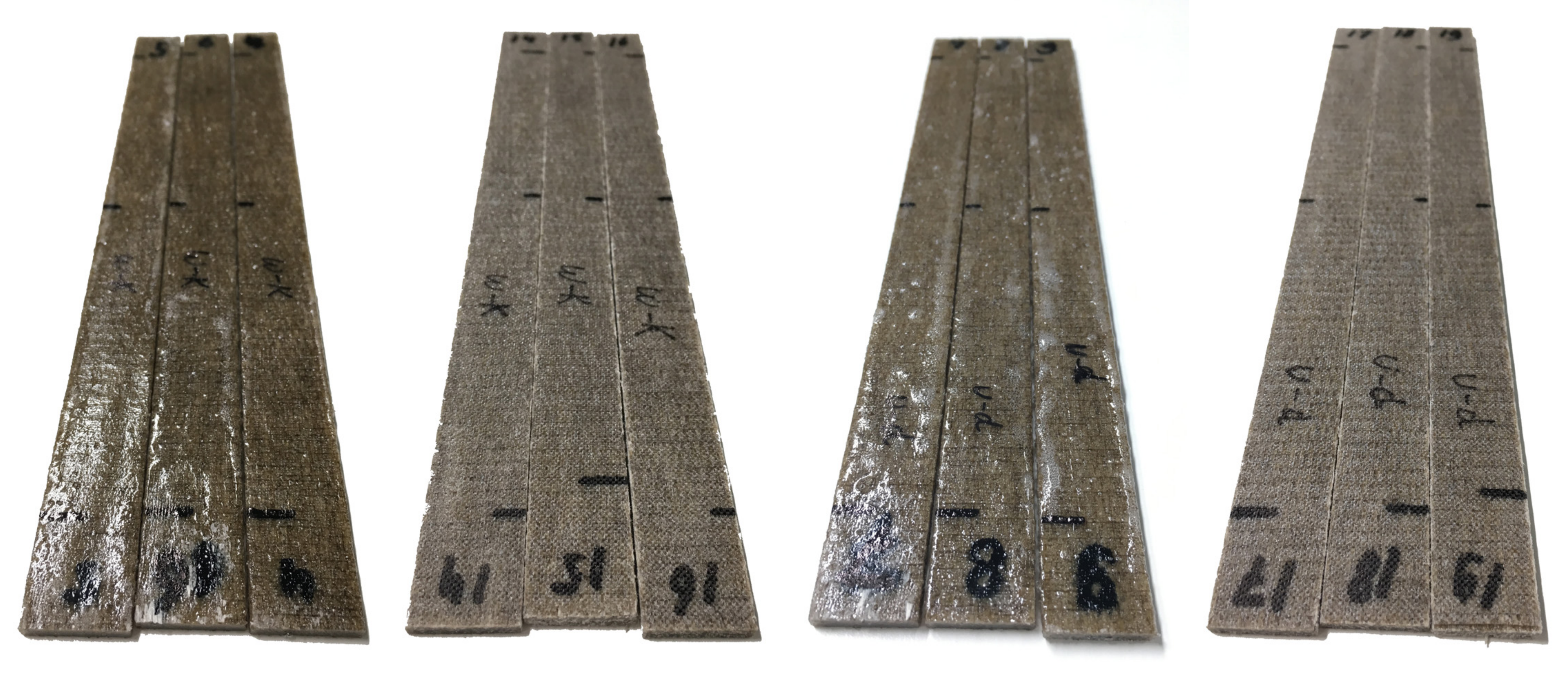


DURABILITY

DURABILITY | Tests

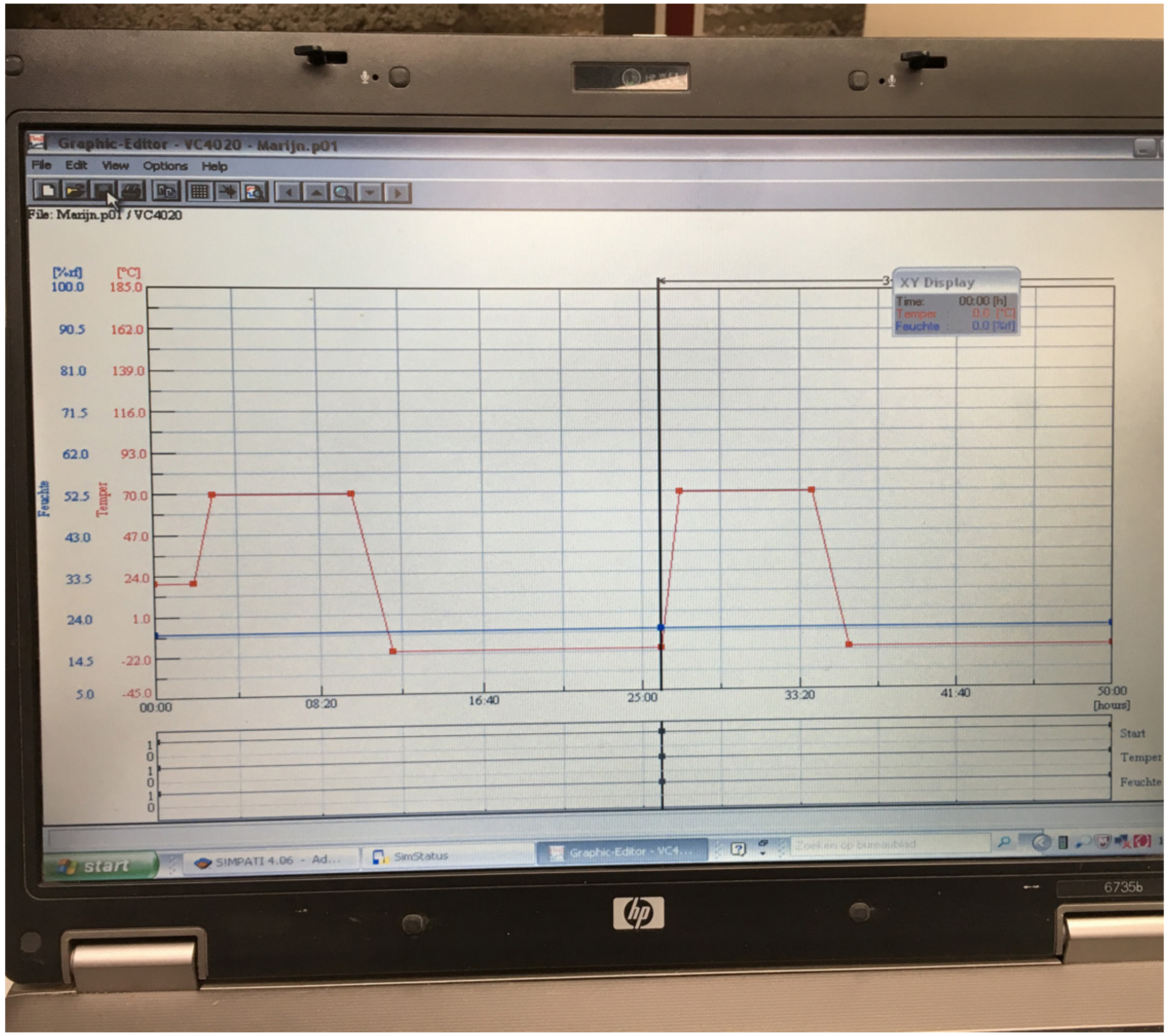
- Establish the durability of biobased composite
- Estimate the lifetime

SKG-IKOB



Warmth-Cold cycles

5 days: -20°C to 70°C

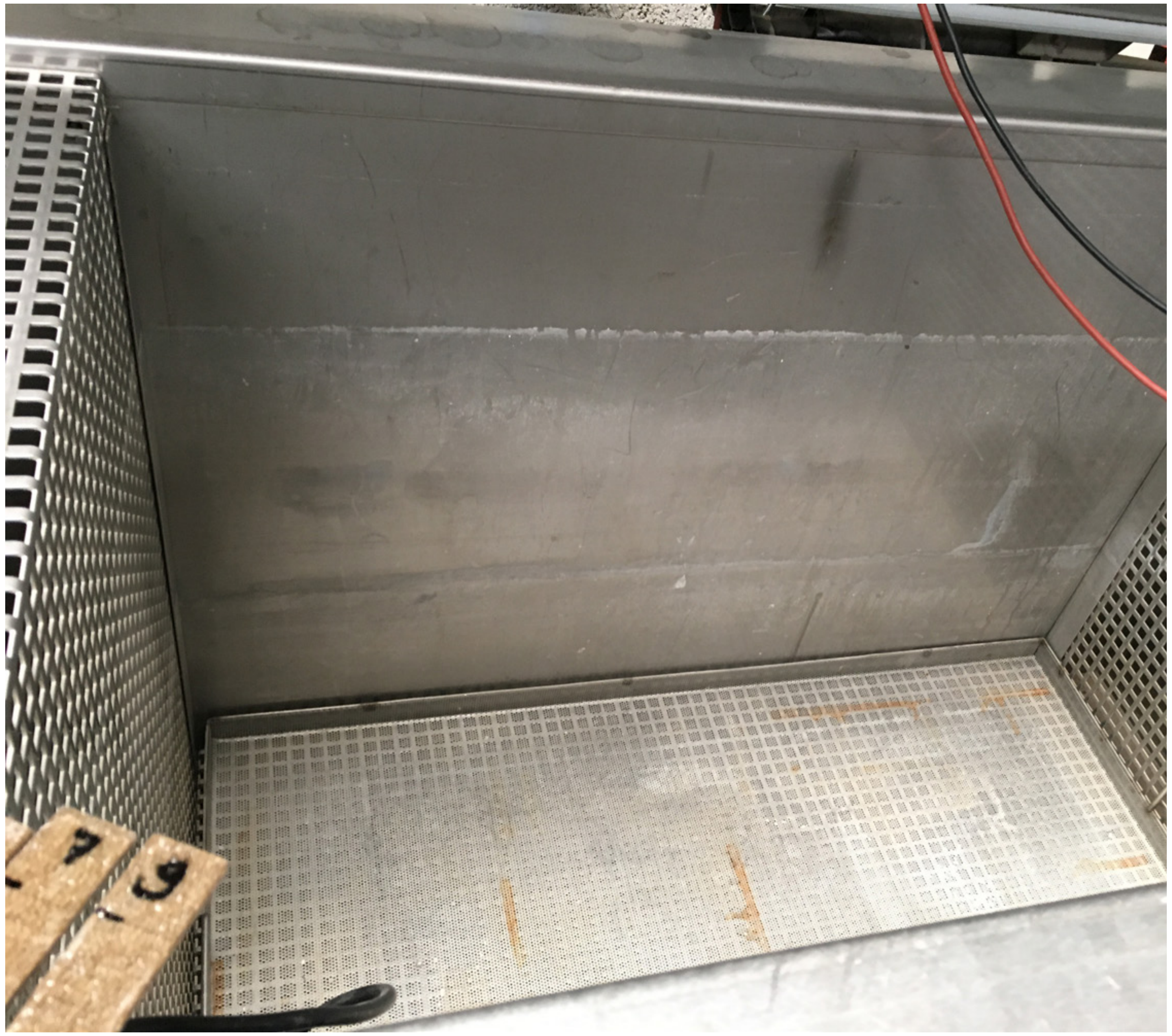


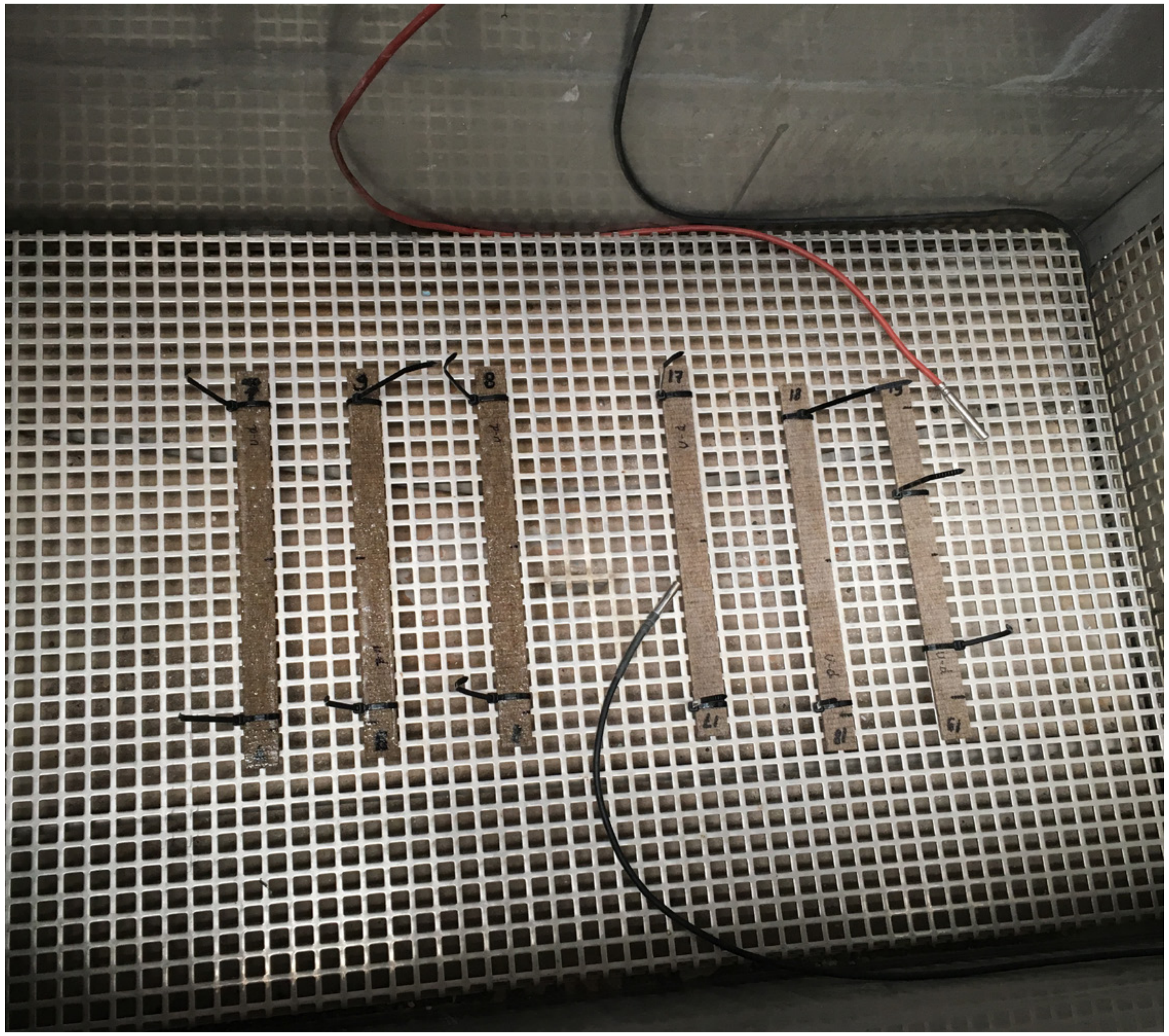
dGm[R]

DURABILITY | Tests

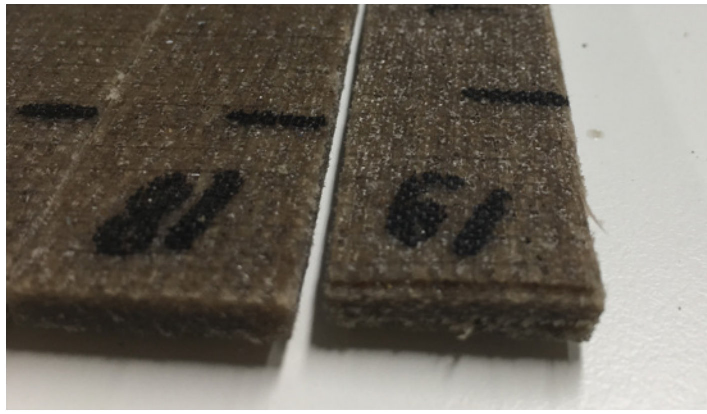
Freeze-thaw cycles

One month: Water/ -20°C



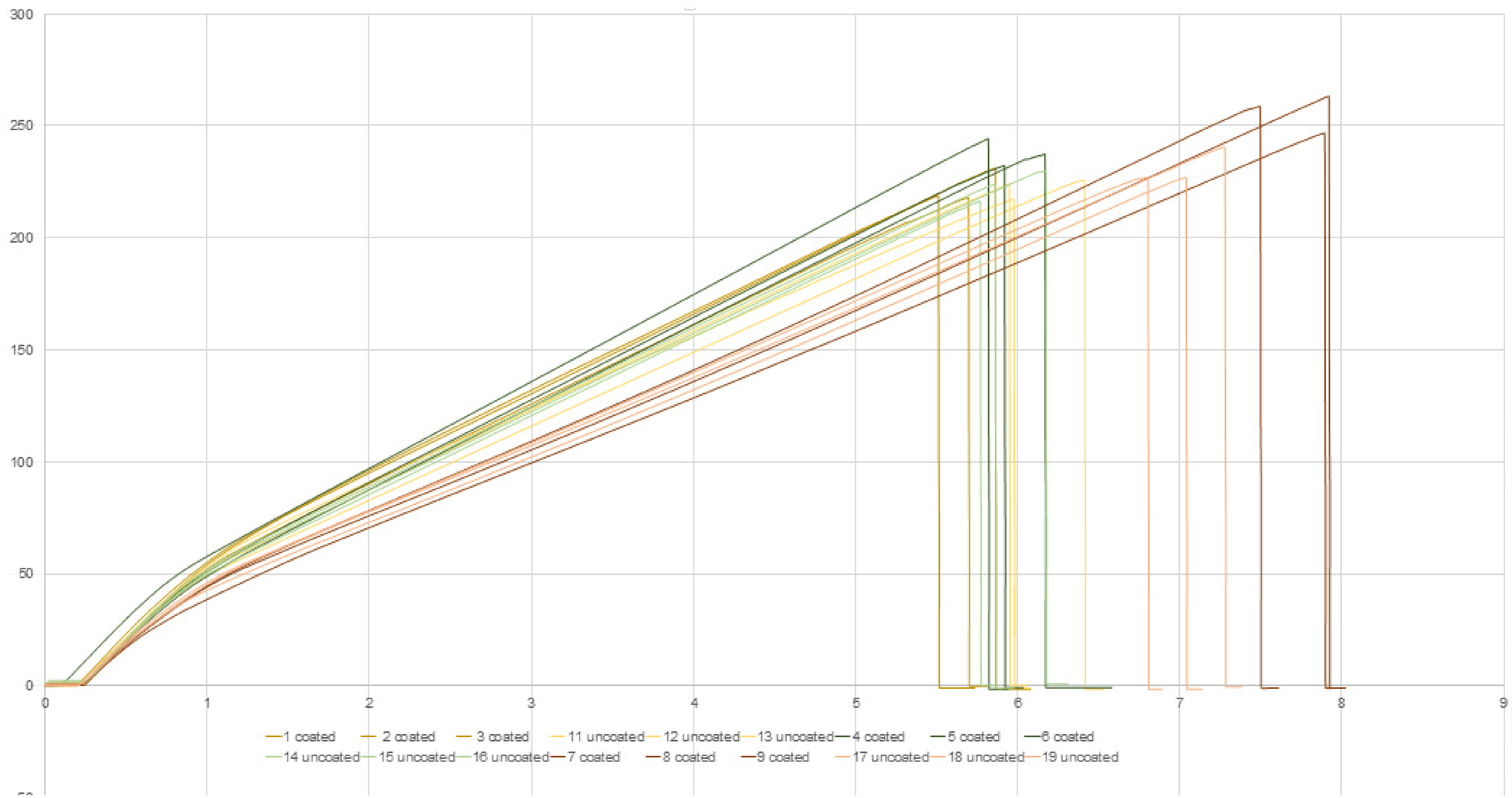


DURABILITY | Tests results - Visual



DURABILITY | Tests results - Tensile strength

Warmth-cold: Coated +7% Uncoated +0.7%
Freeze-thaw: Coated +15% Uncoated +4.4%

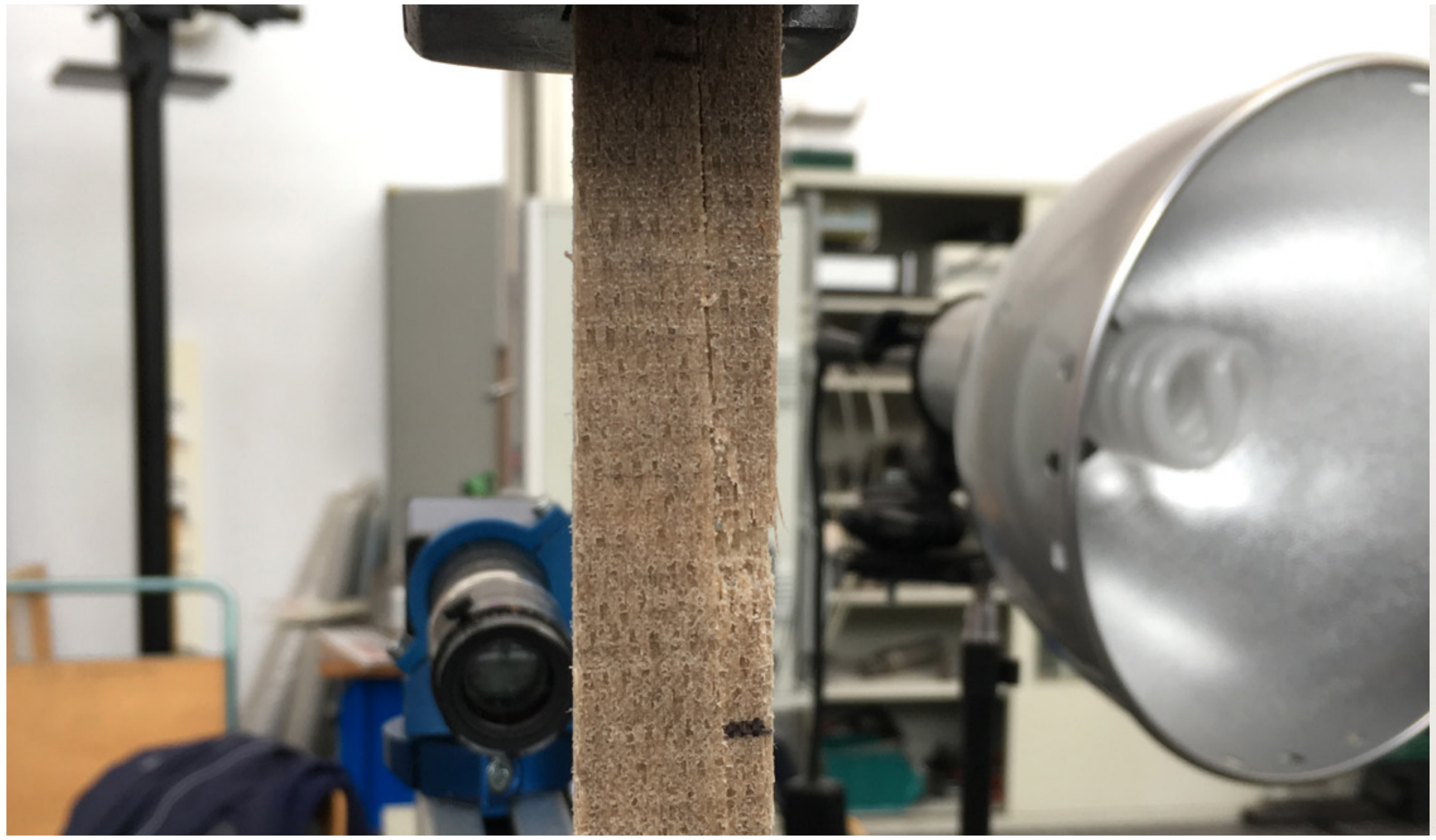


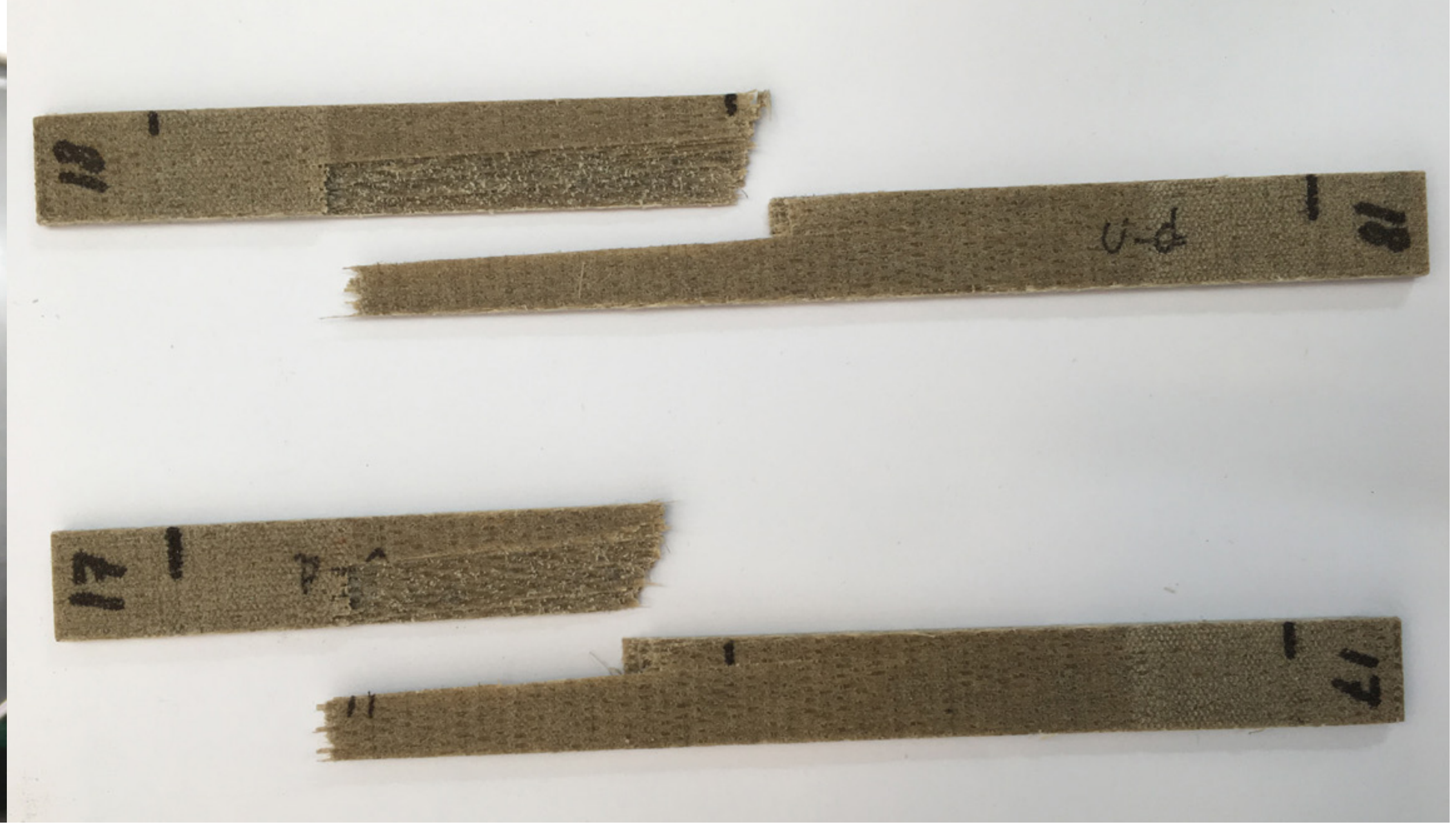
DURABILITY | Tests results - Youngs modulus

Warmth-cold: Coated -3% Uncoated -1%

Freeze-thaw: Coated -13% Uncoated -13%

DURABILITY | Tests results - Breaking pattern

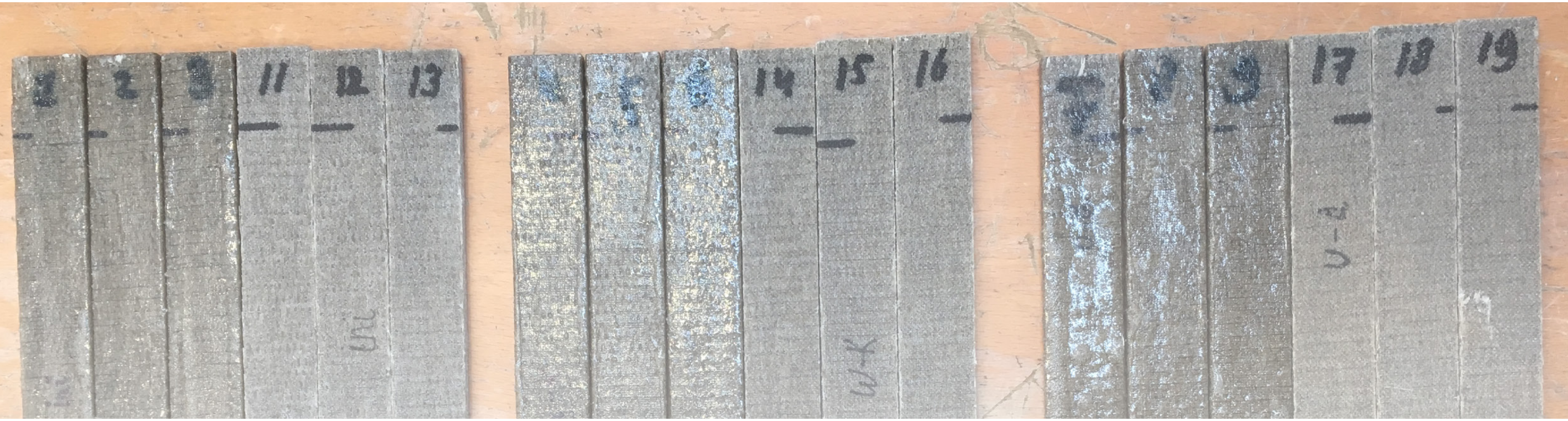




DURABILITY | Conclusions

When the material is coated and the bending stiffness is designed including a safety margin, the lifetime is estimated to be similar to other common facade materials

Breaking pattern changes after freeze-thaw cycles



SHADOWCOSTS

"Shadowcosts are the cost for the preventive measures which must be taken to reduce the emissions to a sustainable level"

dGm[R]

SHADOWCOSTS | Different materials

Material	**S-c (€)**	**per**
Steel		
Cladding	€ 0,17	kg
Light construction steel	€ 0,17	kg
Stainless steel	€ 2,12	kg
Coatings		
Powdercoating	*€ 1,54*	*kg*
Wetpainting	*€ 0,97*	*kg*
Galvanising (zinc)	*€ 1,09*	*kg*
Aluminum		
Aluminum (47% secondary)	€ 2,65	kg
Coatings		
Anodising	*€ 0,58*	*m2*
powder coating	*€ 1,52*	*m2*
Wood		
Hard, sustainably managed	€ 0,02	kg
Hard, not-sustainably managed	€ 0,02	kg
Soft, sustainable managed	€ 0,04	kg
Soft, not-sustainably managed	€ 0,07	kg
Soft, laminated	€ 0,07	kg

Coatings		
Paint, nature based/ water based	*€ 0,15*	*kg*
Paint, acrylate	*€ 0,34*	*kg*
Paint, alkyd	*€ 0,57*	*kg*
Paint, stony ground	*€ 0,57*	*kg*
Composite		
Glass fibre reinforced polyester	€ 0,76	kg
Biobased composite	€ 0,23	kg
Coatings		
Spray paint	€ 1,20	kg
Insulation		
Rockwool	€ 0,10	kg
PUR foam	€ 0,38	kg
PLA	€ 0,80	kg
Flax fibre	€ 0,23	kg
Additional		
Gypsum board	€ 0,03	kg
Granite	€ 0,01	kg

SHADOWCOSTS | Shadowcosts per m_2

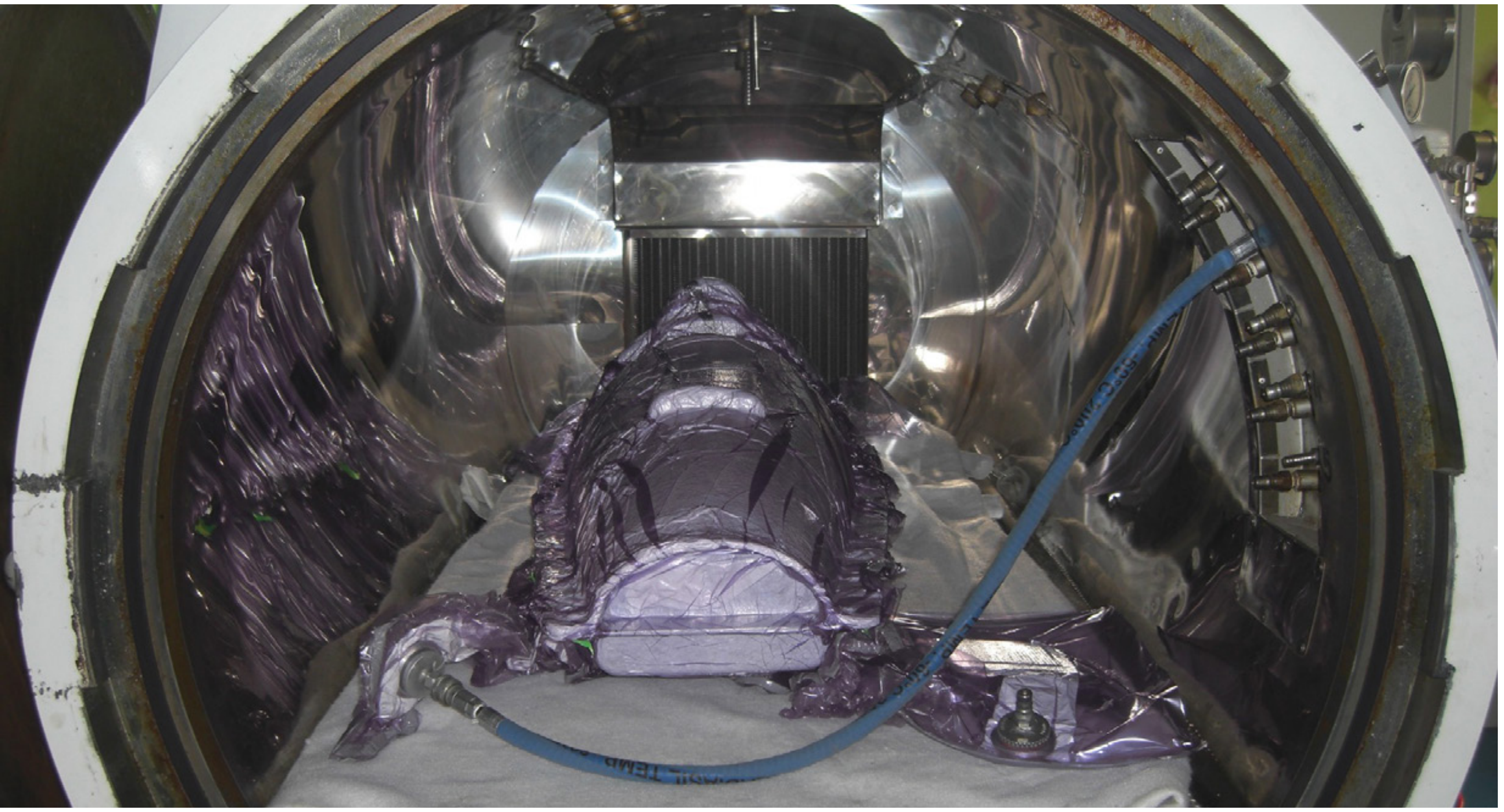
Material	**Density (kg/m3)**	**Shadowcosts (€)**	**Youngs modulus**	**Shadowcosts/m2**
Wood	530	€ 0,02	13	0.17
Steel	7870	€ 0,17	210	1.33
Aluminum	2700	€ 2,65	69	21.47
Glassfibre-reinforced composite	2000	€ 0,76	69	4.56
Biobased composite	1115	€ 0,23	11,4	4.61

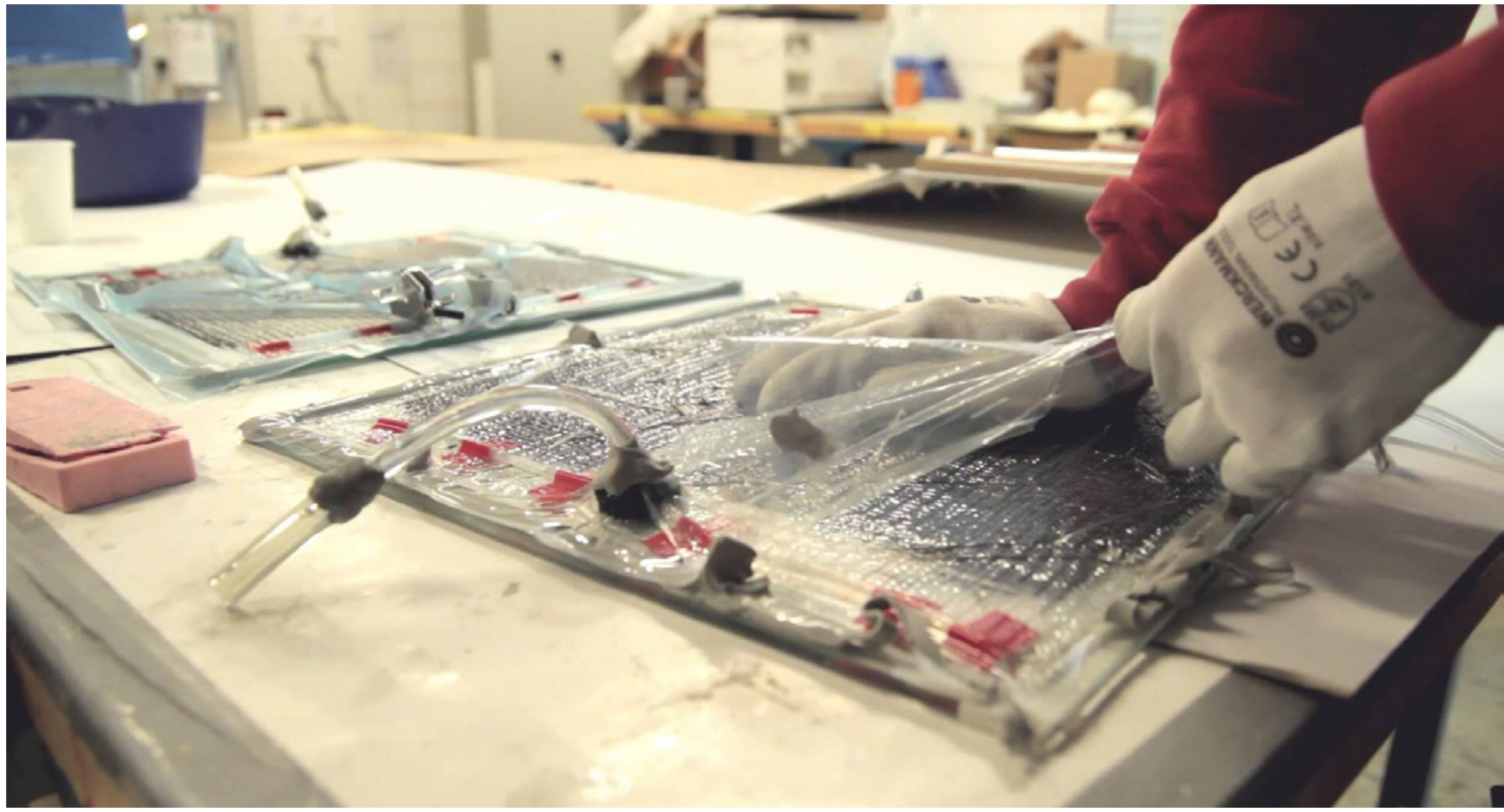
DESIGN PARAMETERS

DESIGN PARAMETERS | Production techniques

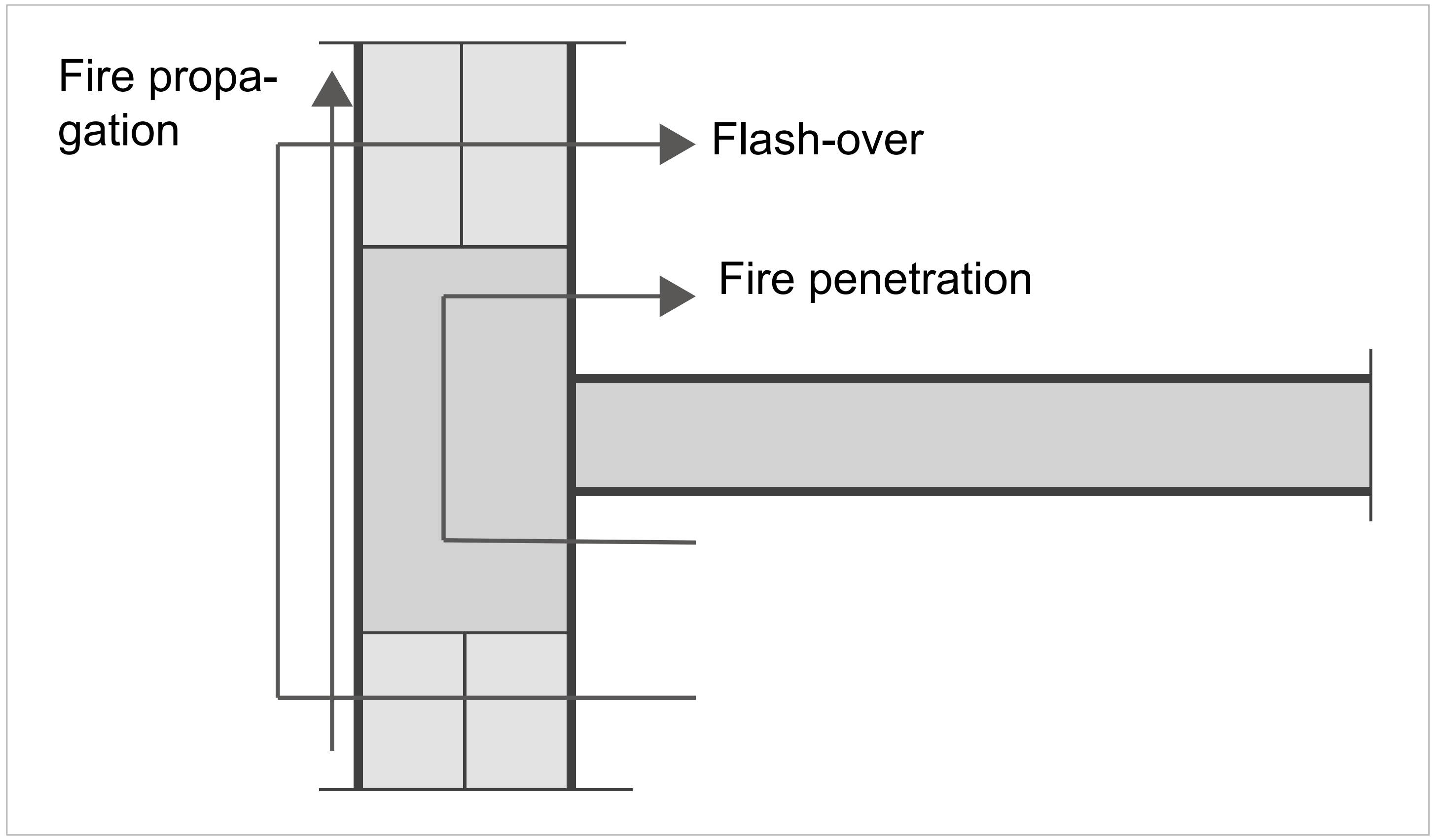
Avoid:

- An autoclave
- Additional material like molds, vacuum bags, etc
- Emissions evaporating during the process





DESIGN PARAMETERS | Safety requirements - Fire-safety



- ☐ Apply a fire-retardant coating
- ☐ Use a fire retardant resin
- ☐ Apply the material only to low-rise buildings

DESIGN PARAMETERS | Thermal transmittance

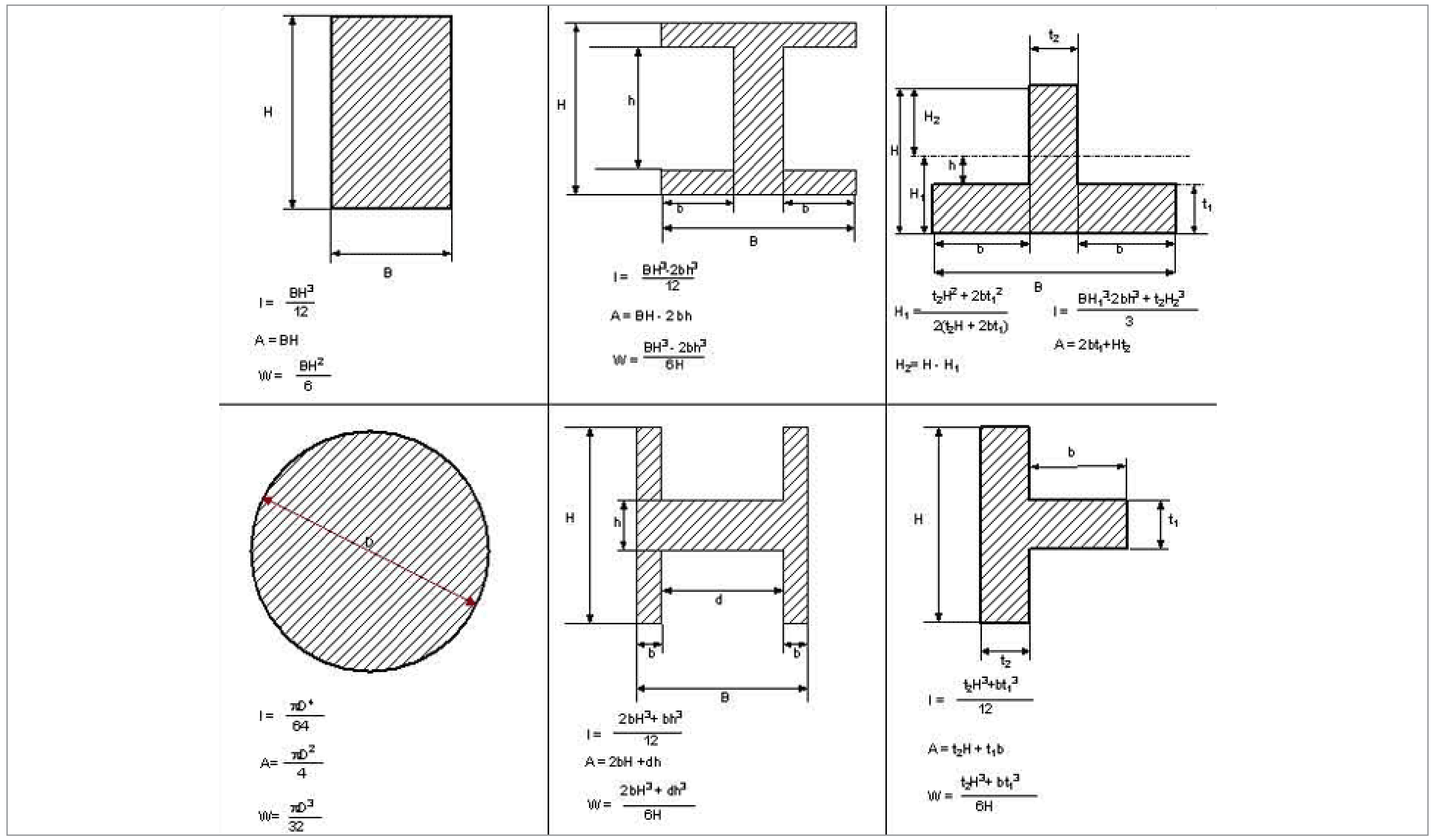
Wood: 0.16 W/m^{2}K
Biobased composite: 0.056 W/m^{2}K

Material	λ (W/m*K)	d (mm)	Rd (m)	Density (kg/m3)	Weight (kg/m2)
Gypsum board 0,95 cm	0,16	9,5	0,0059375	7,62 (kg/m2)	7,62 (kg/m2)
Gypsum board 1,25 cm	0,16	12,5	0,0078125	10,2 (kg/m2)	10,2 (kg/m2)
Steel reinforced concrete per dm	1,7	100	0,06	2400	240
Steel per mm	50	1	0,00002	7870	7,87
Aluminum per mm	200	1	0,000005	2700	2,7
Wood (Fir) per cm	0,18	10	0,06	530	5,3
Balsae wood per cm	0,048	10	0,21	1600	16
Biobased composite (flax-supersap)per cm	0,056	10	0,18	1115	11,15
Biobased composite (hemp-supersap)per cm	0,056	10	0,18	1148	11,48
Fibreglass-polyester composite per cm	0,015	10	0,67	1522,4	15,22
Aircavity (stationary, 15°) per cm	0,026	10	0,38	1,225	0,01
Glass	1,05	4	0,0038095	2500	10
Ceramic	0,8	40	0,05	2200	110

DESIGN PARAMETERS | Geometry - Bending stiffness

Bending stiffness = Moment of Inertia * Youngs modulus

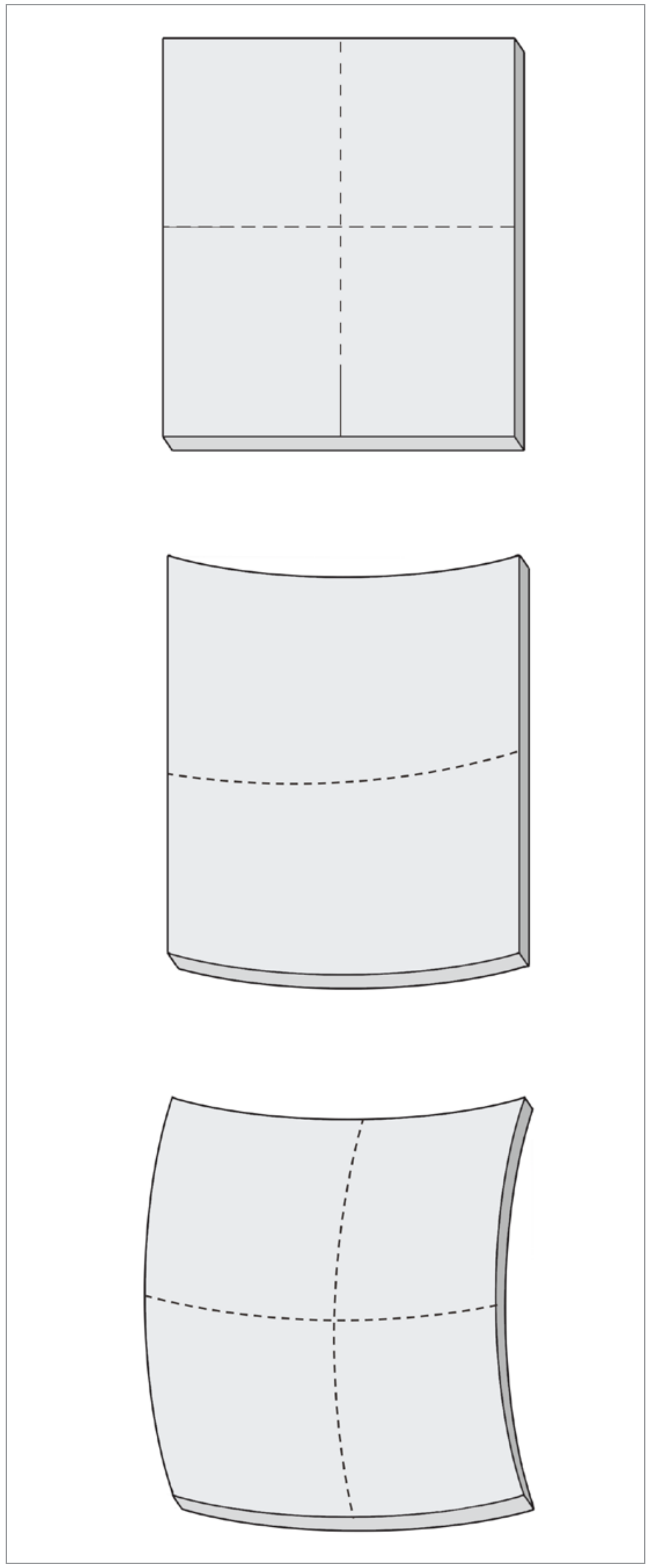
Moment of inertia

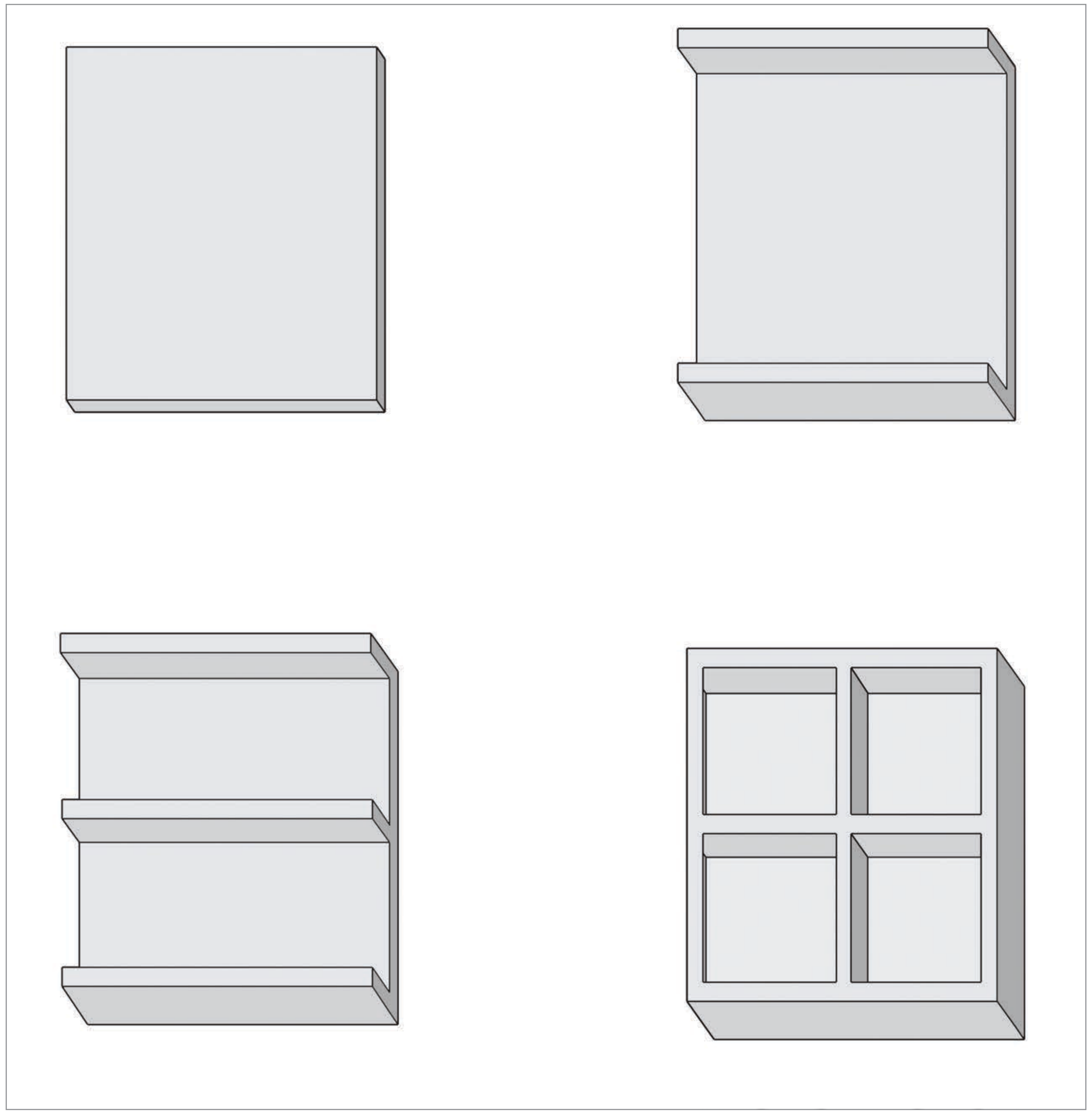


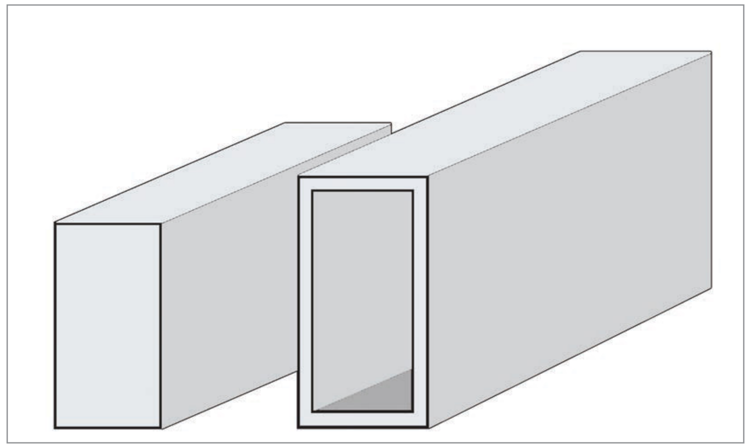
Youngs modulus

	Y-M (Gpa)	Density (kg/m3)
Steel	210	7870
Aluminum	69	2700
Biobased composite	11,4	1115

DESIGN PARAMETERS | Geometry - Bending stiffness



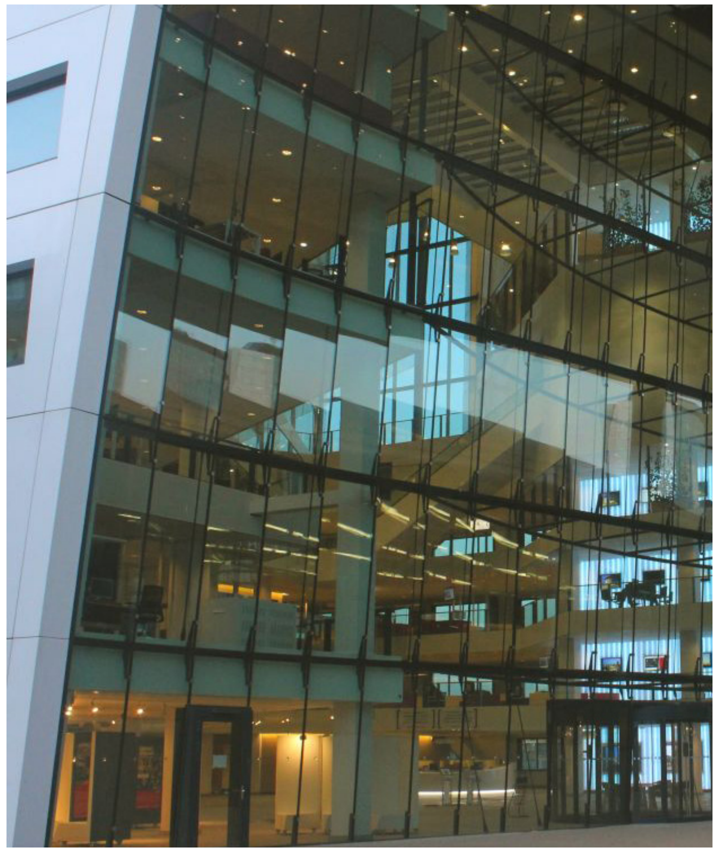




CASE STUDIES

CASE STUDIES | Facades

What is possible with biobased composite, when used for a facade design?

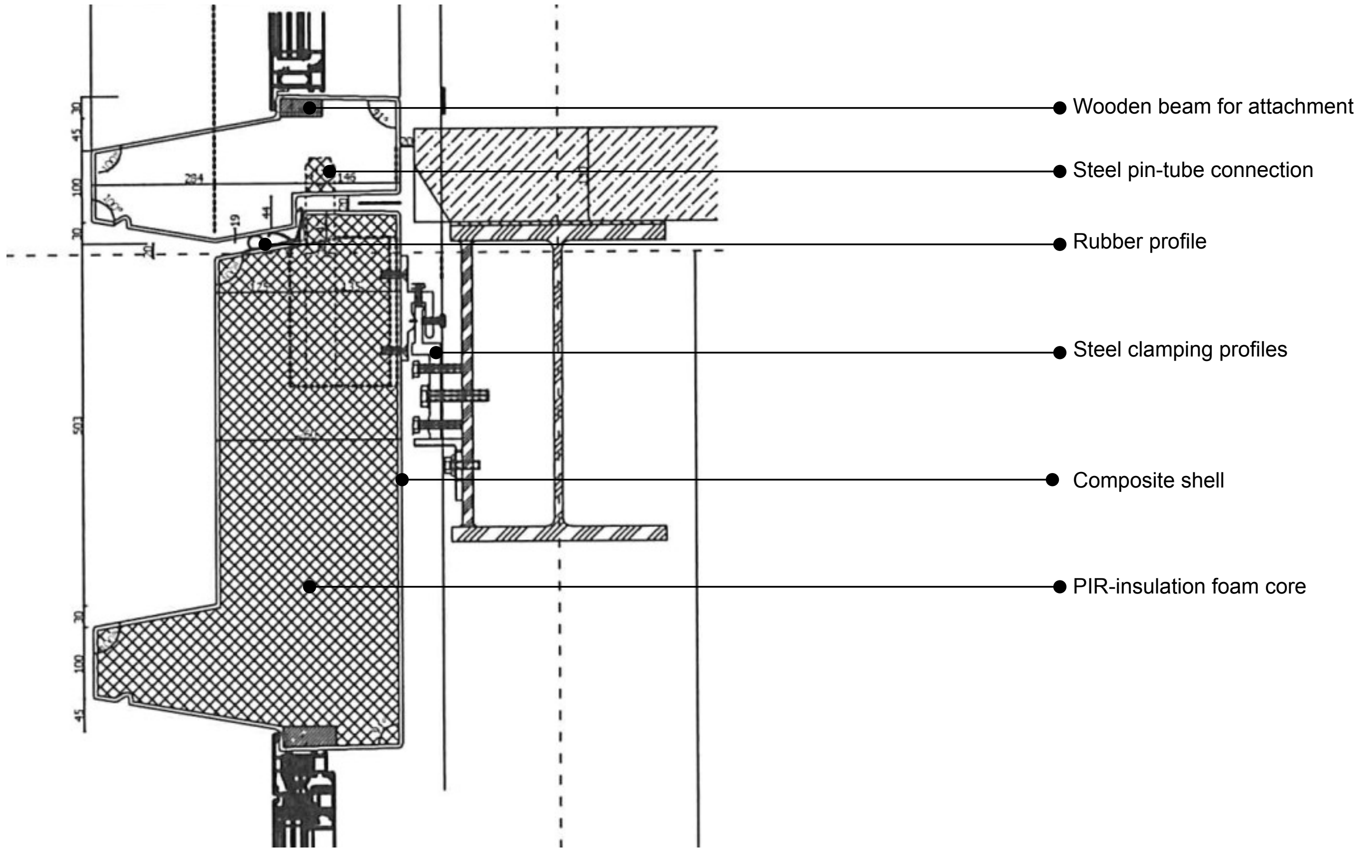


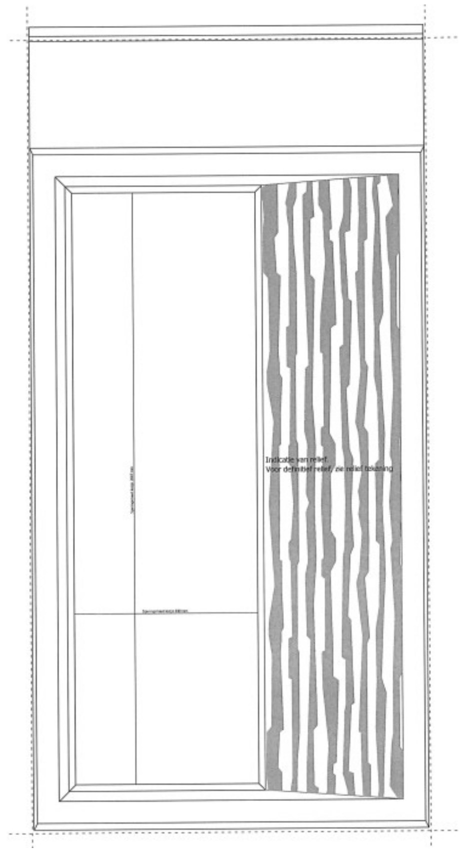
CASE STUDIES | Products - Approach

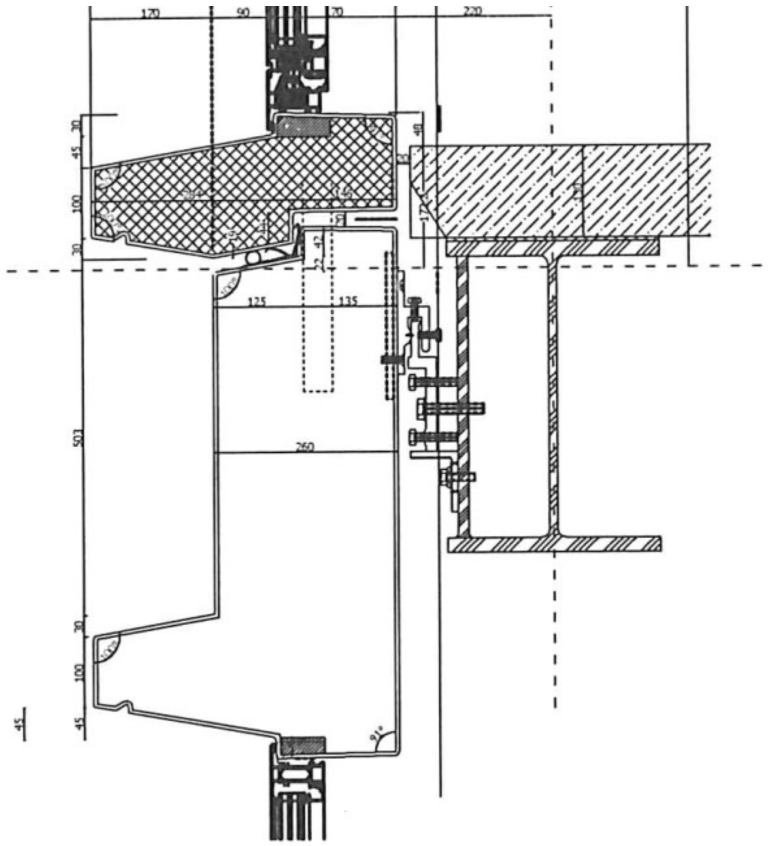
Weight	kg/m²	12.15
Rc-value	m²*K/W	4.53
Schadowcosts	€/m²	3.52
Circular scenario	Re-use / Adapt / Recycle	10

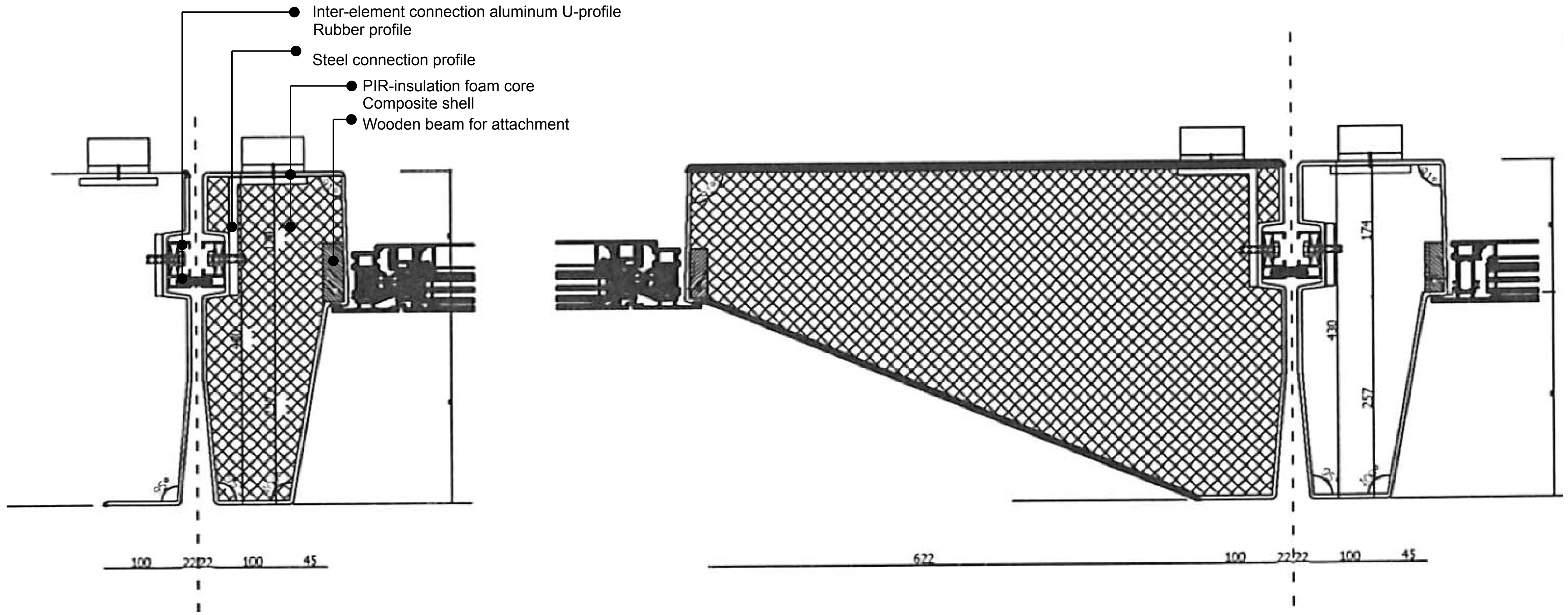
Weight	kg/m²	25.24
Rc-value	m²*K/W	4.5
Schadowcosts	€/m²	10.12
Circular scenario	Re-use / Adapt / Recycle	10

CASE STUDIES | Element Facade

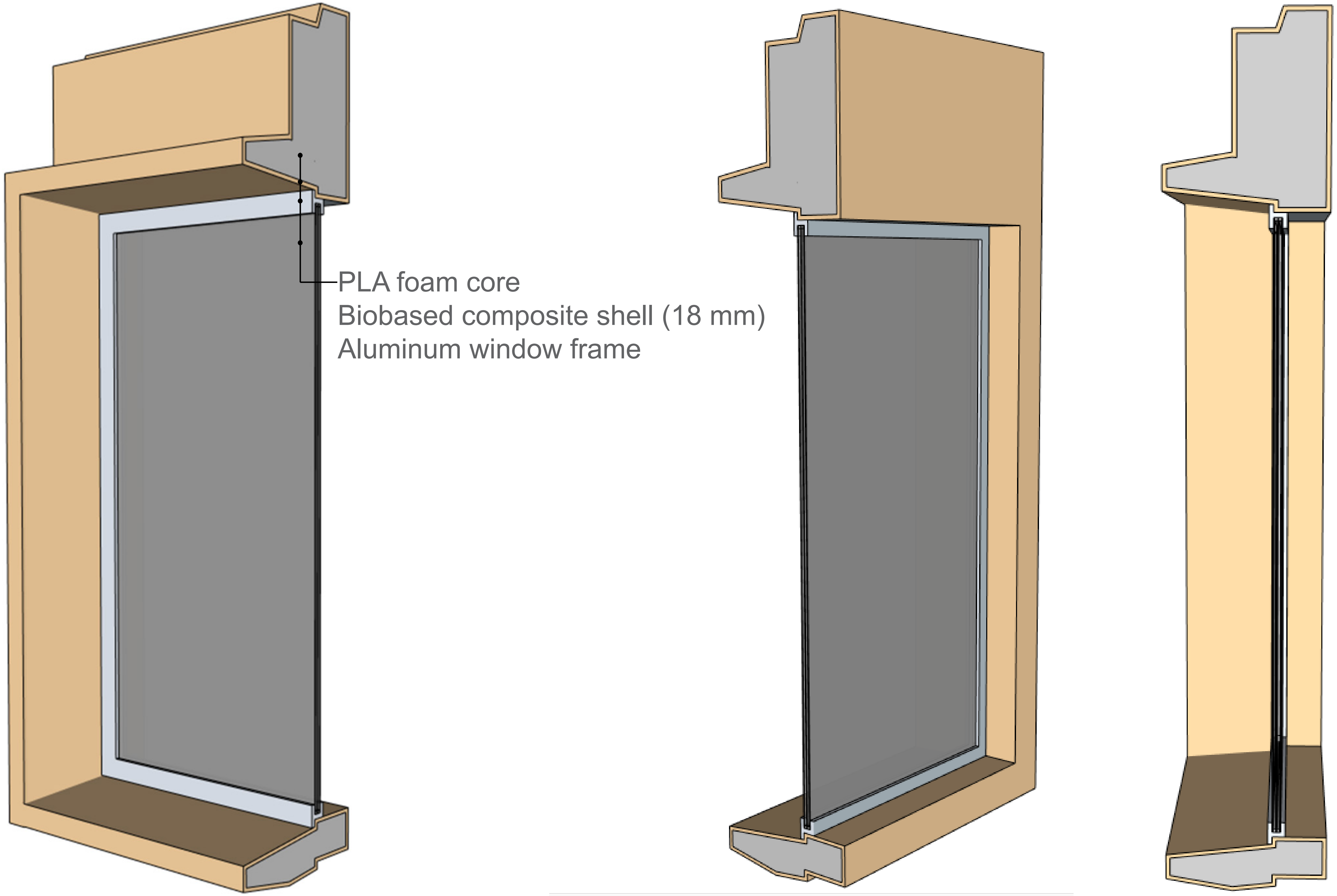




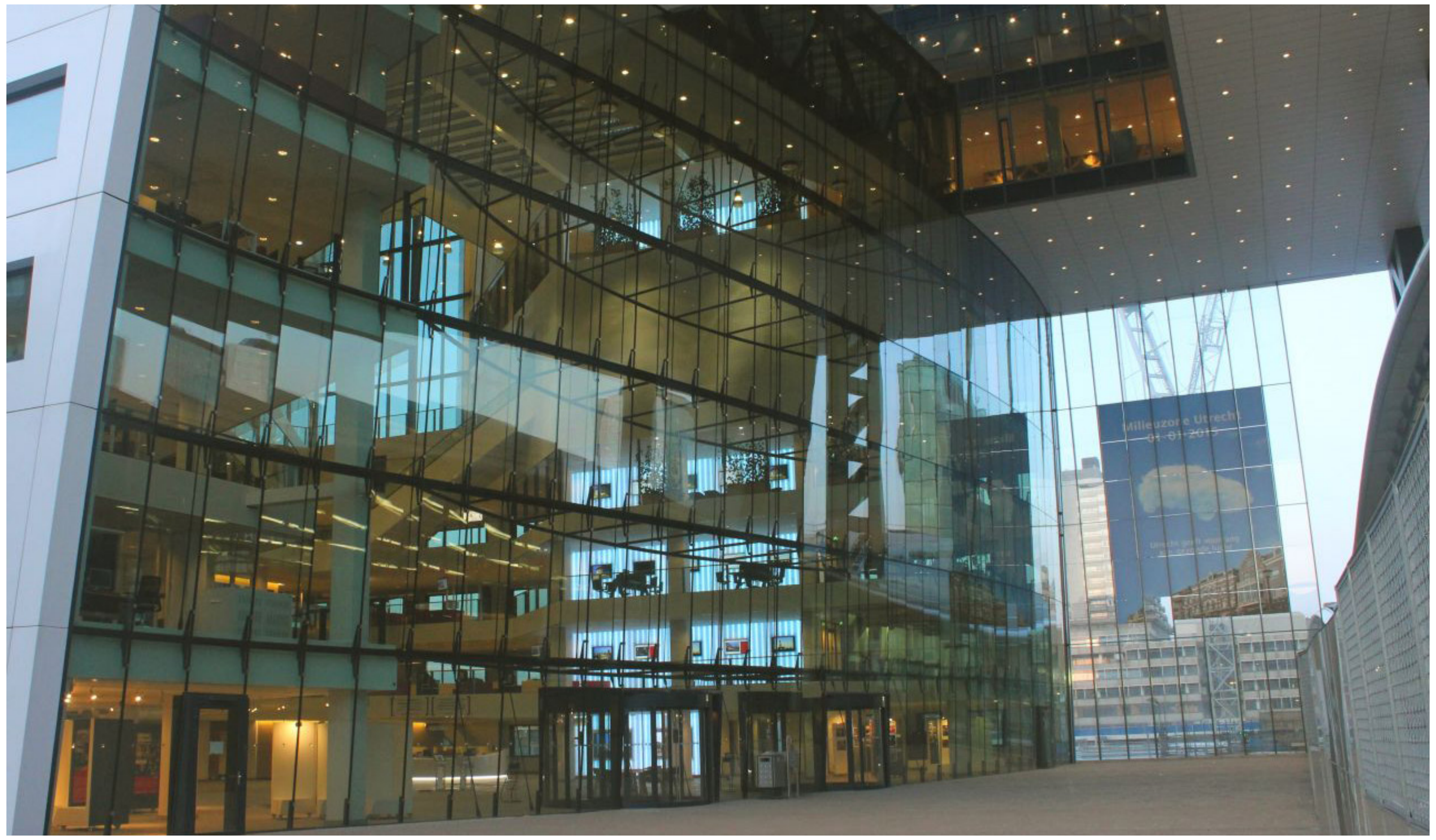


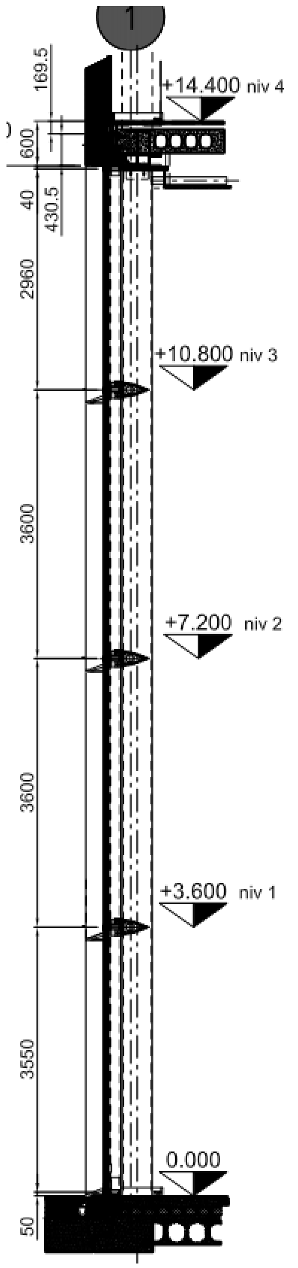


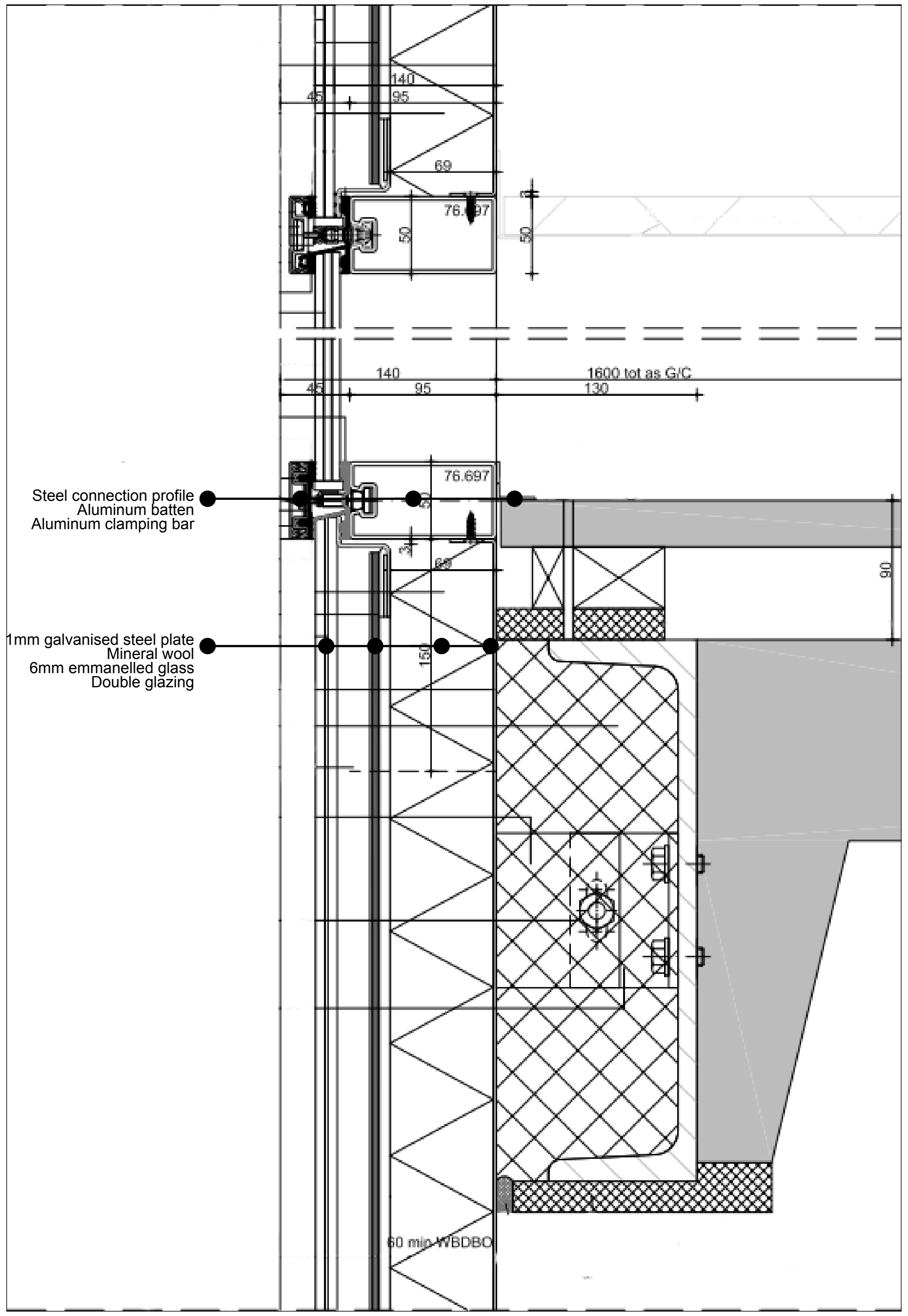
CASE STUDIES | Element Facade

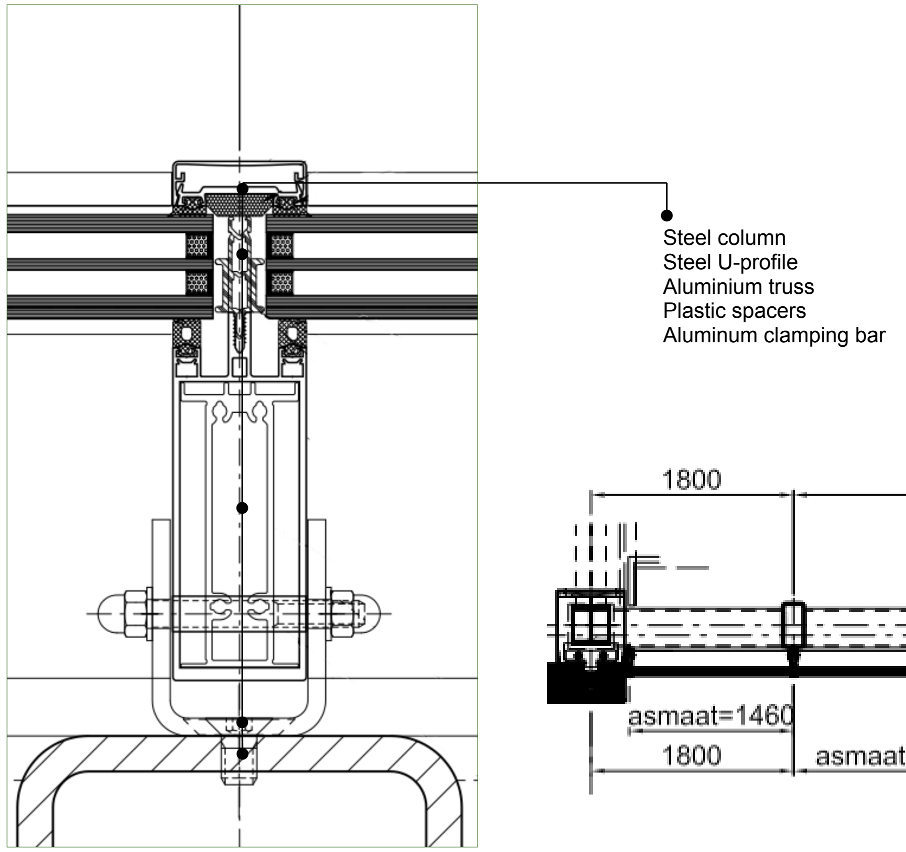


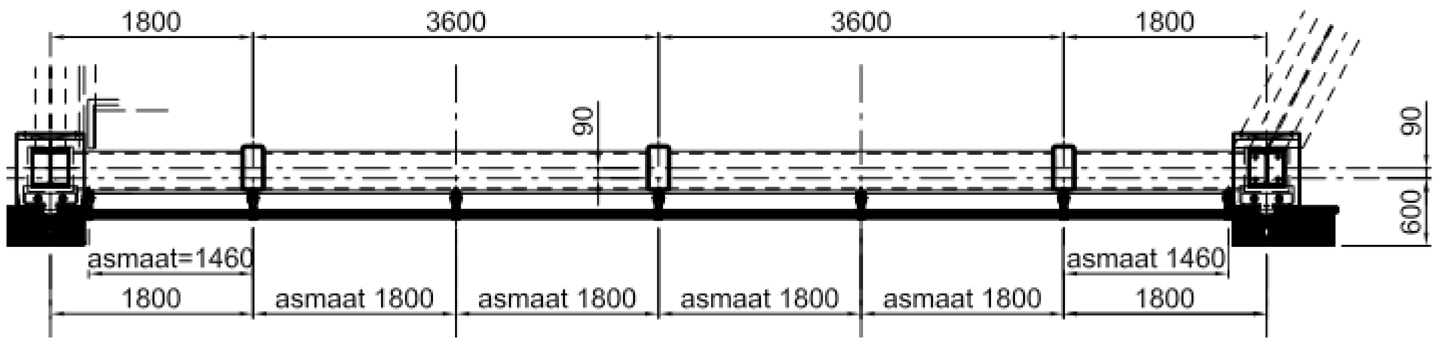
CASE STUDIES | Curtain wall



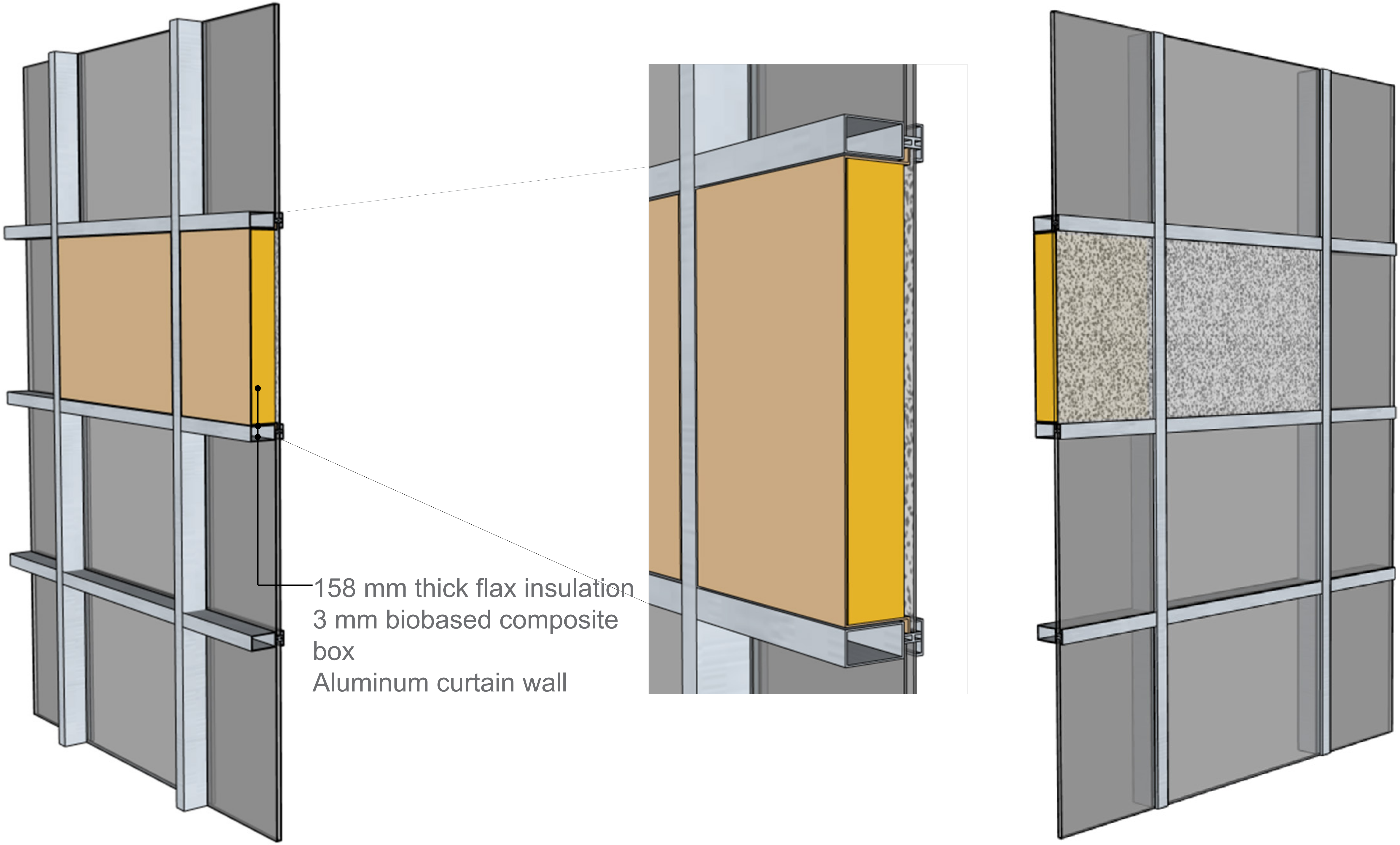






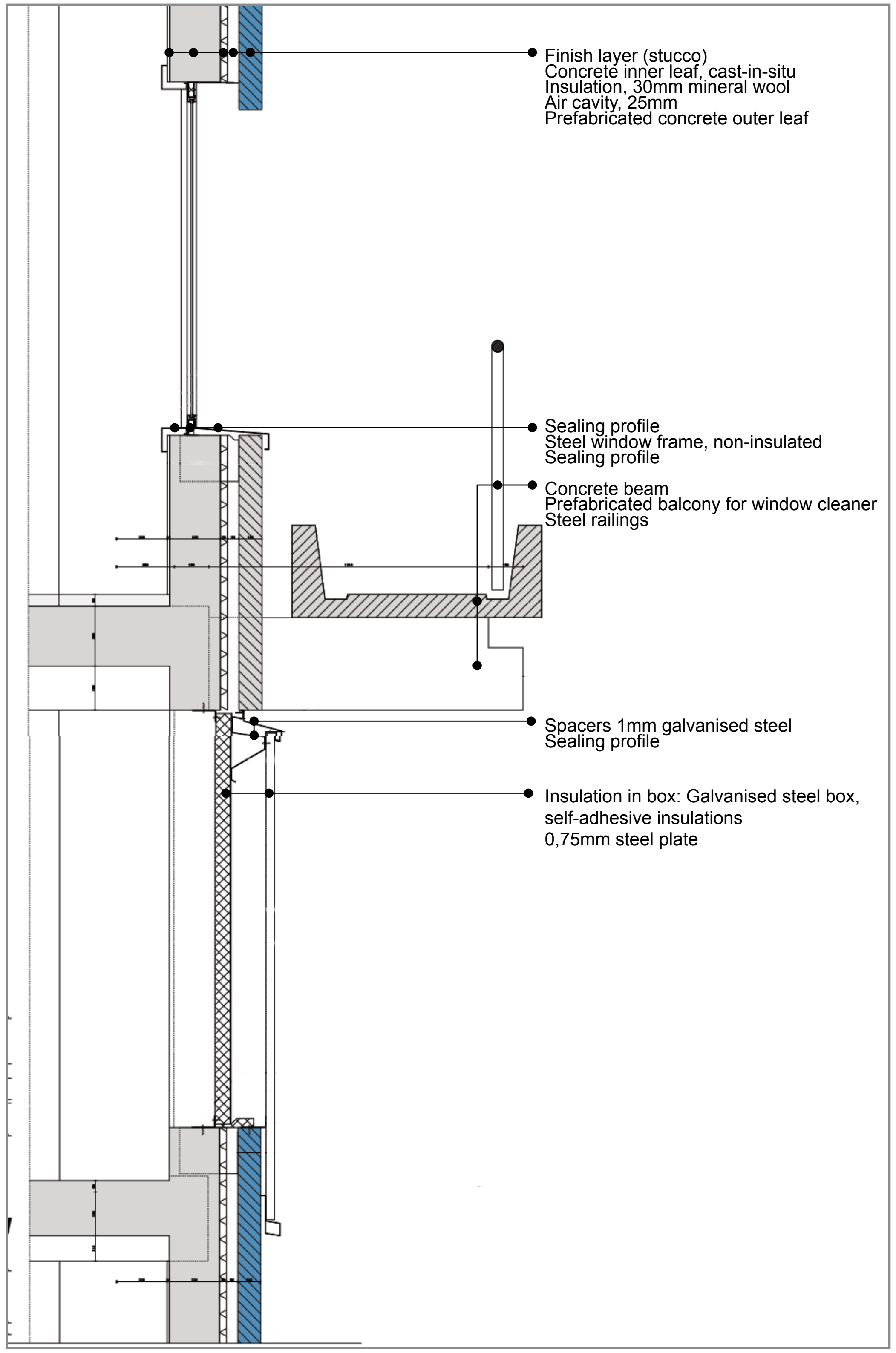


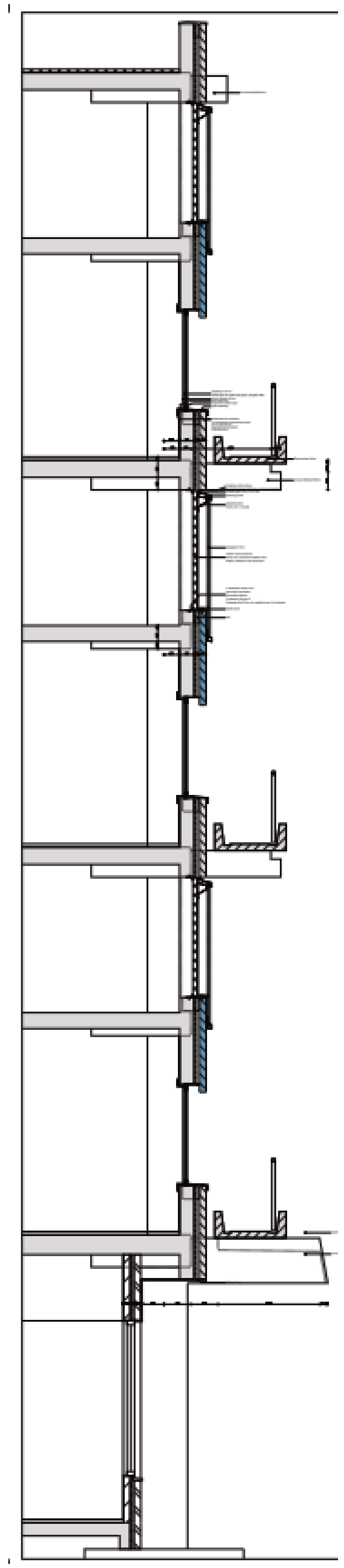
CASE STUDIES | Curtain wall



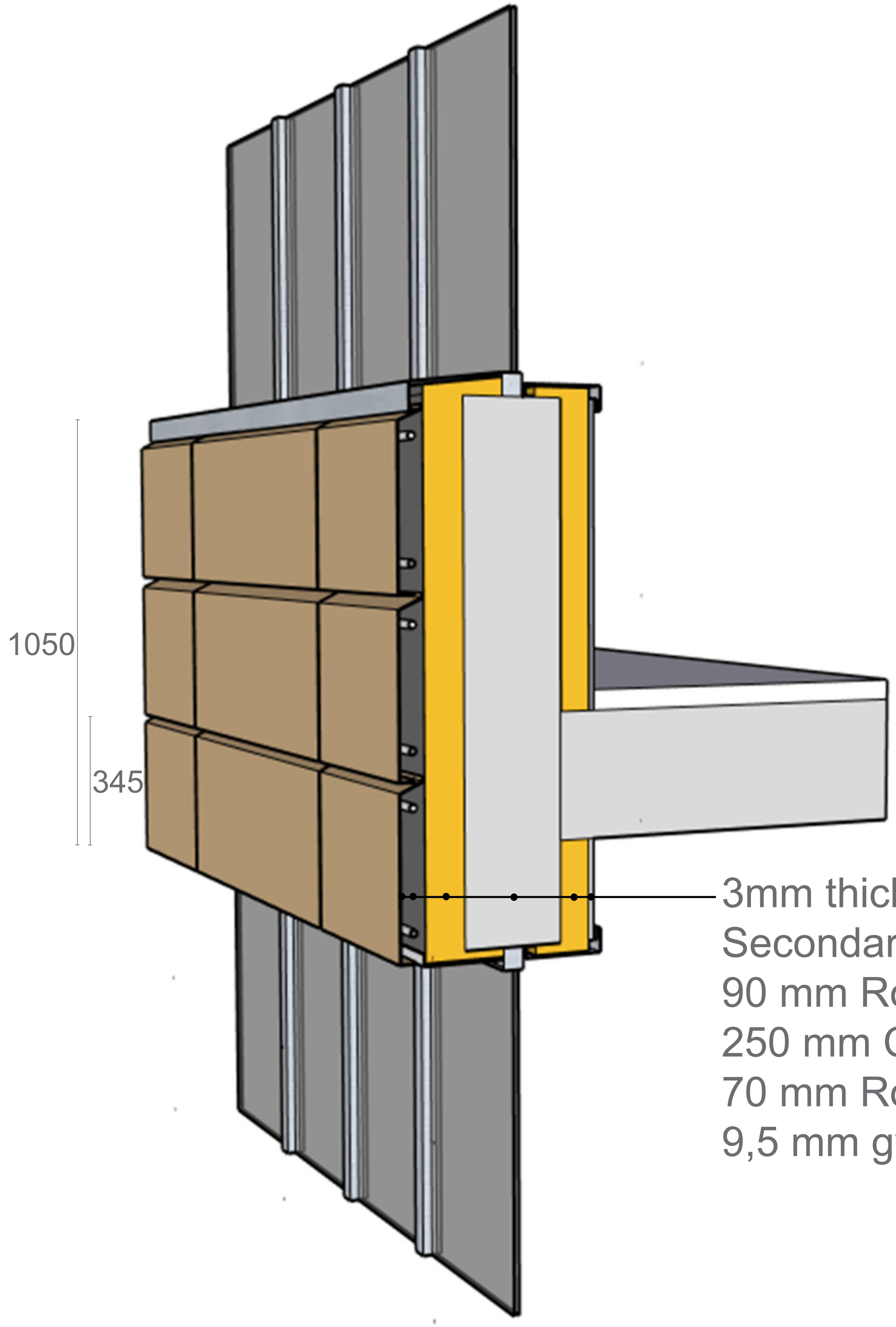
dGm[R]

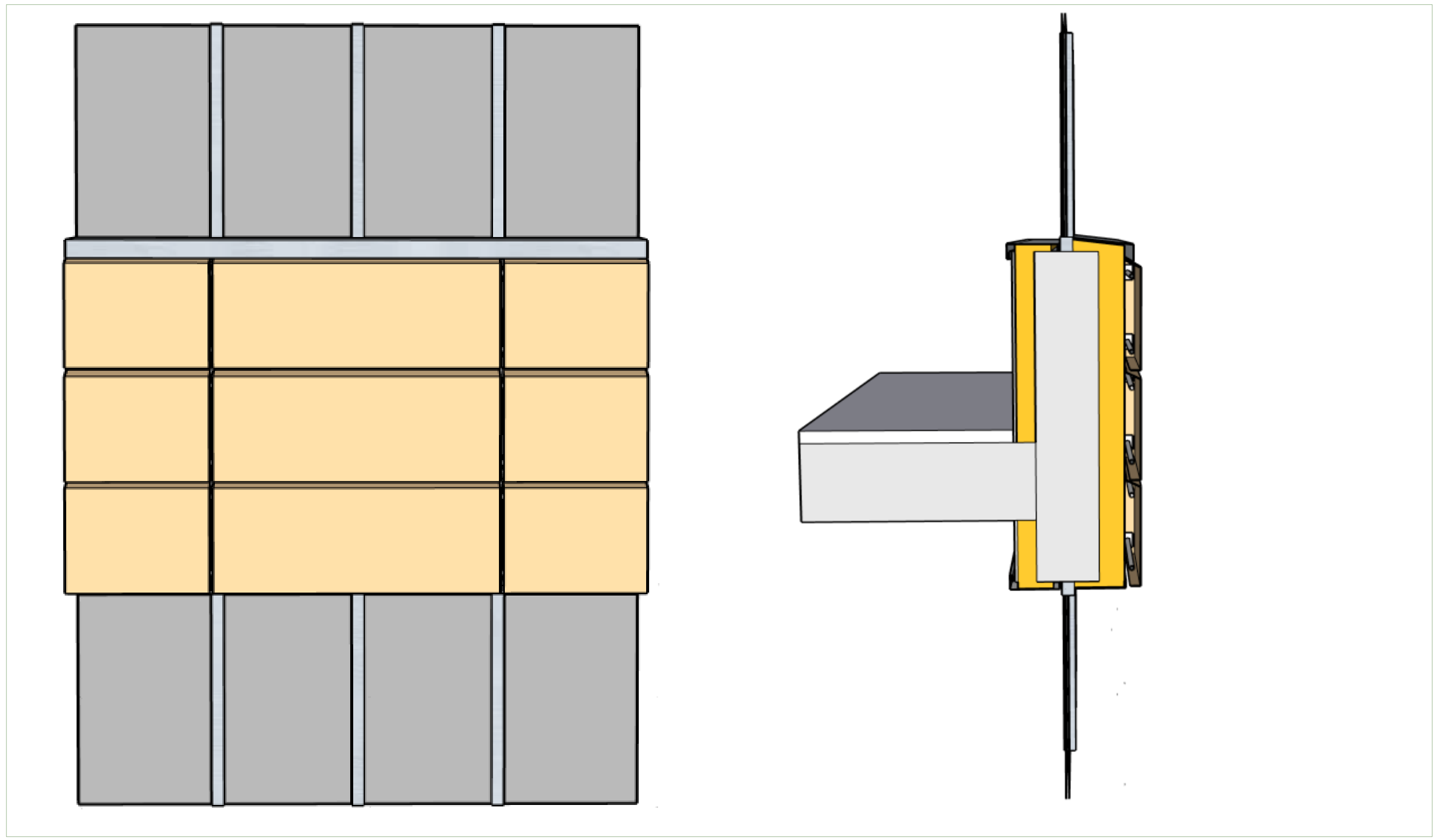
CASE STUDIES | Parapet facade



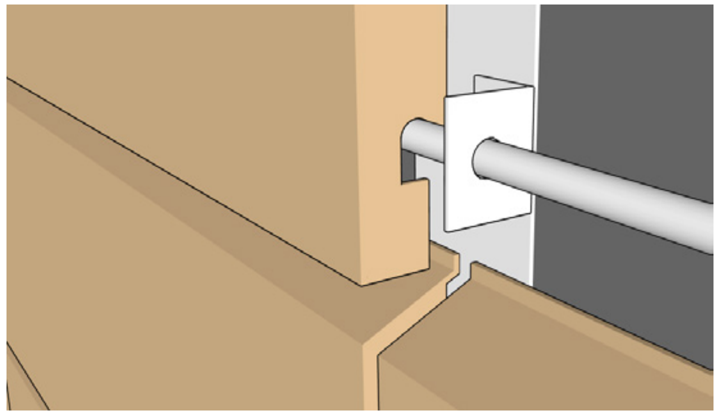


CASE STUDIES | Parapet facade

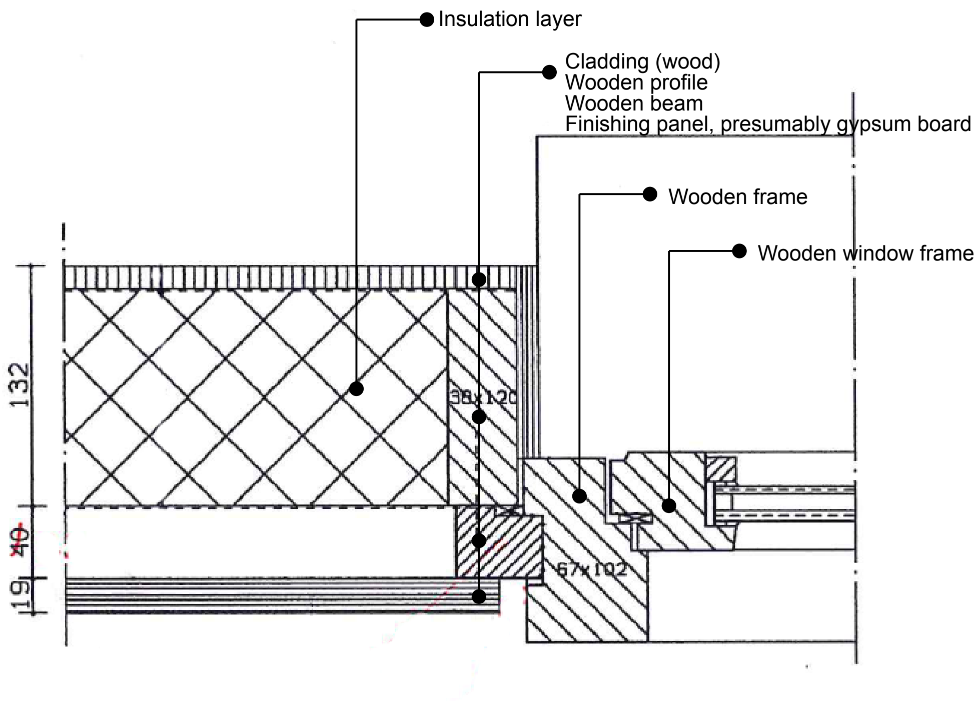


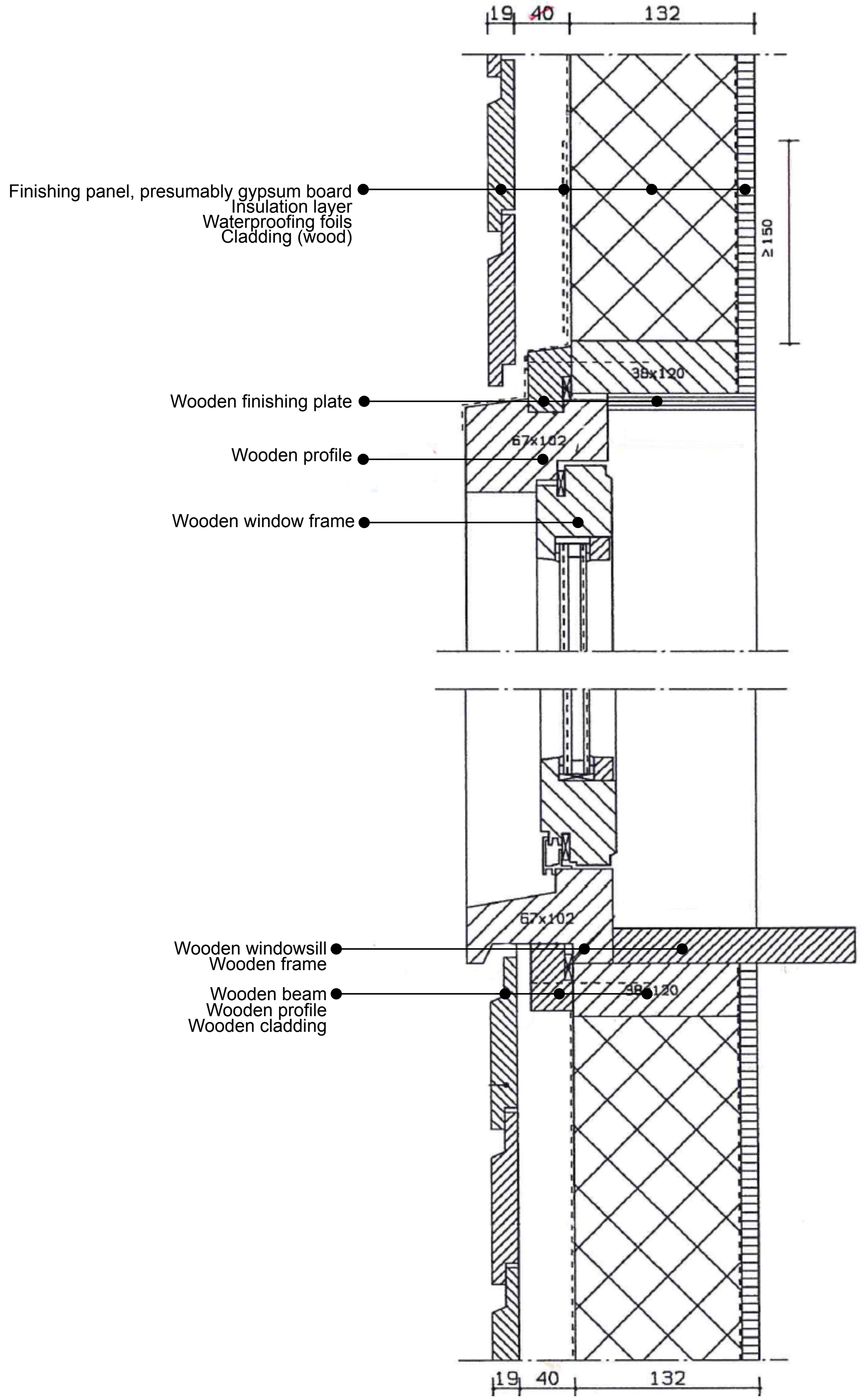


3mm thick biobased composite casettes
Secondary structure
90 mm Rockwool insulation
250 mm Concrete (existing)
70 mm Rockwool
9,5 mm gypsum board

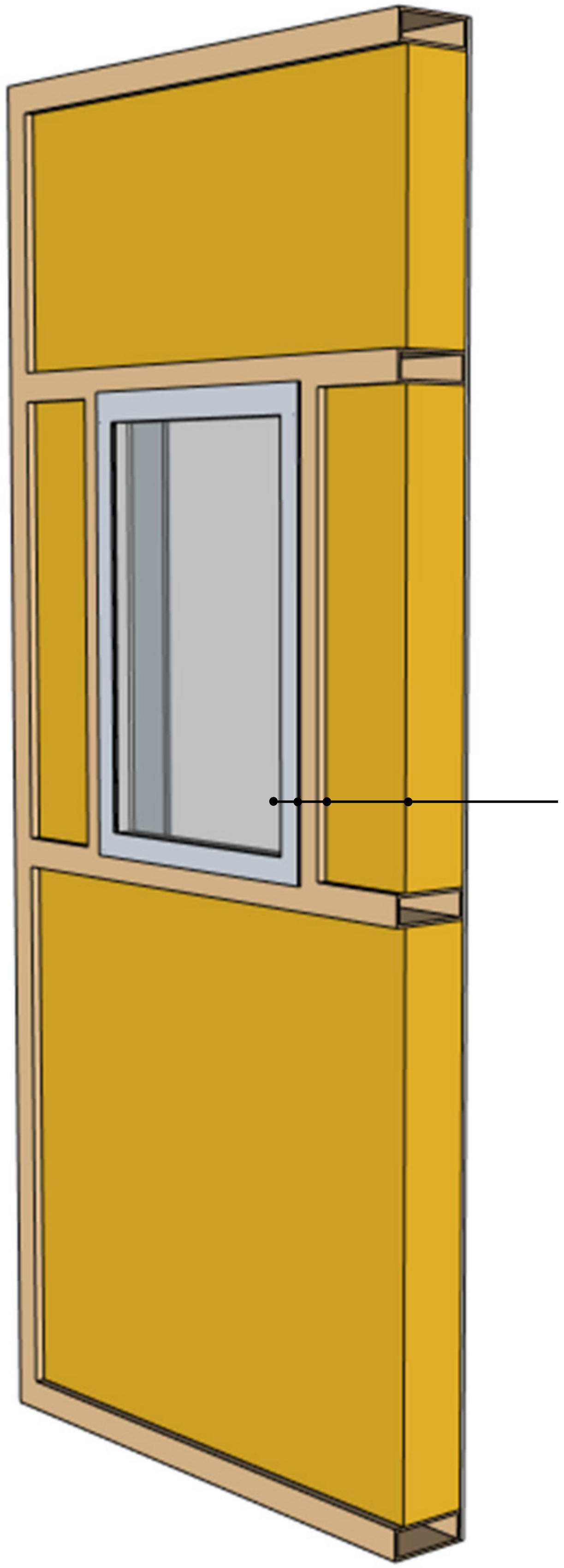


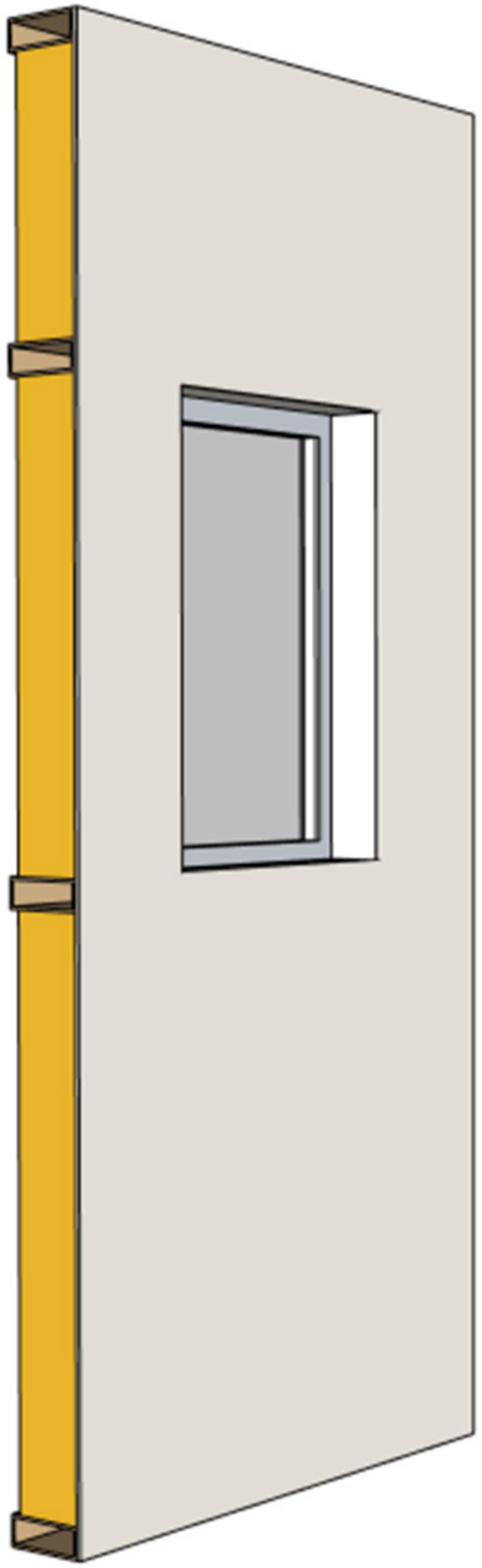
CASE STUDIES | Timber frame

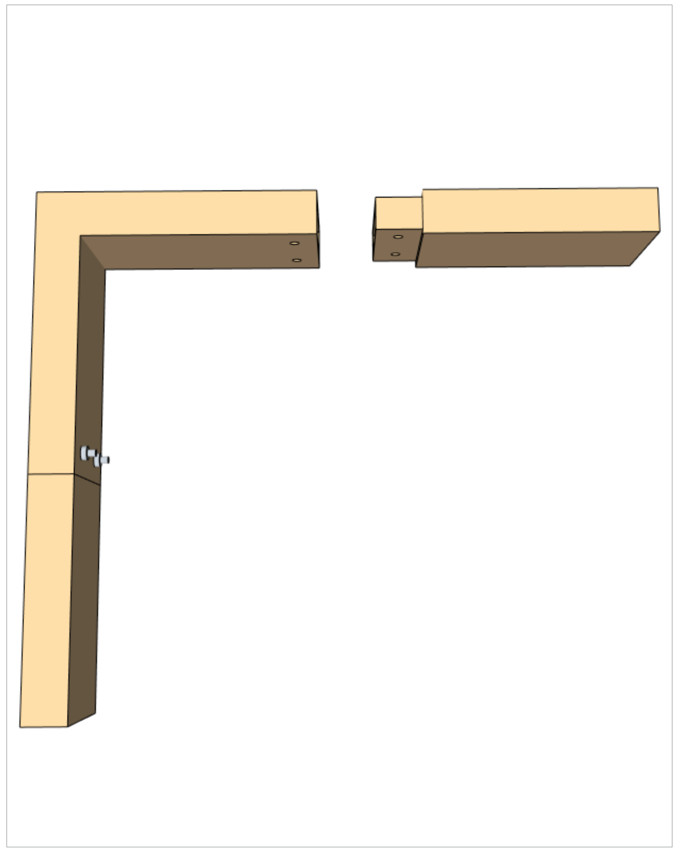


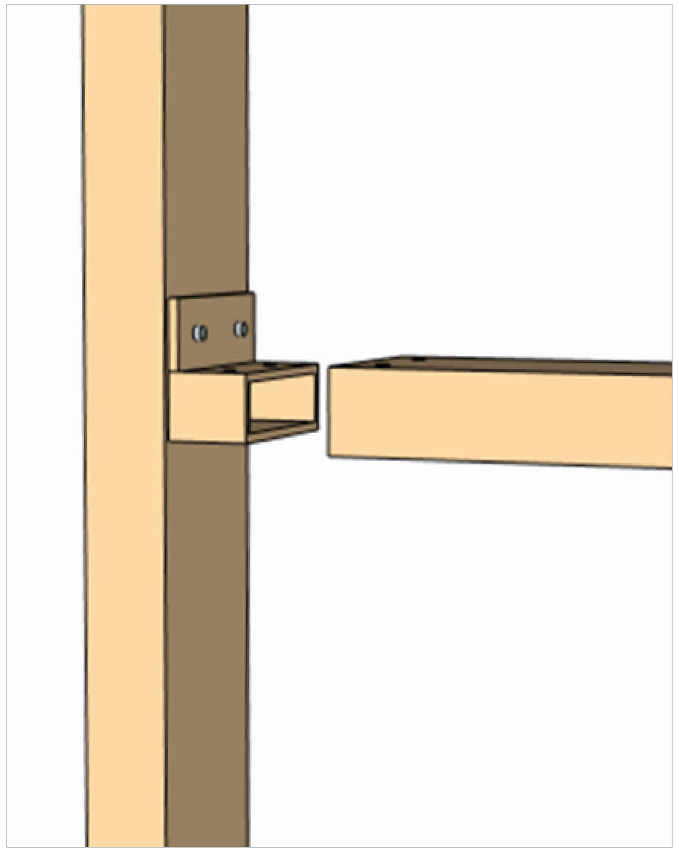


CASE STUDIES | Timber frame



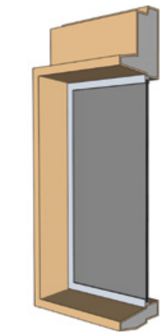
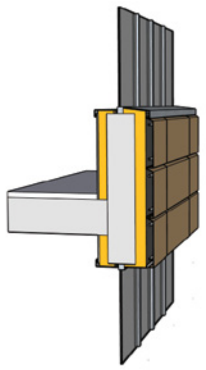
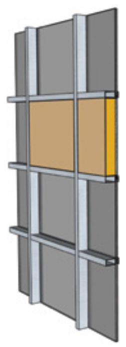
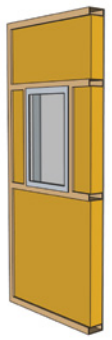






CASE STUDIES | Results

CASE STUDIES | Results

Concept	Weight (kg)			Shadowcosts (€)			Circular scenario
	46.63	113.58	65.37	26.17	41.99	35.83	
	213.22	18.65		2.87	2.73		
	29.09	11.32		4.01	2.60		
	42.11	27.41	20.72	2.20	4.75	3.16	

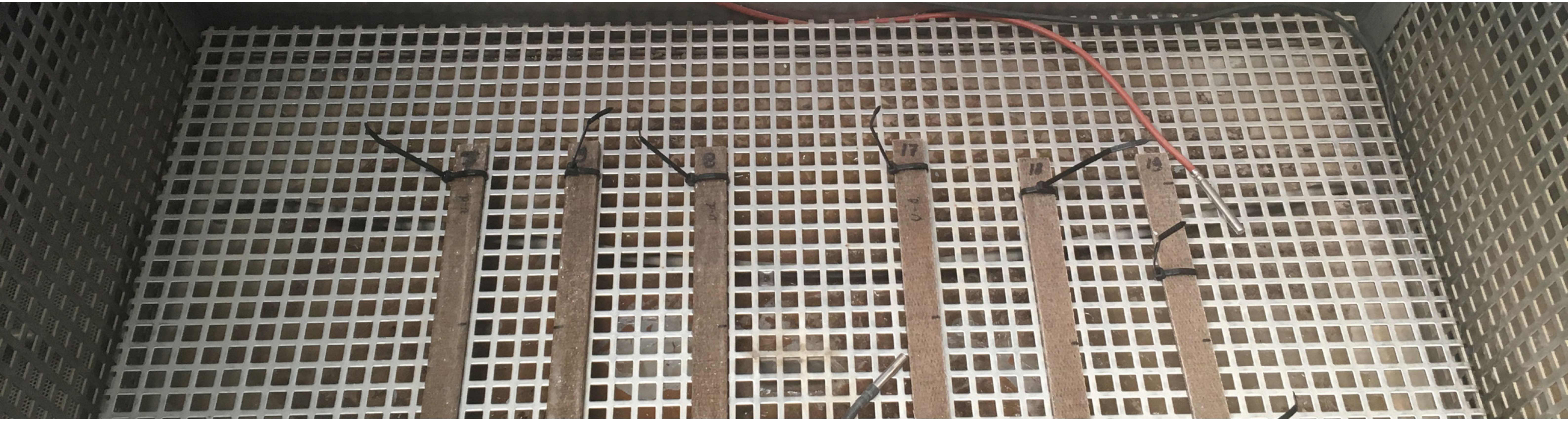
CONCLUSIONS

CONCLUSIONS | Shadowcosts

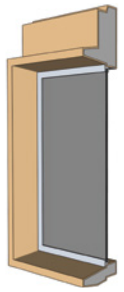
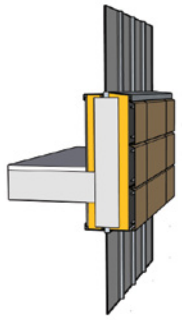
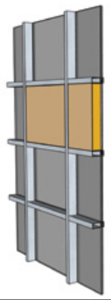
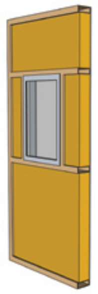
Material	Youngs modulus	Bending stiffness	“Needed” shadowcosts
Steel	3.5	1.3	0.17
Wood	27	22.5	0.01
GRP	1.01	-2	X
Aluminum	-4.7	X	X

CONCLUSIONS | Durability

The expectation is that when the material is coated and the bending stiffness is designed including a safety margin, the lifetime will be similar to other common facade materials



CONCLUSIONS | Circularity

Concept	Circular scenario	Concept	Circular scenario
			
			

CONCLUSIONS | Material scarcity

Environmental impact still quite high

□ Opportunity in replacing scarce materials

CONCLUSIONS | "Best concept"

"The aim is to explore whether a more environmental friendly composite material could be offered to designers while retaining the same design options current materials offer"

CONCLUSIONS | "Best concept"

Is biobased composite an environmental friendly alternative?

Does biobased composite offer the same design options current materials do?

"What is the best concept for a design with biobased composite ?"

RECOMMENDATIONS

RECOMMENDATIONS | Material development

1. Share information

RECOMMENDATIONS | Material development

2. Shadowcosts & Coating

Material	Youngs modulus	Bending stiffness	"Needed" shadowcosts
Steel	3.5	1.3	0.17
Wood	27	22.5	0.01
GRP	1.01	-2	X
Aluminum	-4.7	X	X

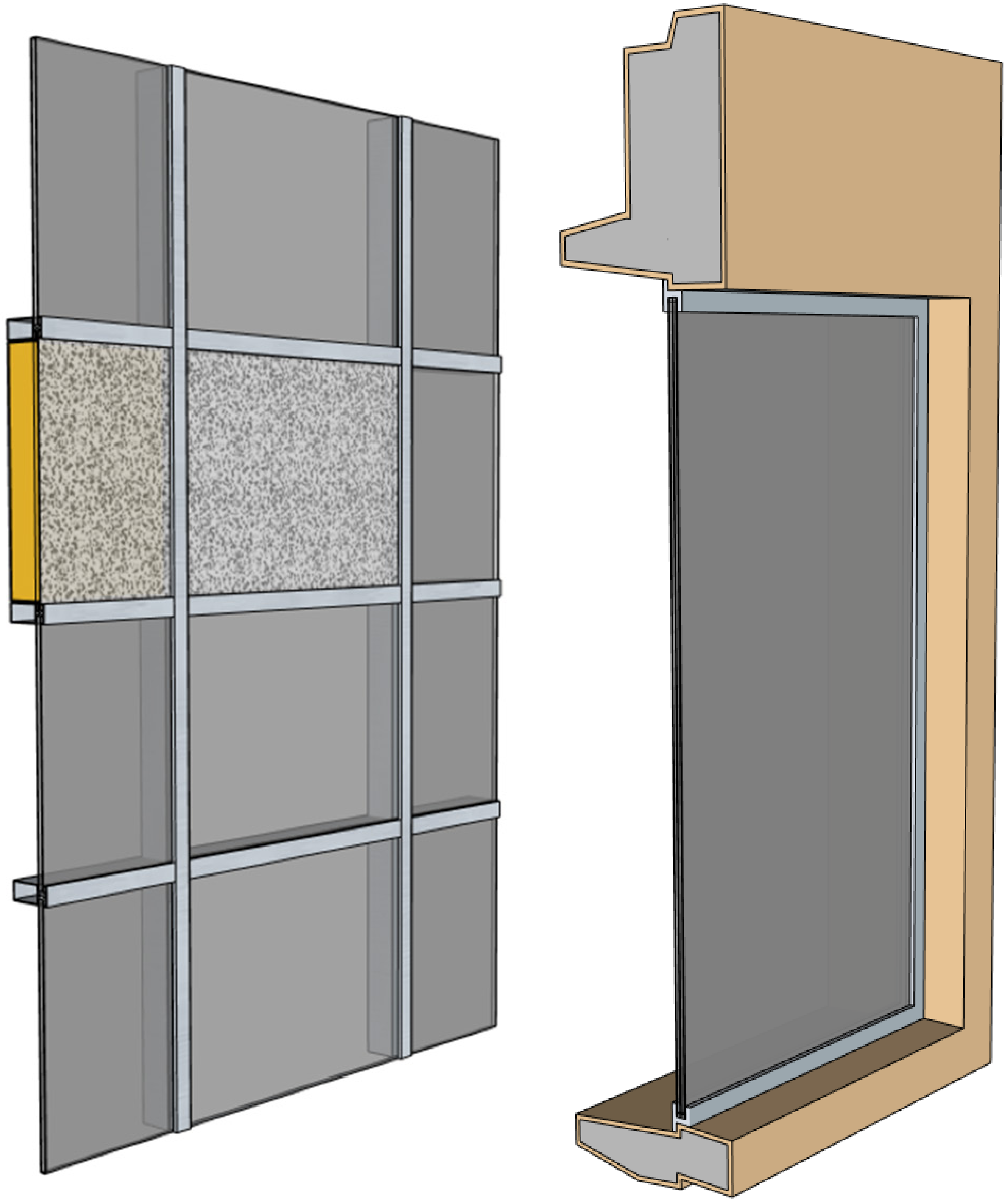
3. Testing Durability

3. Testing Recycling

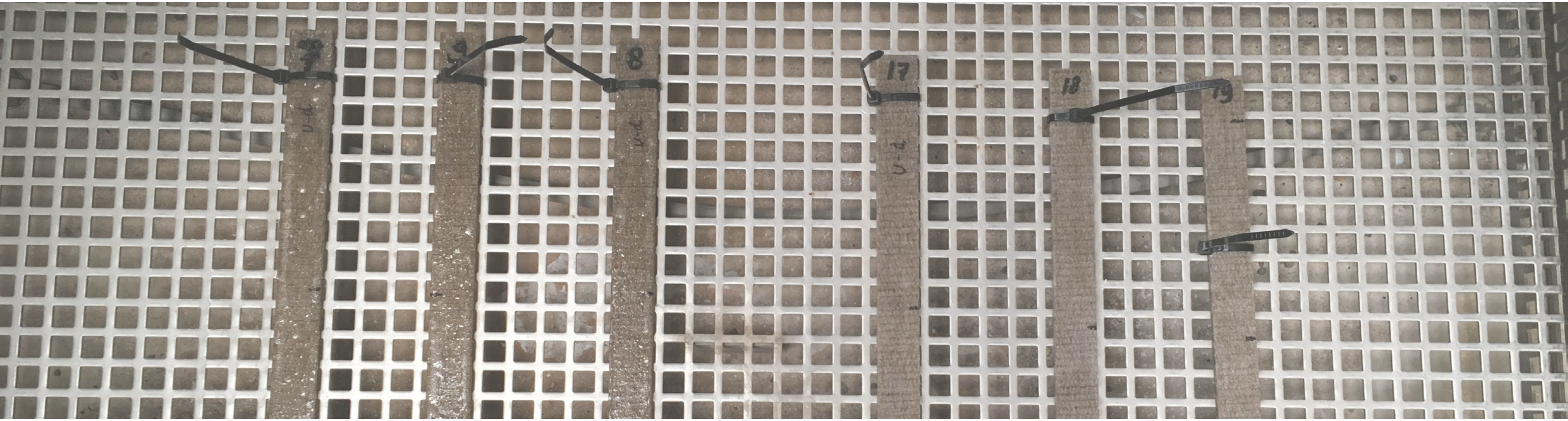
RECOMMENDATIONS | Concepts

6. Further design/elaboration of the concepts

- Improve circular scenario



7. Define a European/ Worldwide test method for new, innovative materials



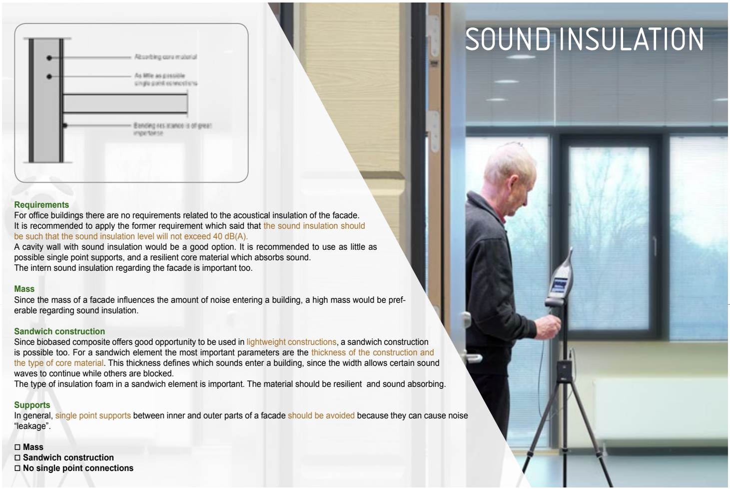
(Bio) Chemical:

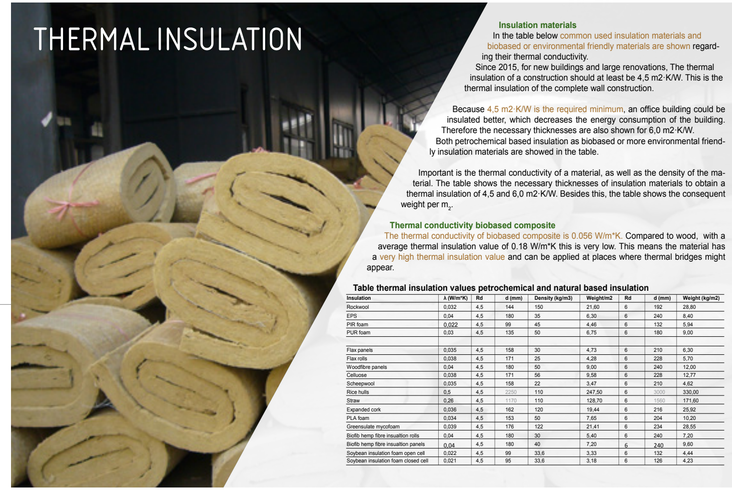
- Possibility of recycling (on large scale)
- Resin improvement
- Coating improvement

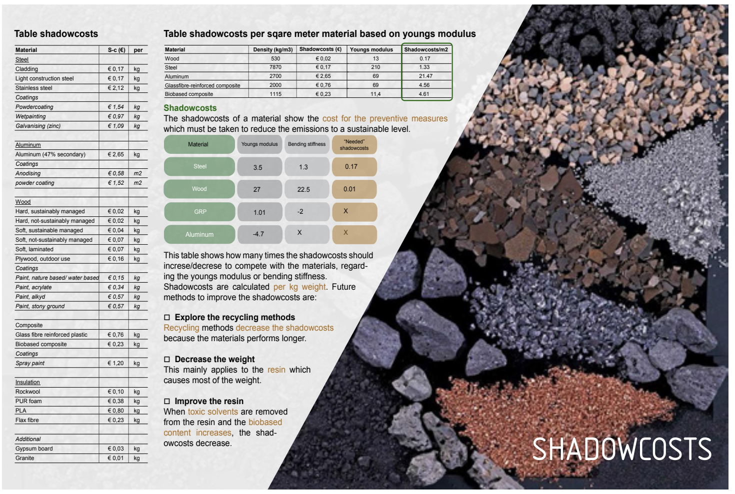
Facade technical:

- Structural calculations
- Circular building concepts

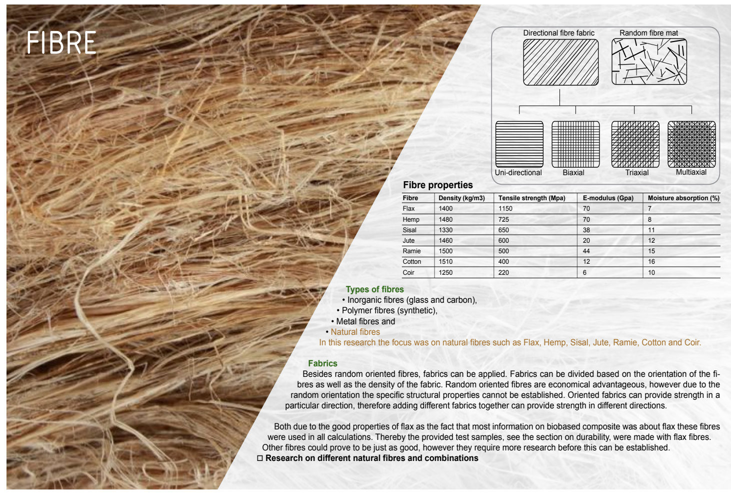
□ **How can the circular scenario of the concept facades be improved?**

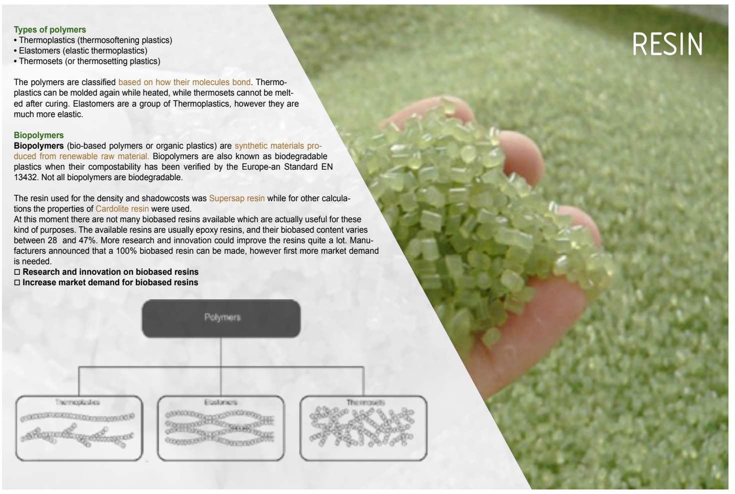


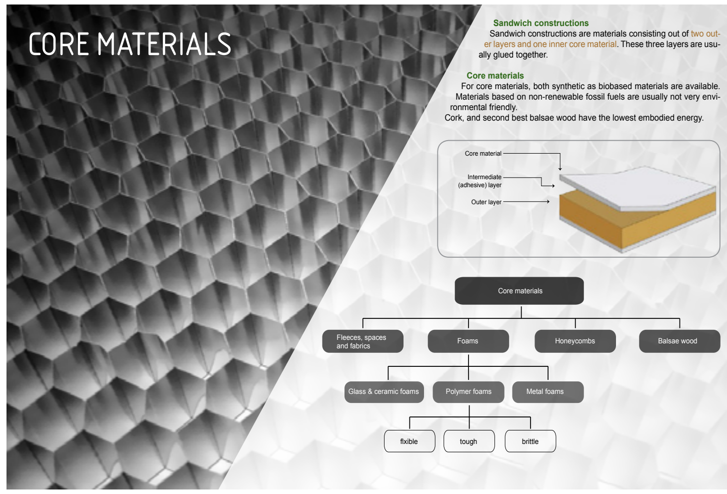


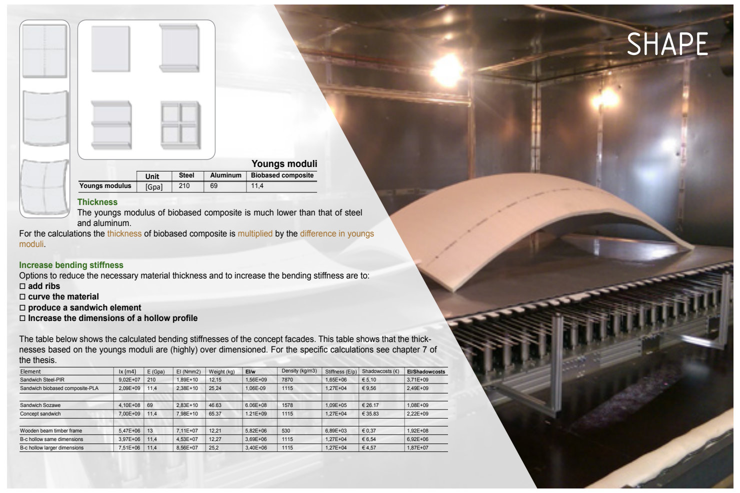


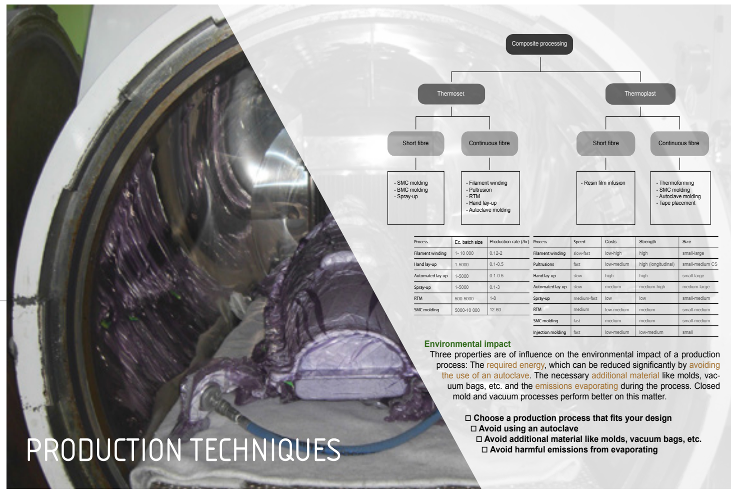
HOW TO DESIGN AND MANUFACTURE A CIRCULAR BIOBASED COMPOSITE FACADE

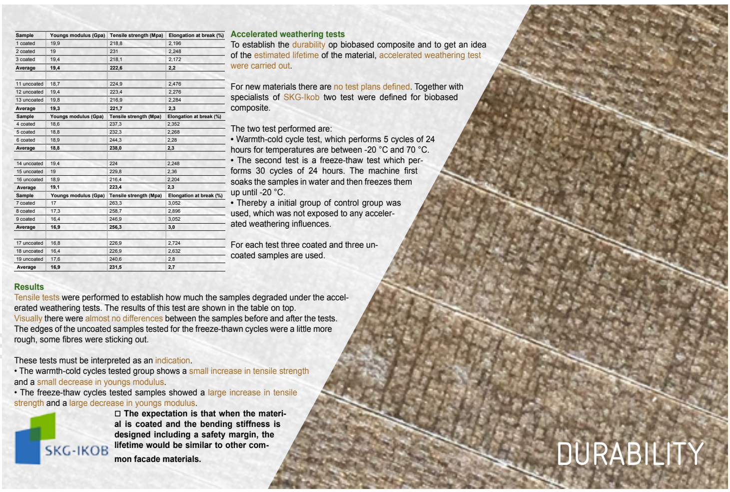


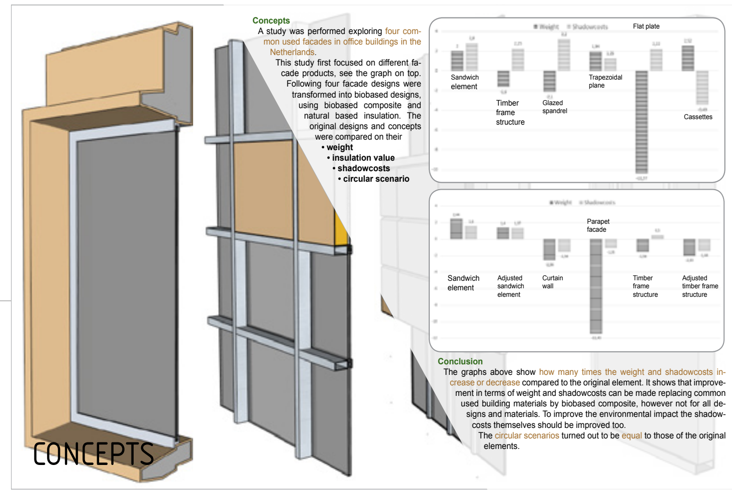


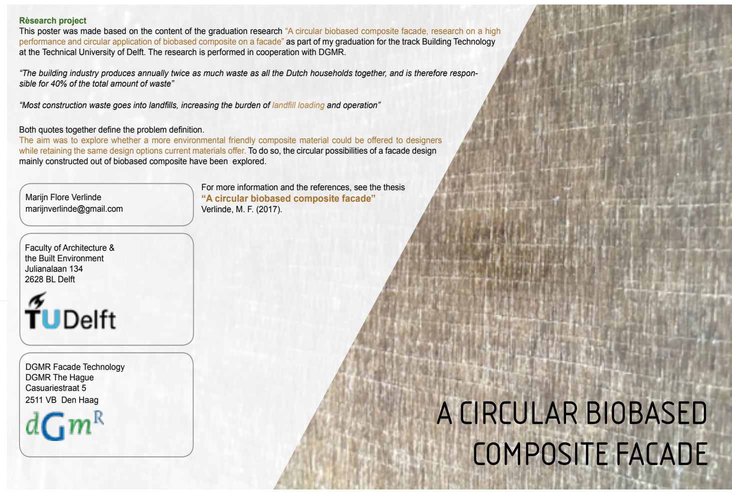












THANK YOU FOR YOUR ATTENTION