nZEBIO

Adoption of V4 buildings to nZEB standard using natural and bio-based materials

Olsztyn 09. – 12 . 09. 2021

Visegrad Fund

Project ID: 22010231

DEVELOPMENT OF BIOCOMPOSITE THERMAL INSULATION

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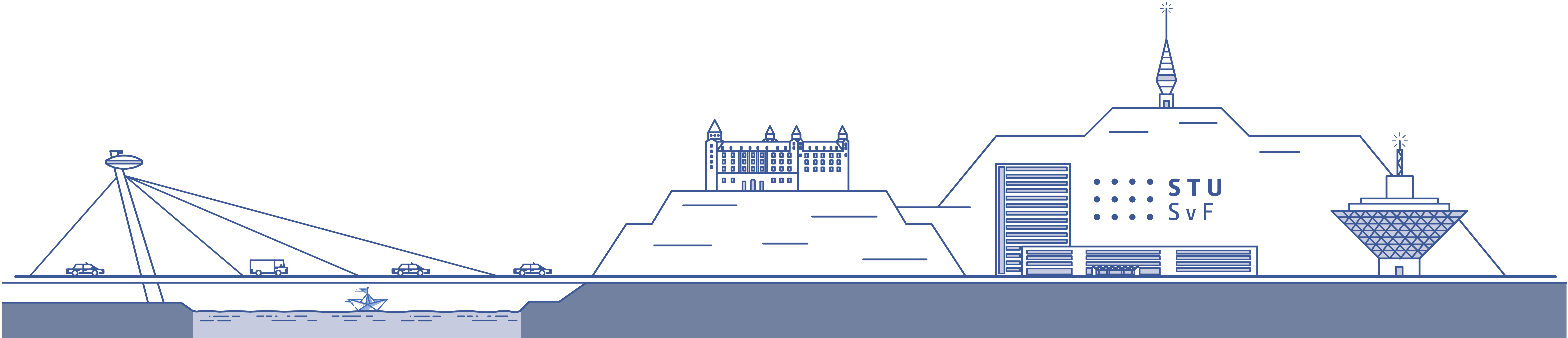
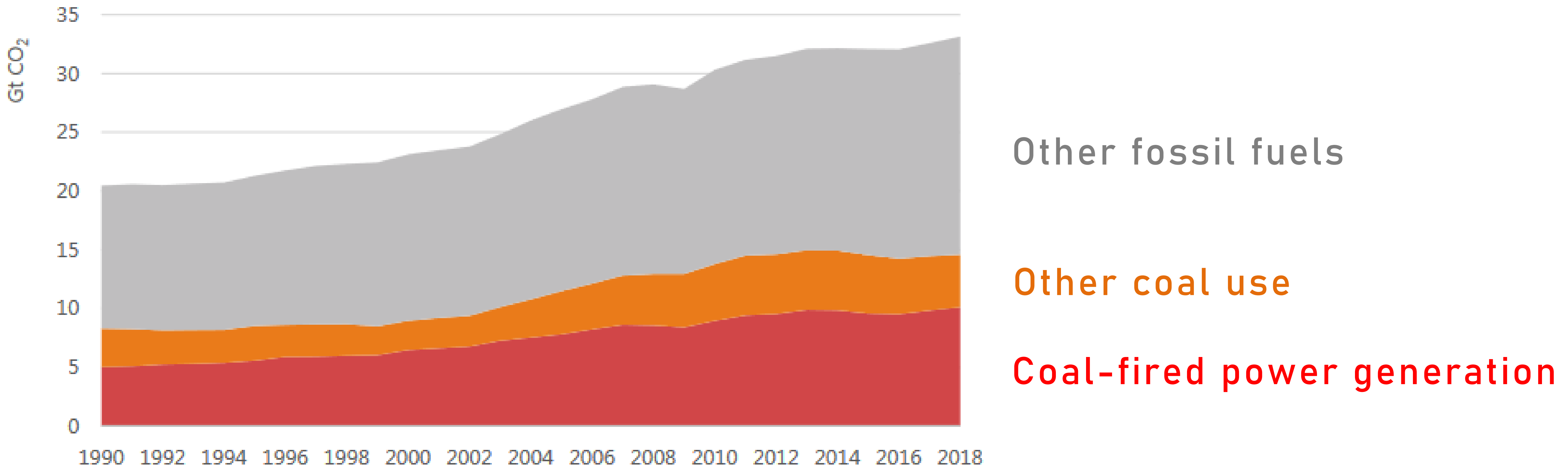


INTRODUCTION

I

Buildings consume about 40% of the world global energy, 25% of global water, 40% of global resources.

Buildings are responsible of about 1/3 of greenhouse gas emissions.



Global energy-related carbon dioxide emissions

LIFE CYCLE ASSESSMENT (LCA)

II

The reduction of the energy demands in all life phases of the buildings is an important challenge of the future.

Thermal insulation is one of the best ways to reduce the energy consumption due to both winter heating and summer cooling.

LIFE CYCLE ASSESSMENT (LCA)

LCA is a method evaluating the potential environmental impacts of products and services and their resource consumption.

In a building sector, LCA is a part of the assessment of building environmental sustainability.

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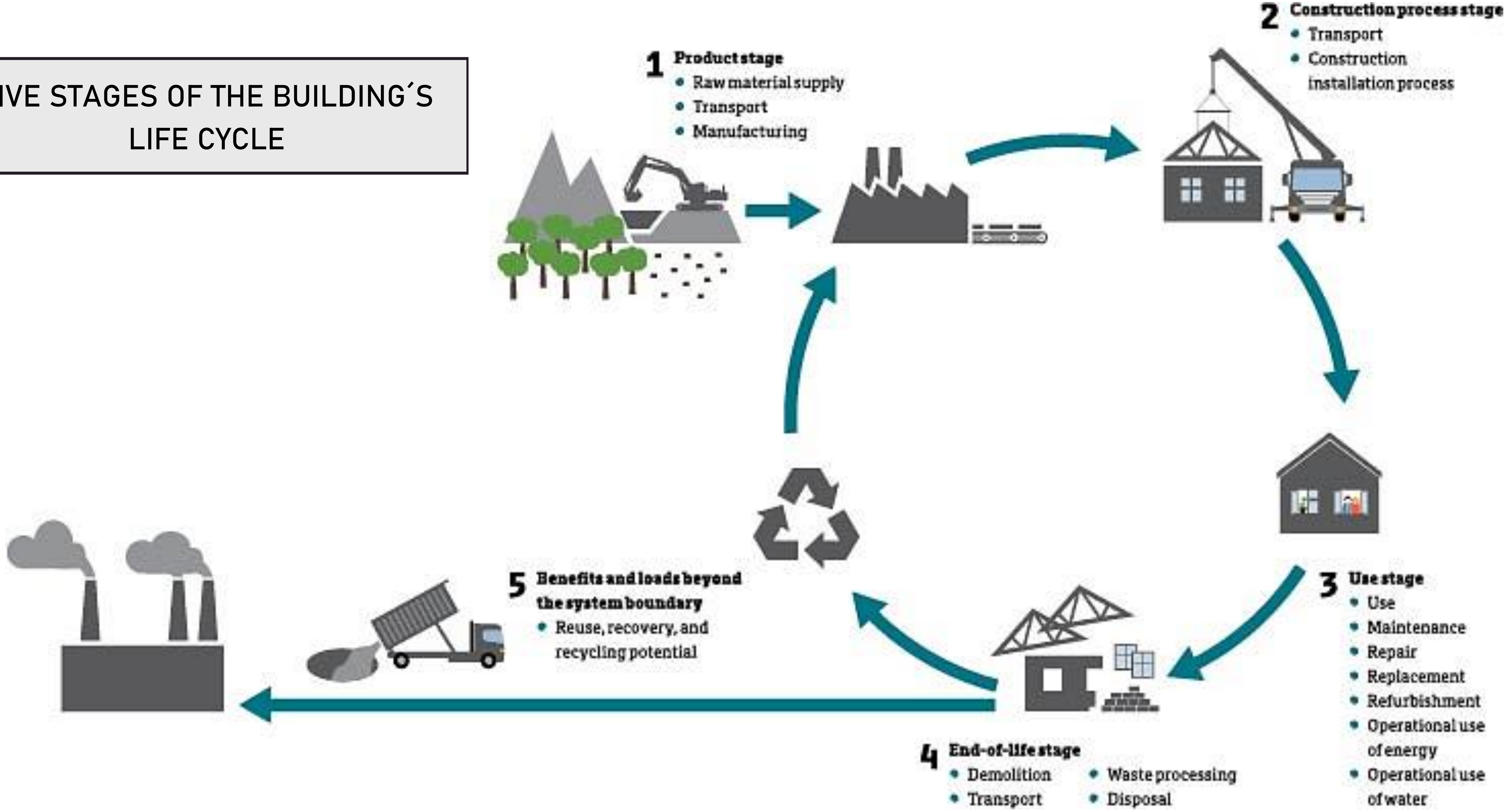
FIVE STAGES OF THE BUILDING´S LIFE CYCLE



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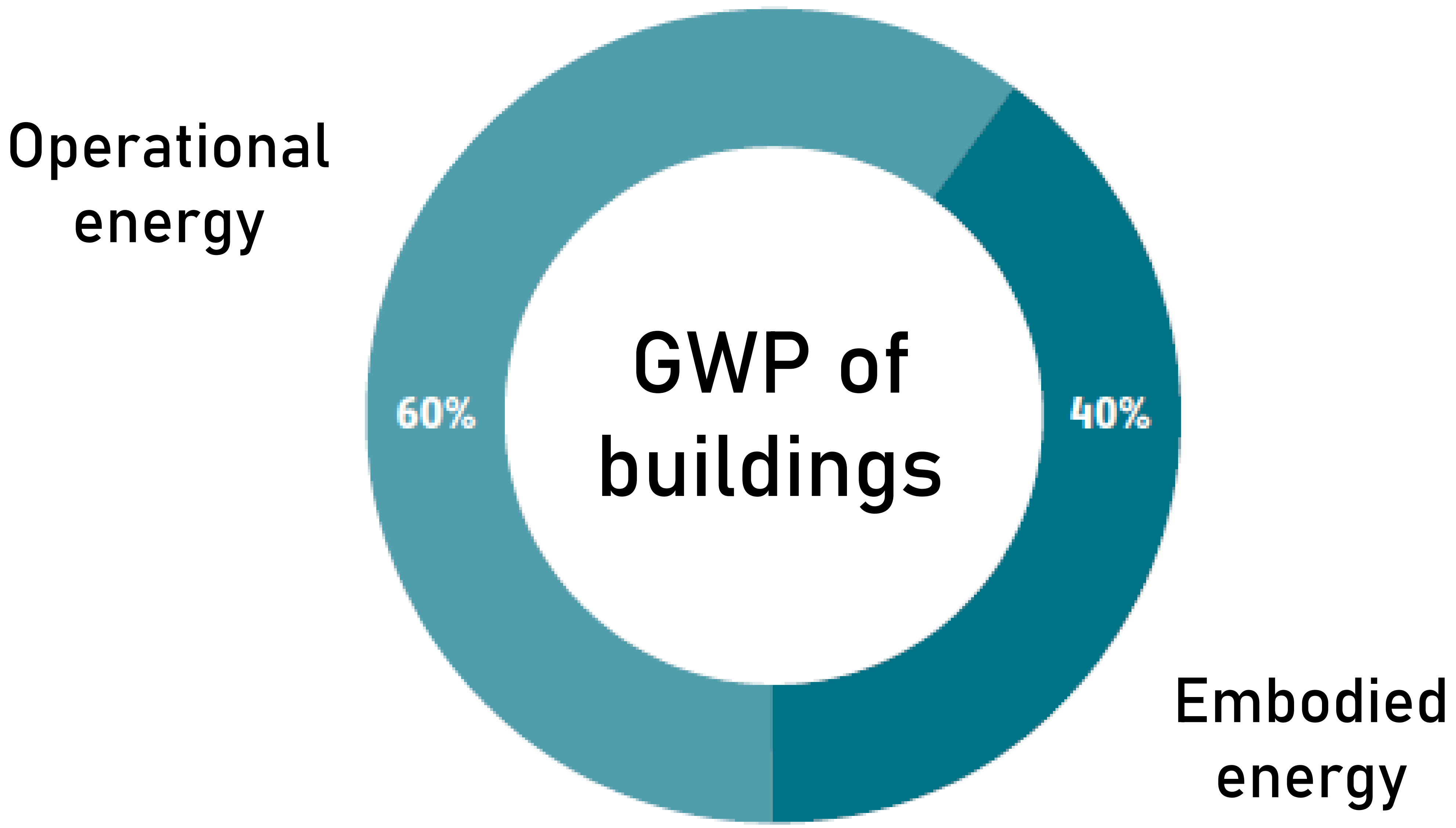
The most used indicators for assessing environmental impact and resource use

Global Warming Potential (CO_2 equivalents)

Total Use of Primary Energy (MJ or kWh)

Embodied vs. operational energy



CHARACTERIZATION OF INSULATION MATERIALS

III

THERMAL

Thermal conductivity

λ

W/(m.K)

CHARACTERIZATION OF INSULATION MATERIALS

ENVIRONMENTAL

Cumulative Energy Demand is the primary energy consumed during the considered life cycle of a product. (MJ or kWh)

Global Warming Potential evaluates impact to the global warming of a product. (CO_2 equivalents)

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

IV

Commonly used thermal insulating materials contain petrochemicals (mainly polystyrene) or they are processed with high energy consumption (glass and rock wool).

These materials have negative impact on environment
in production stage and in disposal stage (problem with reusing or recycling).

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Use of a thermal insulation ensures reduction of energy loss of buildings whole year.

- Commonly used thermal insulations
- Thermal insulations based on natural materials
- Thermal insulations based on recycled materials

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Thermal characteristics

Material	Density [kg/m³]	Thermal conductivity [W/(mK)]
Stone wool	40 - 200	0,033 – 0,040
Expanded Polystyrene	15 - 35	0,031 – 0,038
Extruded Polystyrene	32 - 40	0,032 – 0,037
Kenaf	30 - 180	0,034 – 0,043
Sheep wool	10 - 25	0,038 – 0,054

Commonly used thermal insulations

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Thermal characteristics

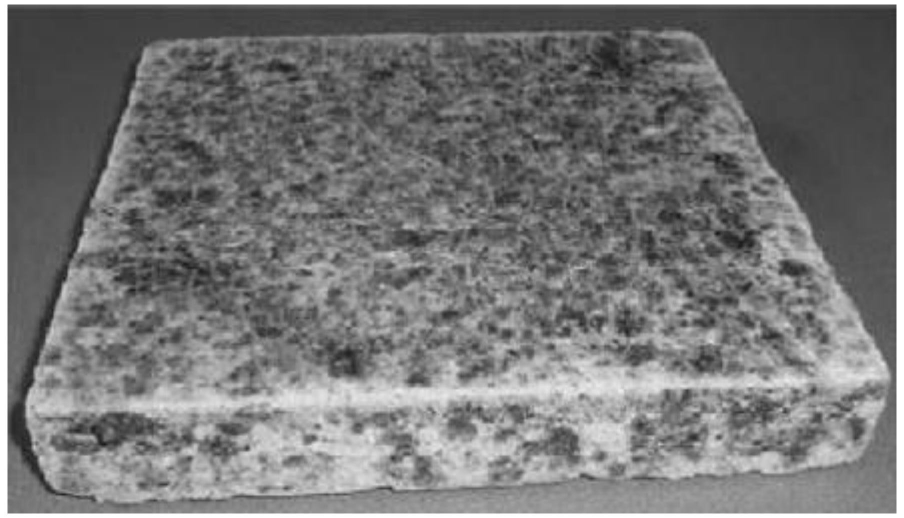
Material	Density [kg/m³]	Thermal conductivity [W/(mK)]
Banana and polypropylene fiber	980 - 1040	0,157 - 0,182
Bagasse	70 - 350	0,046 - 0,055
Corn cob	171 - 334	0,101
Cotton stalks	150 - 450	0,0585 - 0,0815
Date palm	187 - 389	0,072 - 0,085
Durian	357 - 907	0,064 - 0,185
Oil palm	20 - 120	0,055 - 0,091
Pecan	600 - 680	0,0884 - 0,1030
Pineapple leaves	178 - 232	0,035 - 0,042
Reeds	130 - 190	0,045 - 0,056
Rice	154 - 168	0,0464 - 0,566
Sansevieria fiber	1410	0,132
Sunflower (cake from biorefinery)	500 - 585	0,0885 - 0,110
Sunflower pith	36 - 152	0,0385 - 0,0501
Straw bale	50 - 150	0,038 - 0,067

Thermal insulations based on natural materials

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Sugarcane

Sunflower pith agromaterial



Straw bale wall

Reed panel

Pineapple leaf fiber

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Thermal characteristics

Material	Density [kg/m³]	Thermal conductivity [W/(mK)]
Cotton (recycled)	25 - 45	0,039 - 0,044
Cotton (recycled denim)	N	0,036 - 0,038
Recycled glass	450	0,031
Recycled glass	100 - 165	0,038 - 0,050
Recycled PET	30	0,0355
Recycled PET	15 - 60	0,034 - 0,039
Recycled textile	30 - 80	0,0358 - 0,042
Recycled textile fibres (polyester, polyurethane)	440	0,044
Recycled textile fibres (syntetic)	200 - 500	0,041 - 0,053
Recycled textile a paper	433	0,034 - 0,039

Thermal insulations based on recycled materials

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Recycled denim

Recycled cotton

Recycled PET samples

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Environmental characteristics

Material	f.u. weight	Thermal conductivity	Energy consumption	Global warming potential	Approach and system boundary
	[kg]	[W/(mK)]	[MJ per f.u.]	[kg CO_2 per f.u.]	
Cellulose	2,34	0,039	19,39	0,73	CTGA, Europe
Cork	7,35	0,049	378,65	5,93	N
Expanded clay (loose)	31,50	0,090	161,14	10,31	CTGA, Europe
Expanded perlite (panels)	4,50	0,050	67,31	3,99	CTGA, Europe
Expanded polystyrene	0,80	0,040	127,31	5,05	CTGA, Europe
Expanded polystyrene	1,13	0,038	118,67	8,25	N
Expanded polyurethane	0,90	0,030	126,40	5,31	CTGA, Europe
Expanded vermiculite	6,30	0,070	53,37	3,36	CTGA, Europe
Extruded polystyrene	1,75	0,350	127,31	13,22	CTGA, Europe
Glass wool	8,00	0,050	229,02	9,89	CTGA, Europe
Hemp	1,20	0,038	23,65	0,17	CTGR, N
Jute fibres	5,00	0,050	105,54	2,79	CTGA, Europe
Kenaf	1,52	0,038	59,37	3,17	CTGA, Italy
Kenaf fibres	1,90	0,038	42,32	1,13	CTGA, Europe
Natural pumice	55,00	0,110	1,82	0,08	CTGA, Europe
Polyurethane	0,96	0,032	99,63	6,51	N
Recycled PET	1,07	0,036	83,72	1,78	CTGA, Italy
Recycled PET	1,48	0,037	21,06	3,12	CTGR, N
Recycled textile	1,79	0,036	17,57	1,55	CTGR, N
Sheep wool	0,76	0,038	17,12	1,46	CTGR, N
Rock wool	1,20	0,040	53,09	2,77	CTGA, Europe

A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Environmental characteristics

Energy consumption

Cork
378,65 MJ/f.u.

Glass wool
229,02 MJ/f.u.

Expanded clay
161,14 MJ/f.u.

Expanded polystyrene
127,31 MJ/f.u.

Extruded polystyrene
127,31 MJ/f.u.

Extruded polyurethane
126,4 MJ/f.u.

Material	f.u. weight [kg]	Thermal conductivity [W/(mK)]	Energy consumption [MJ per f.u.]	Global warming potential [kg CO_2 per f.u.]	Approach and system boundary
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A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Environmental characteristics

Energy consumption

Natural pumice
1,82 MJ/f.u.

Sheep wool
17,12 MJ/f.u.

Recycled textile
17,12 MJ/f.u.

Cellulose
19,39 MJ/f.u.

Recycled PET
21,06 MJ/f.u.

Hemp
23,65 MJ/f.u.

Material	f.u. weight [kg]	Thermal conductivity [W/(mK)]	Energy consumption [MJ per f.u.]	Global warming potential [kg CO_2 per f.u.]	Approach and system boundary
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A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Environmental characteristics

Global warming potential

Extruded polystyrene
13,22 kg CO_2/f.u.

Expanded clay
10,31 kg CO_2/f.u.

Glass wool
9,89 kg CO_2/f.u.

Expanded polystyrene
8,25 kg CO_2/f.u.

Polyurethane
6,51 kg CO_2/f.u.

Material	f.u. weight [kg]	Thermal conductivity [W/(mK)]	Energy consumption [MJ per f.u.]	Global warming potential [kg CO_2 per f.u.]	Approach and system boundary
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A REVIEW AND COMPARISON OF THERMAL BUILDING INSULATION MATERIALS

Environmental characteristics

Global warming potential

Natural pumice
0,08 kg CO_2/f.u.

Hemp
0,17 kg CO_2/f.u.

Cellulose
0,73 kg CO_2/f.u.

Kenaf fibres
1,13 kg CO_2/f.u.

Sheep wool
1,46 kg CO_2/f.u.

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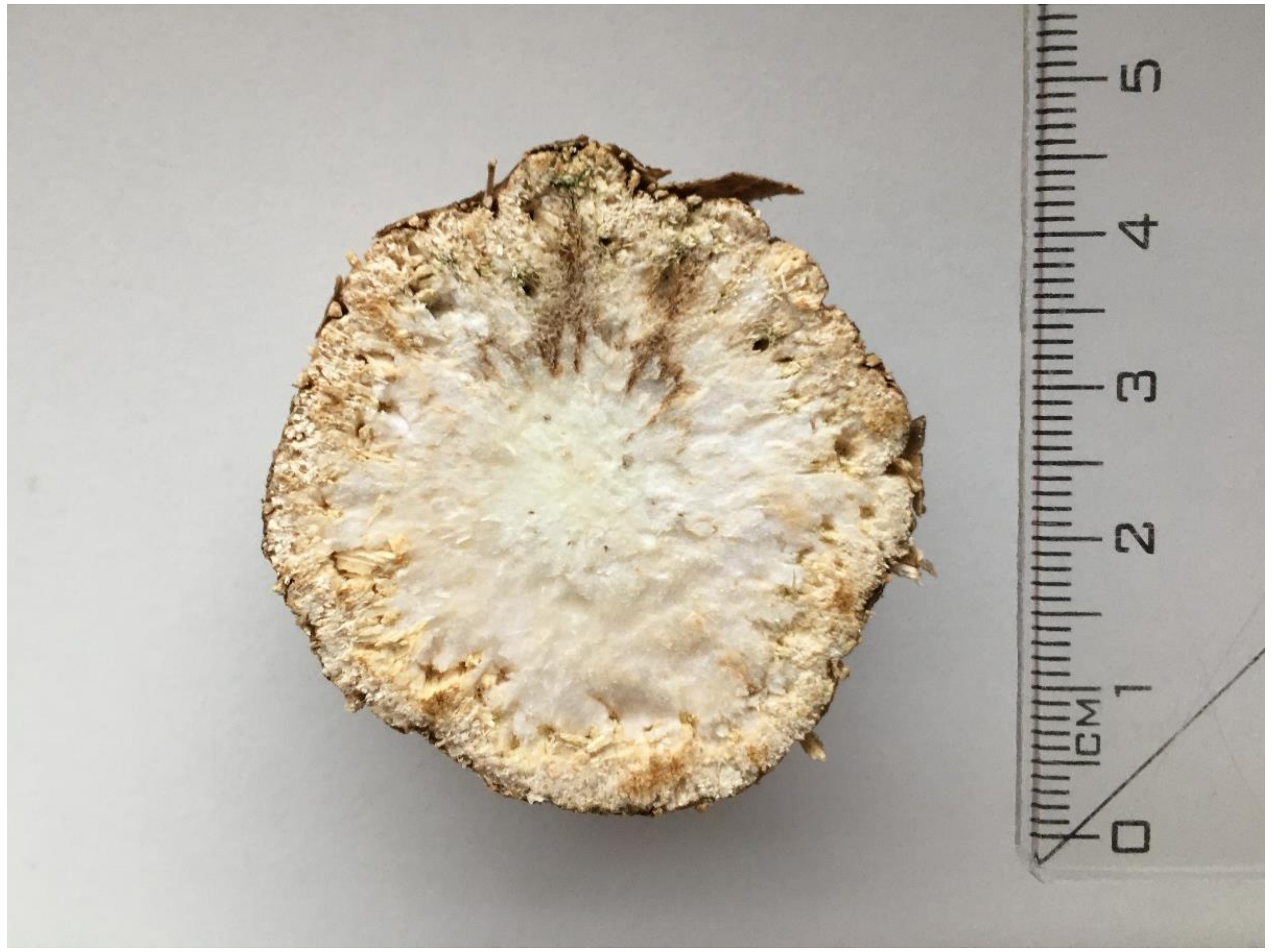
PREVIEW CONCLUSION

Currently used thermal insulations have a greater environmental impact than most of the unconventional materials mentioned in the overview.

The only objective is not to improve the thermo-technical parameters of the materials. It is also essential to focus on the life cycle of materials from production to disposal or recycling.

MATERIAL SELECTED

V



Cross section of dried sunflower stem

MATERIAL SELECTED

Samples of PIR thermal insulation and dried sunflower pith

GOALS

VI

Main goal is to develop high efficiency thermal insulation with low impact on the environment and health.

- creating, testing, optimizing
- calculating
- comparing
- prototype

METODICS

VII

Specimen will be tested in a laboratory.

Guarded hot plate apparatus will be used to find out the thermal conductivity.

STN	Tepelnotechnické vlastnosti stavebných materiálov a výrobkov. Stanovenie tepelného odporu metódou chránenej teplej dosky a metódou meradla tepelného toku. Výrobky s vysokým a stredným tepelným odporom.	STN EN 12667 73 0573

Thermal performance of building materials and products. Determination of thermal resistance by means of guarded hot plate and heat flow meter methods. Products of high and medium thermal resistance

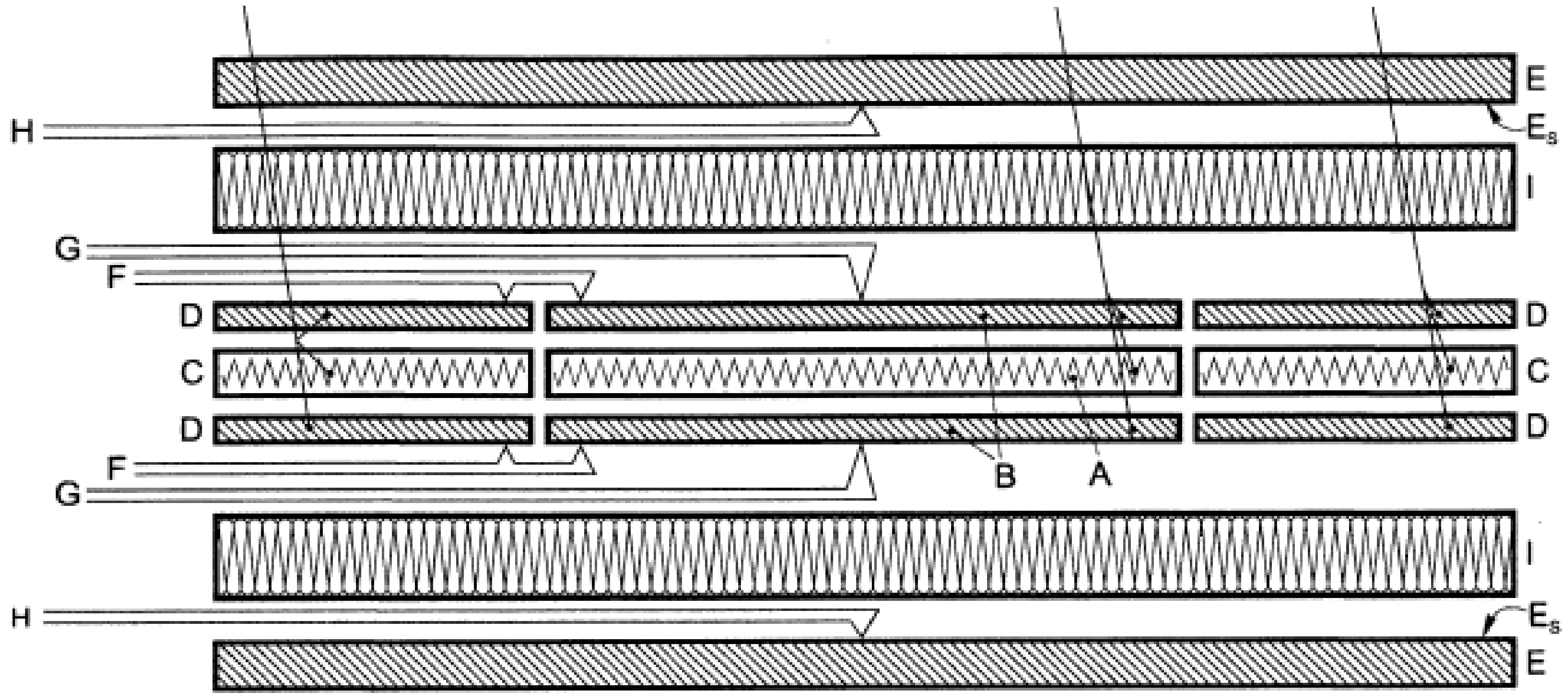
EN 12667:2001
Thermal performance of building materials and products. Determination of thermal resistance by means of guarded hot plate and heat flow meter methods.

METODICS

Heat unit guard section

Heat unit metering section

Heat unit guard section



Guarded hot plate apparatus

A Metering section heater
B Metering section surface plates
C Guard section heater
D Guard section surface plates
E Cooling unit
E_S Cooling unit surface plate
F Differential thermocouples
G Heating unit surface thermocouples
H Cooling unit surface thermocouples I
Testing specimen

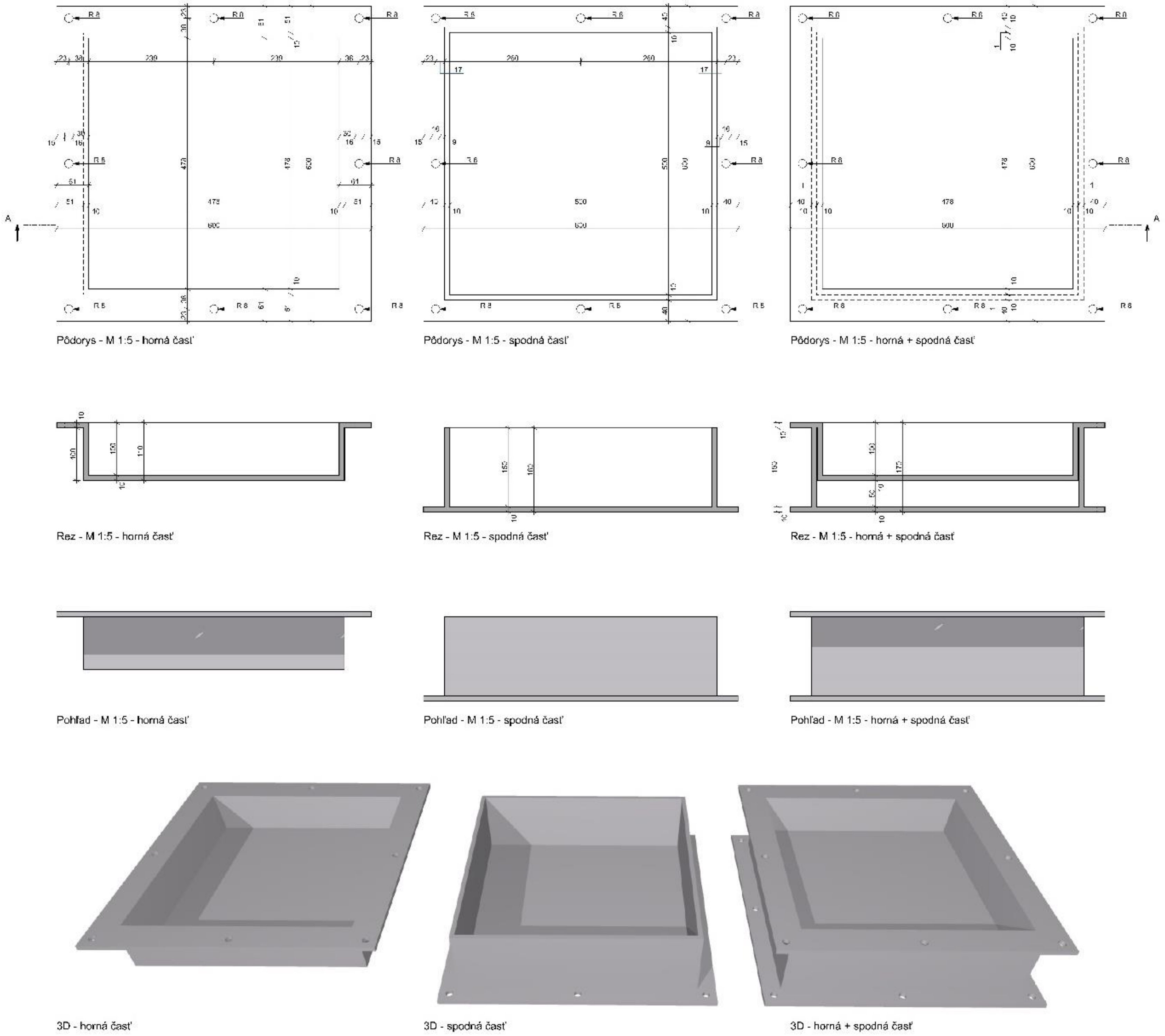
CALCULATIONS

VIII

Thermal conductivity: $\lambda = \frac{\Phi . d}{A.(T_1 - T_2)}$ (W/(m.K))

T_1 the average specimen hot side temperature (K)
T_2 the average specimen cold side temperature (K)
d the average specimen thickness (m)
Φ the average power supplied to the metering section of the heating unit (W)
A the metering area (m^2)

MOLD


Pôdorys - M 1:5 - horná časť
Pôdorys - M 1:5 - spodná časť
Pôdorys - M 1:5 - horná + spodná časť
Rez - M 1:5 - horná časť
Rez - M 1:5 - spodná časť
Rez - M 1:5 - horná + spodná časť
Pohľad - M 1:5 - horná časť
Pohľad - M 1:5 - spodná časť
Pohľad - M 1:5 - horná + spodná časť
3D - horná časť
3D - spodná časť
3D - horná + spodná časť

CONCLUSION

IX

Energy saving should become a strategic goal in the whole world, that will lead to protect the environment and conserve natural sources.

The energy consumption of a building is strongly depending on characteristics of its envelope.

That's why there is a necessity to develop insulating material that possess excellent properties with less environmental impacts.

RESOURCES

[1] *Global Energy and CO2 Status Report: The Latest Trends in Energy and Emissions 2018* [online]. International Energy Agency, Marec 2018, 29s. Dostupné z: https://webstore.iea.org/download/direct/2461?fileName=Global_Energy_and_CO2_Status_Report_2018.pdf

[2] Energy Efficiency: Buildings: The global exchange for energy efficiency policies, data and analysis. *iea.org* [online]. International Energy Agency. Dostupné z: https://www.iea.org/topics/energyefficiency/buildings/

[3] Asdrubali, F., D'Alessandro, F., Schiavoni, S.: A review of unconventional sustainable building insulation materials. *Sustainable Materials and Technologies*, 4. vydanie, s. 1-17, ISSN 2214-9937, 2015.

[4] Valančius, K., Vilutienė,T., Rogoža, A.: Analysis of the payback of primary energy and CO2 emissions in relation to the increase of thermal resistance of a building. *Energy and Buildings*, 179. vydanie, s. 39-48, ISSN 0378-7788, 2018.

[5] Abu-Jdayil, B., Mourad, A-H., Hittini, W., Hassan, M., Hameedi, S.: Traditional, state-of-the-art and renewable thermal building insulation materials: An overview. *Construction and Building Materials*, 214. vydanie, s. 709-735, ISSN 0950-0618, 2019.

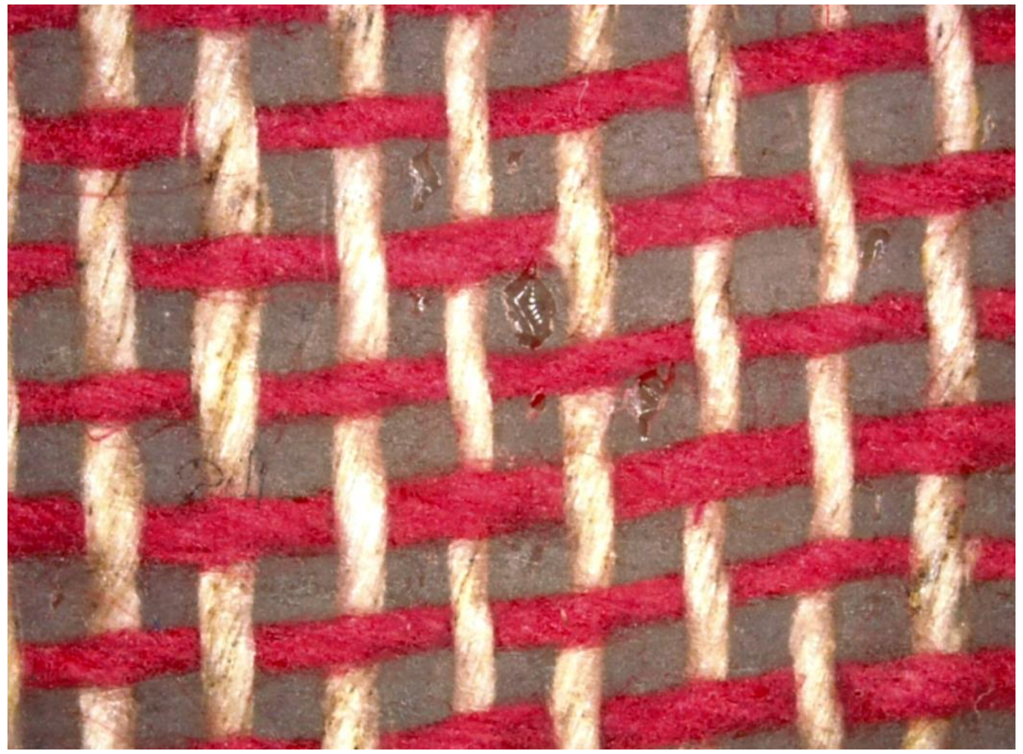
[6] STN EN 12667: 2001. Tepelnotechnické vlastnosti stavebných materiálov a výrobkov. Stanovenie tepelného odporu metódou chránenej teplej dosky a metódou meradla tepelného toku. Výrobky s vysokým a stredným tepelným odporom, 2001.

[7] Introduction to LCA of Buildings. Danish Transport and Construction Agency. ISBN 978-87-90661-59-5. 2016

DEGRADATION of BIO-COMPOSITES

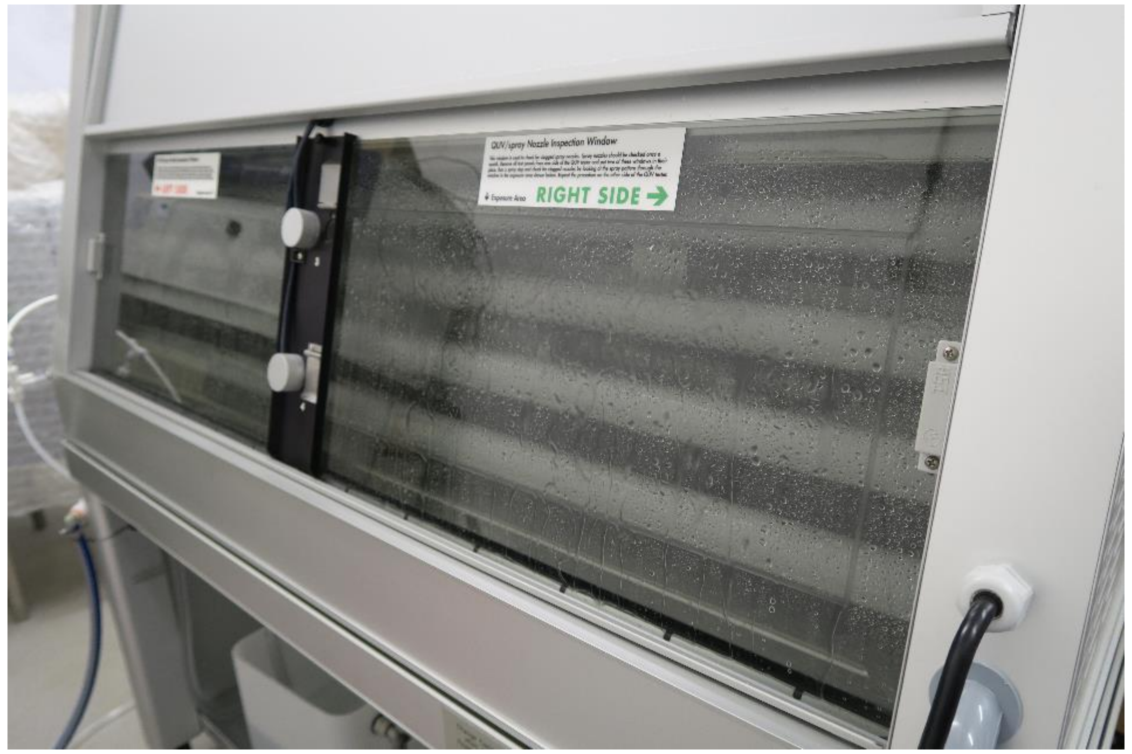
DESIGN AND TESTING– LABORATORY DEGRADATION

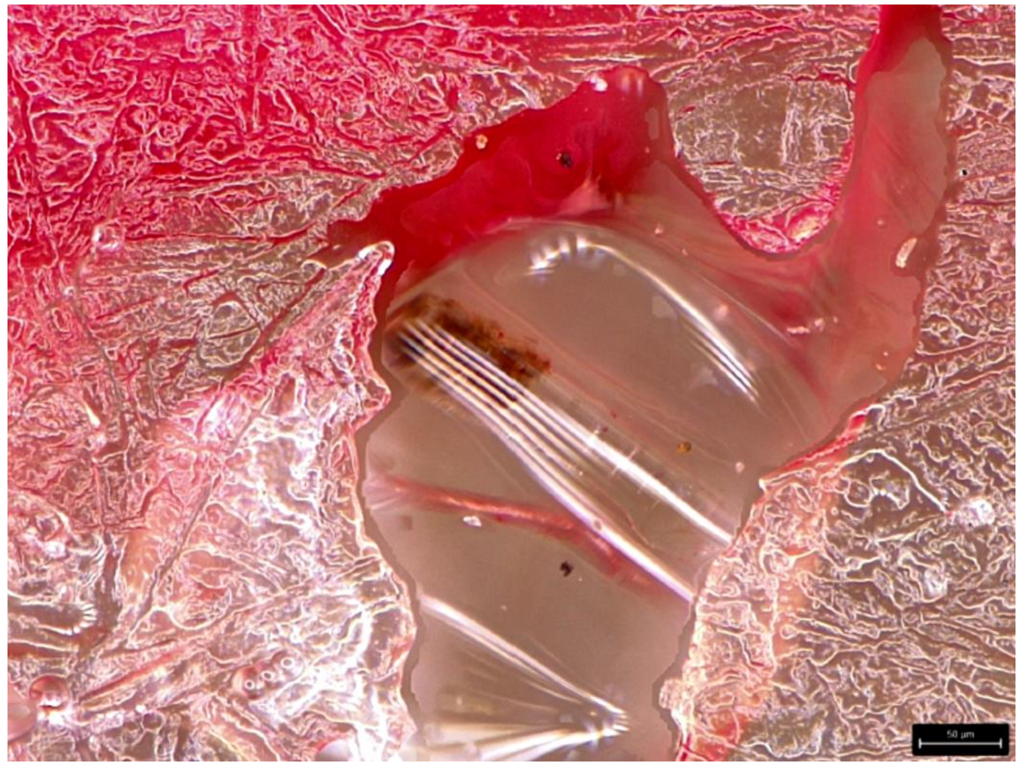
QUV/spray
UV radiation



Imperfection in
the matrix of sample

QUV/spray
condensation





Imperfection in
the matrix of sample

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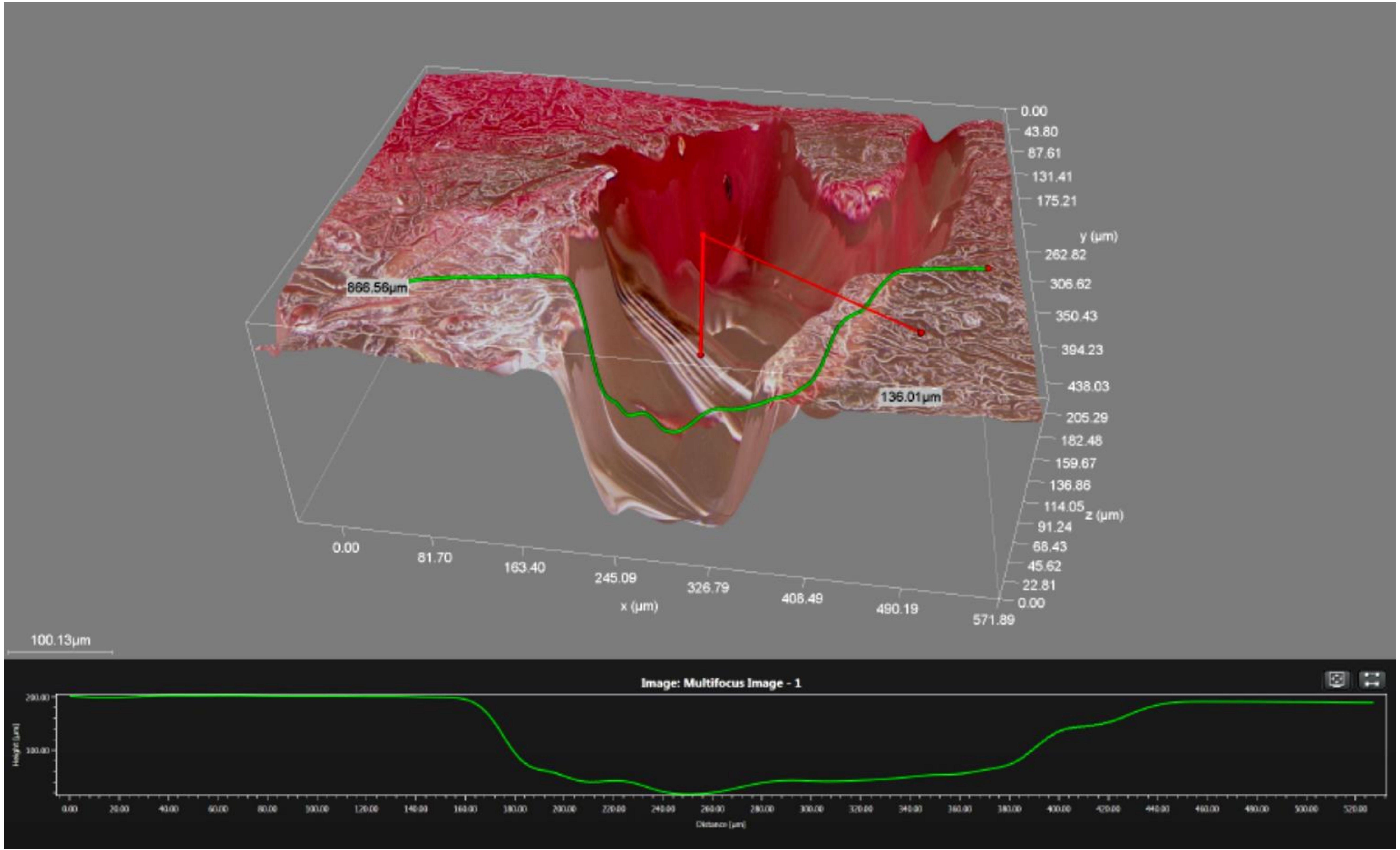
DESIGN AND TESTING– LABORATORY DEGRADATION



IMPERFECTION UNDER MICROSCOPE

Olsztyn
09.–12.09.2021

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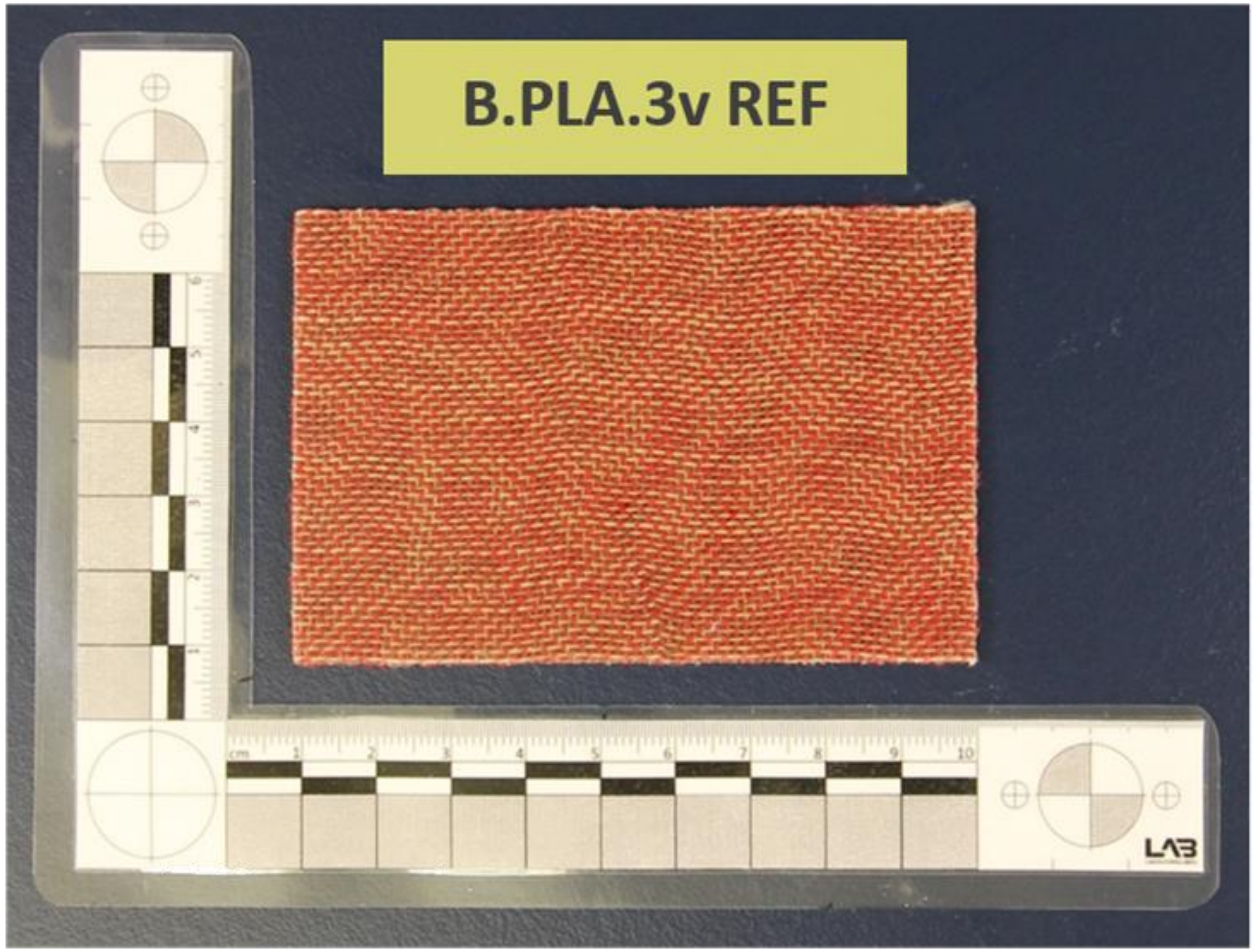
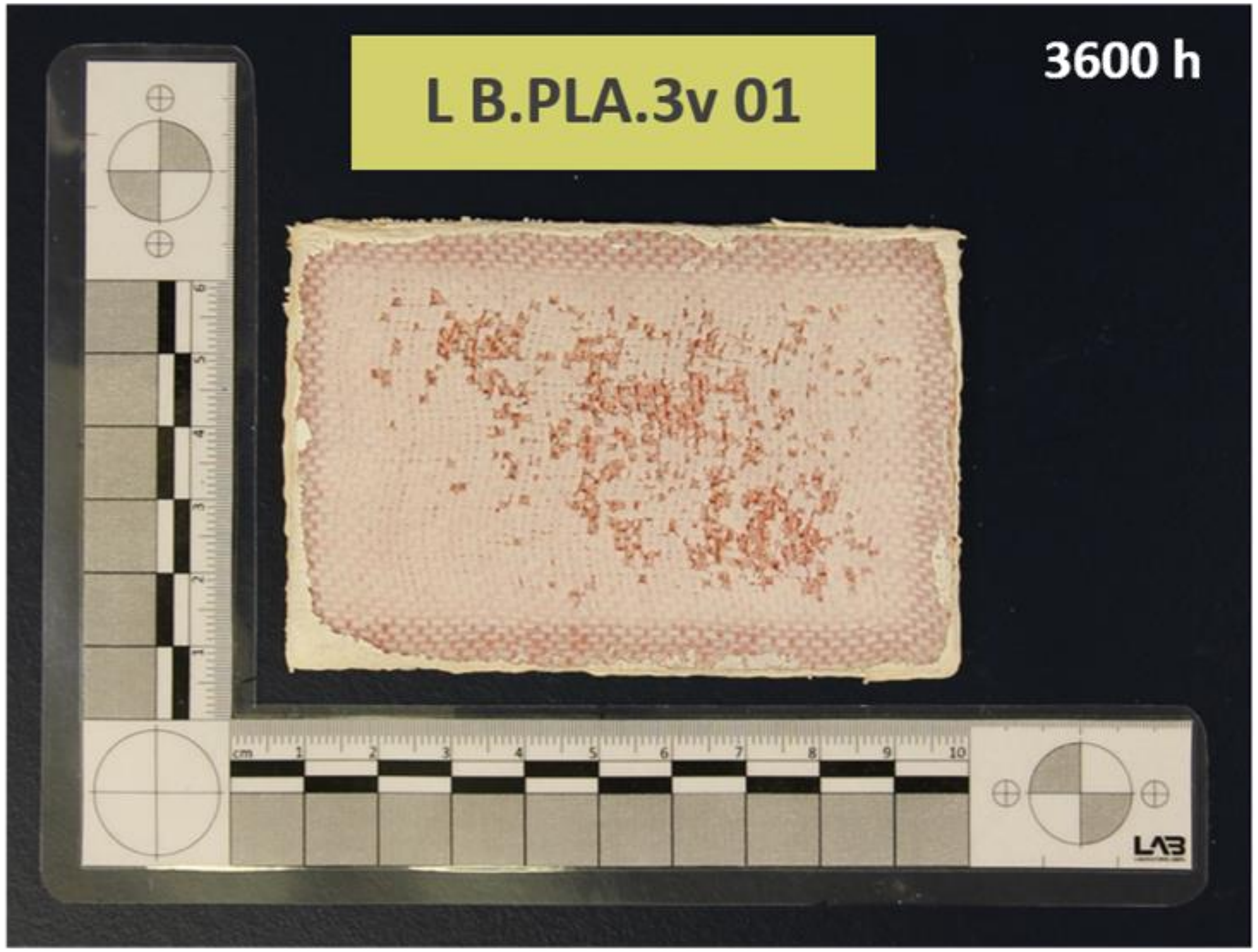
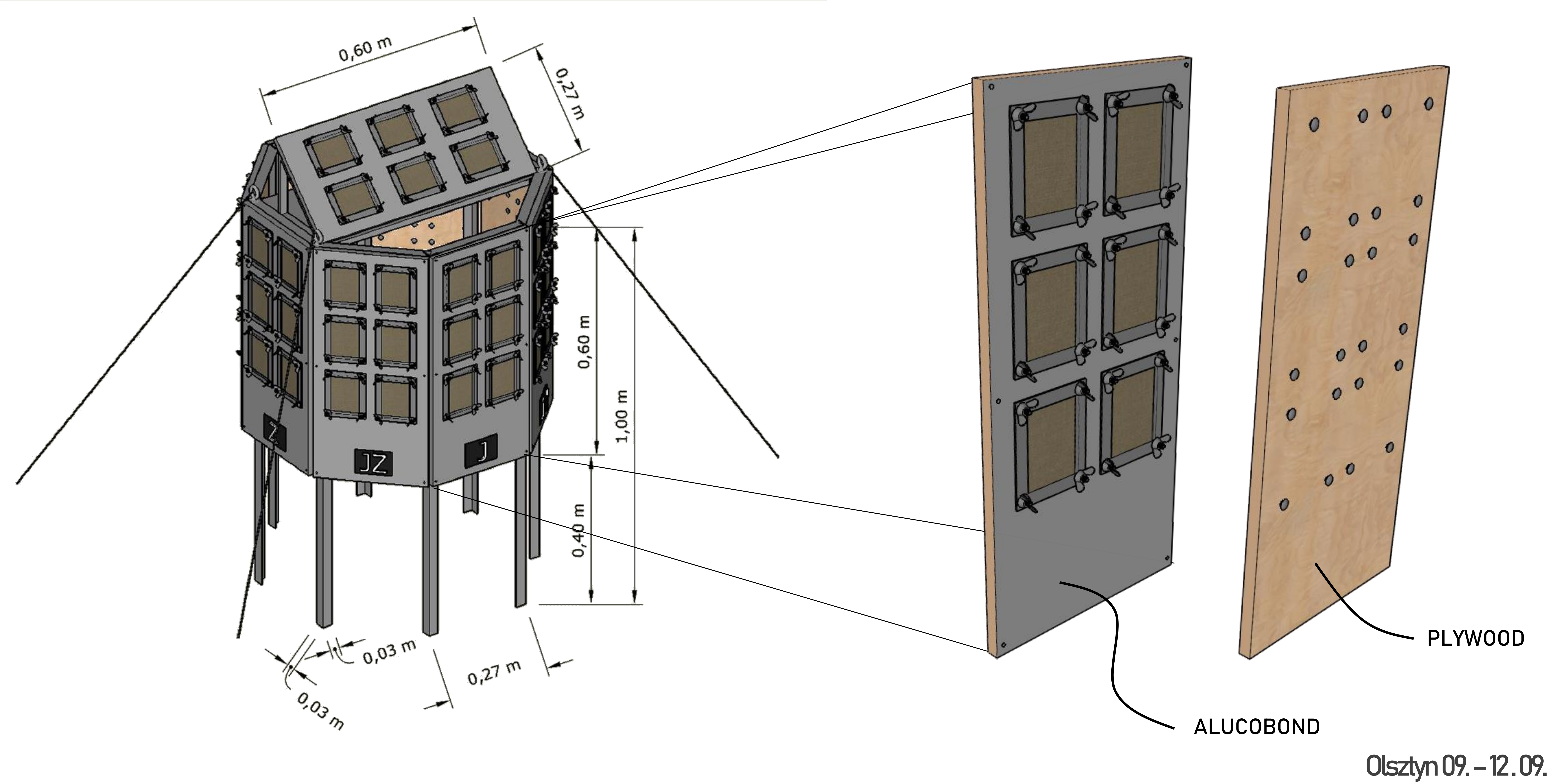
DESIGN AND TESTING– LABORATORY DEGRADATION



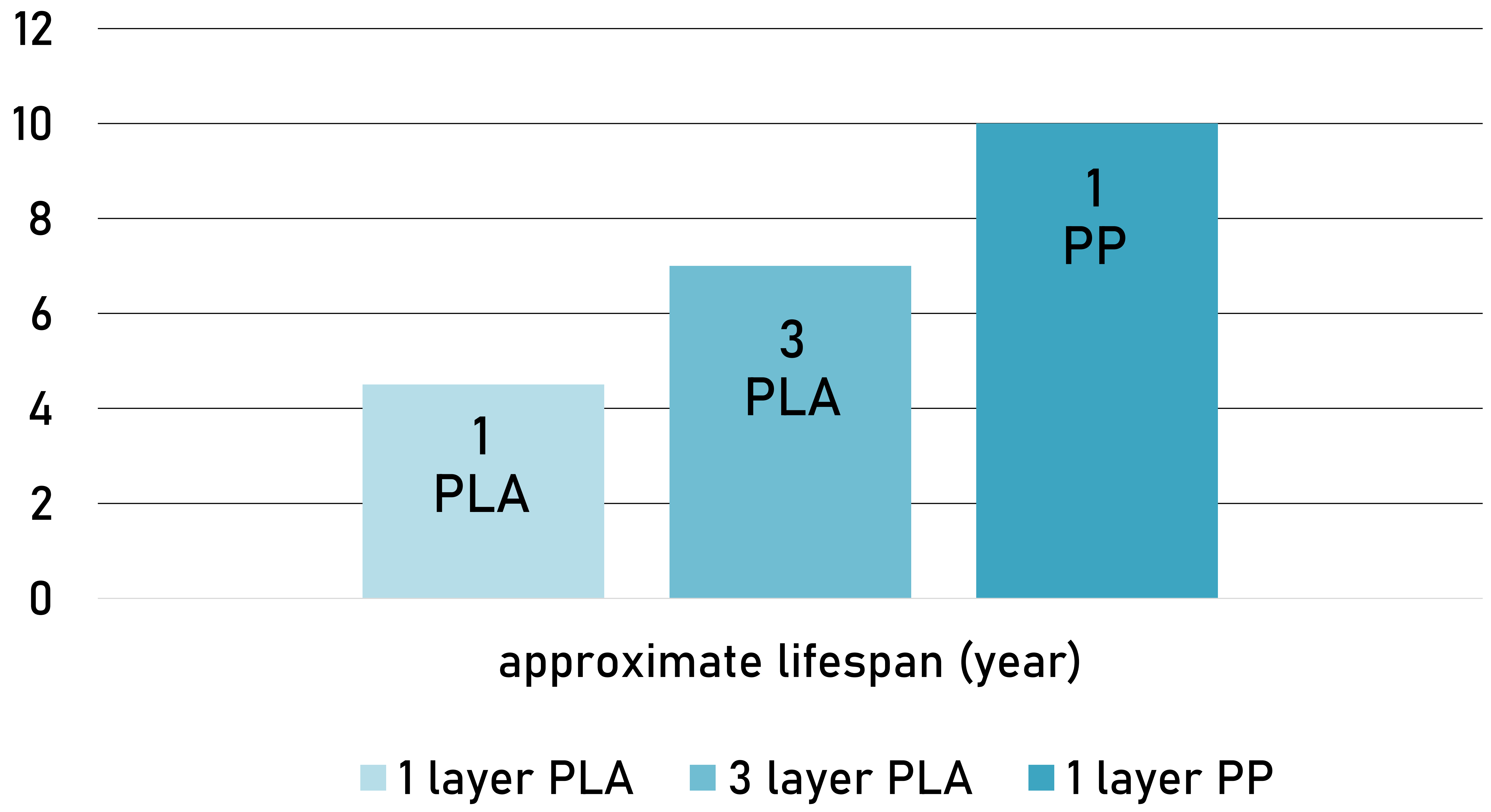


DESIGN AND TESTING– NATURAL DEGRADATION



DESIGN AND TESTING– NATURAL DEGRADATION

DESIGN AND TESTING– NATURAL DEGRADATION



MODIFICATION

MODIFIED SAMPLES

Olsztyn
09. – 12. 09. 2021

MODIFIED SAMPLES

Olsztyn
09. – 12.09.2021

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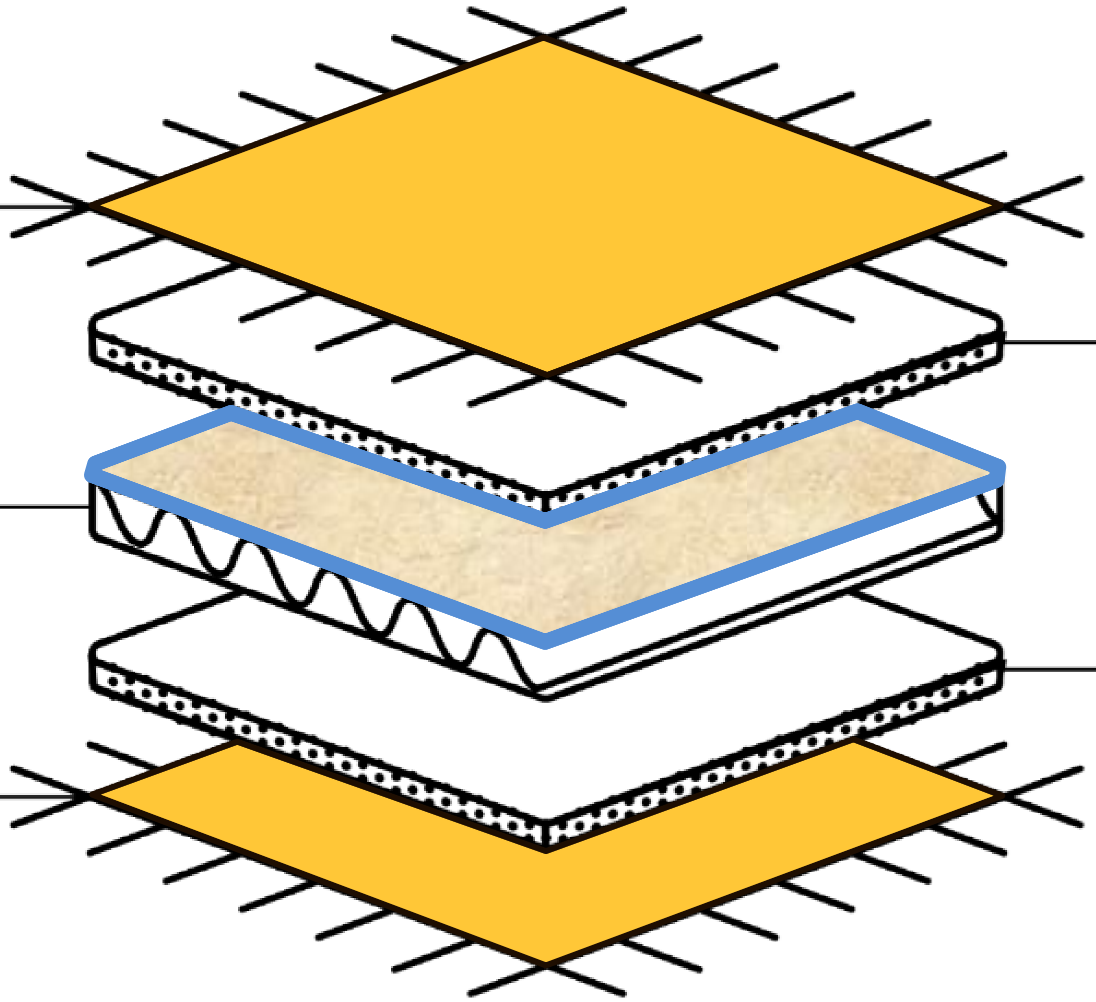
Visegrad Fund

MODIFIED SAMPLES

Olsztyn
09. – 12. 09. 2021

Wall Panel - prototype



THANK YOU FOR YOUR ATTENTION.

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Adoption of V4 buildings to nZEB standard using natural and bio-based materials

http://www.uwm.edu.pl/v4buildings/