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OF WARMIA AND MAZURY
IN OLSZTYN

Visegrad Fund

Thermal properties of natural materials as loose-fill insulations

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www.uwm.edu.pl/zboifb

Natural houses?

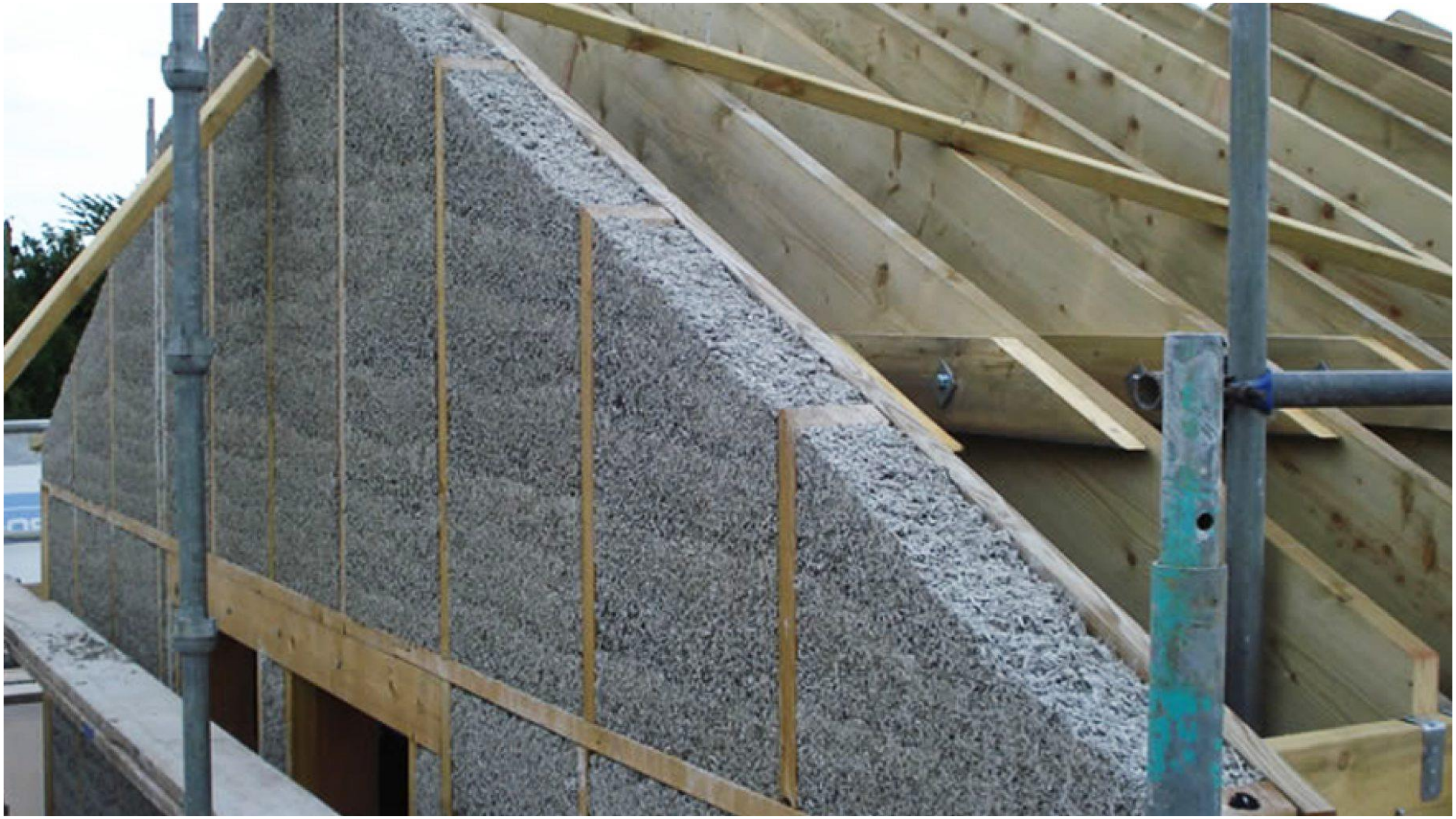
polska.org.pl
garnek.pl

3 little pigs story

Straw? Strawbale!

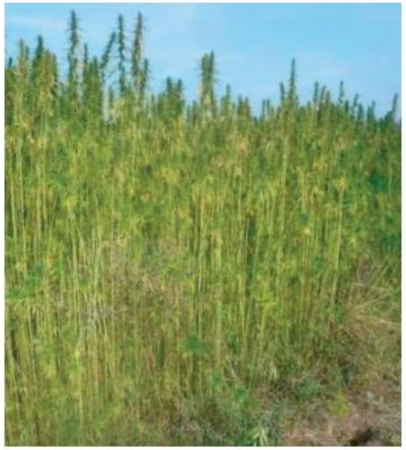
nolvaku.ee

Hempcrete



BudownictwoNaturalne.info.pl

Hempcrete technology

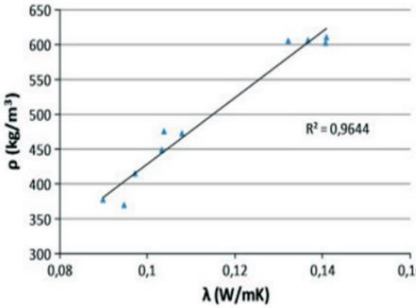


Rys. 1. Konopie włókniste – odmiana Białobrzeskie [archiwum autorów]

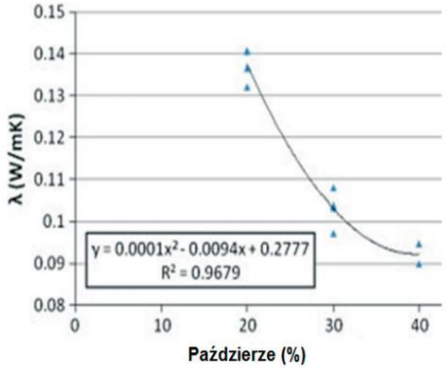
Rys. 2. Paździerze konopne [archiwum autorów]

Rys. 6. Bloczek ścienny wykonany z kompozytu wapienno- konopnego [archiwum autorów]

Przemysław **Brzyski**, Stanisław Fic,
Charakterystyka kompozytu wapienno-konopnego
i jego zastosowanie w budownictwie.
Budownictwo i Architektura 14(2) (2015) 11-19



Rys 10. Wykres zależności wartości współczynnika przewodności cieplnej od gęstości pozornej kompozytu [5]



Rys 11. Wykres zależności wartości współczynnika przewodności cieplnej od zawartości paździerzy w kompozycie [5]

Rammed earth

www.paleotreats.com

Are we new in the idea?

www.ageofempires.com

Are we new in the idea?

How energy efficient are the people of 21th cent.?

- Vanocuver, Canada, 1990 – average energy used in big building 315 kWh/m^2,
- Vanocuver, Canada, 2002 – average energy used in big building 250 kWh/m^2 = exactly the same as in 1929!

How about thermal insulation in EU houses?

- U value, EP regulation require buildings with high thermal resistance partitions,
- 20-30 cm of mineral wool or EPS, XPS? Will it be enough?
- Polyurethane? How about solvent?
- We put a lot of energy to produce energy-saving materials– balance achieved?
- LCA?
- Alternative?

The variety of natural materials


hemp


flax shieves


straw

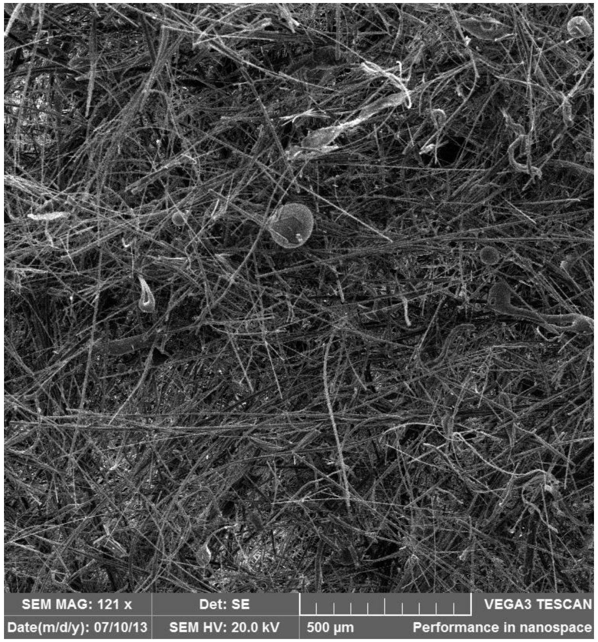

cellulose


wood wool

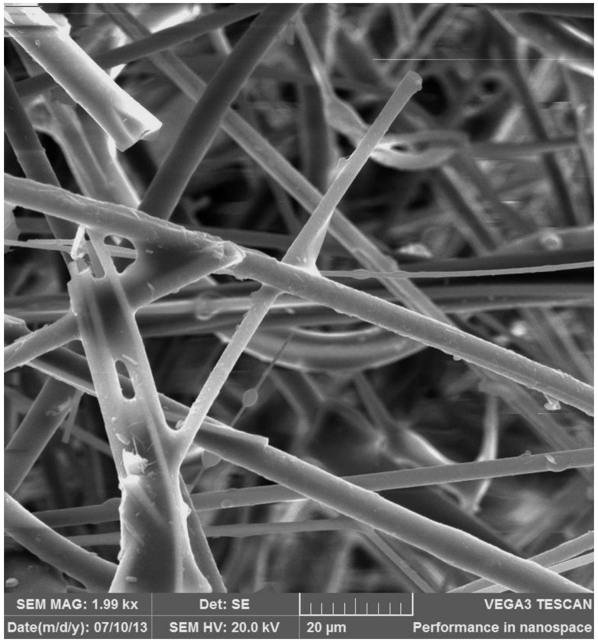
Loose fiber materials

- Mineral wool

1 x



121 x

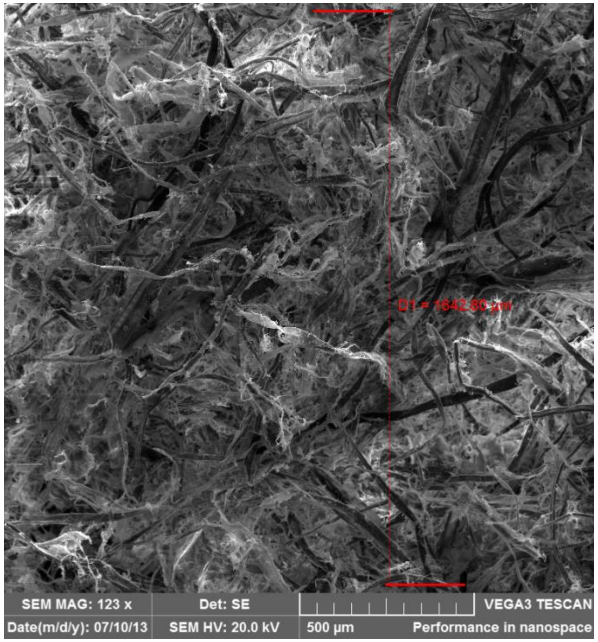


2 000 x

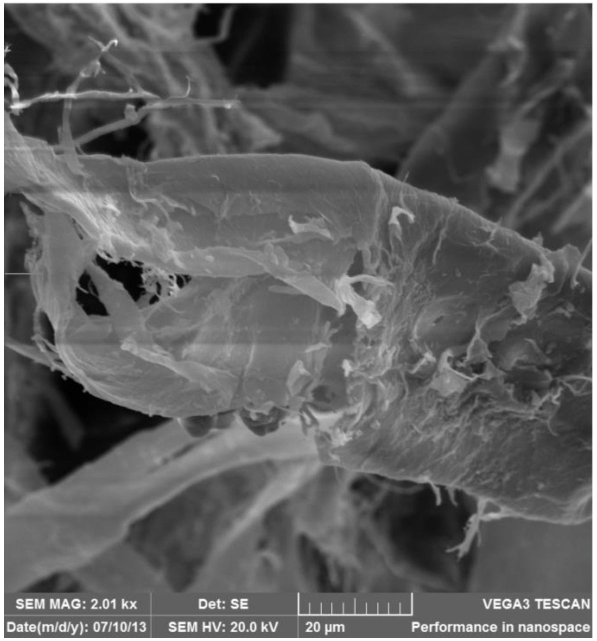
Loose fiber materials

- Cellulose fibers

1 x



121 x

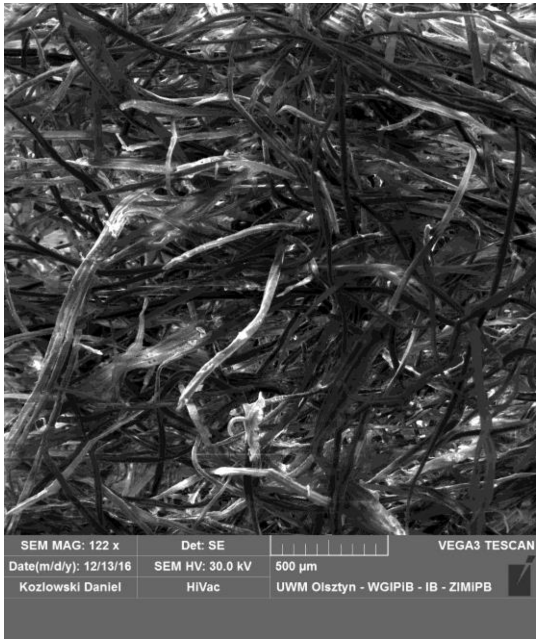


2 000 x

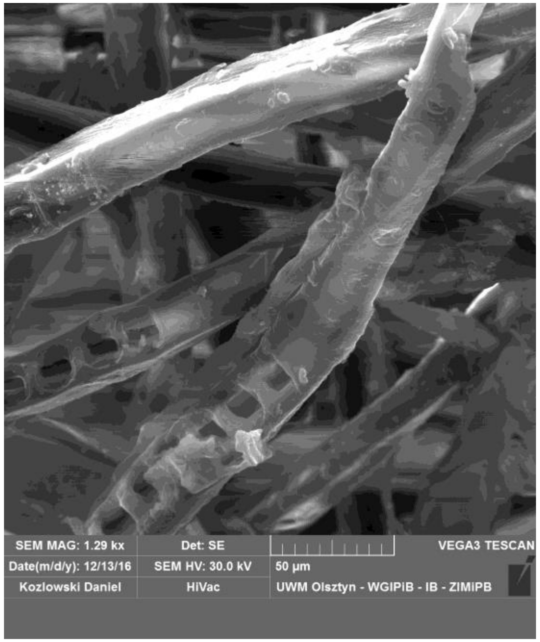
Loose fiber materials

- Wood wool fibers

1 x



122 x

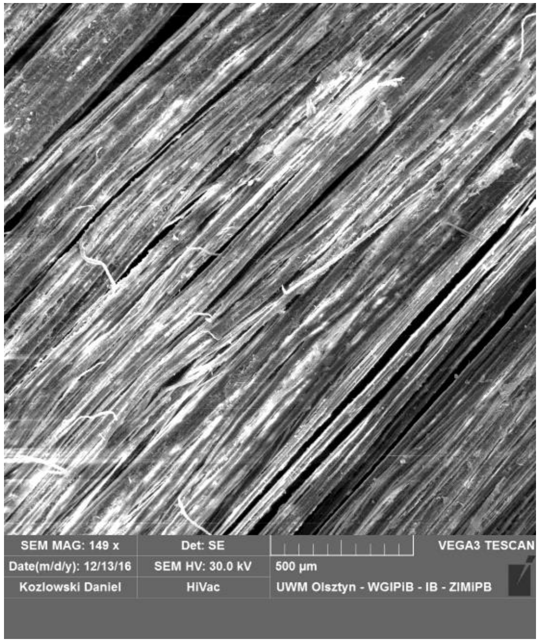


1 290 x

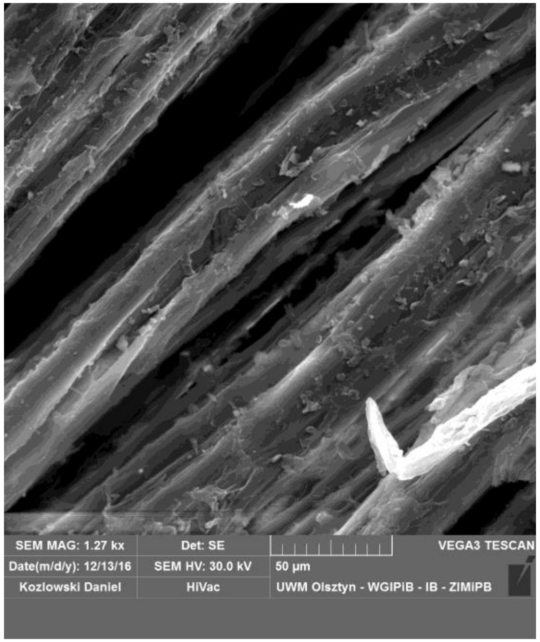
Loose fiber materials

- Hemp fibers

1 x

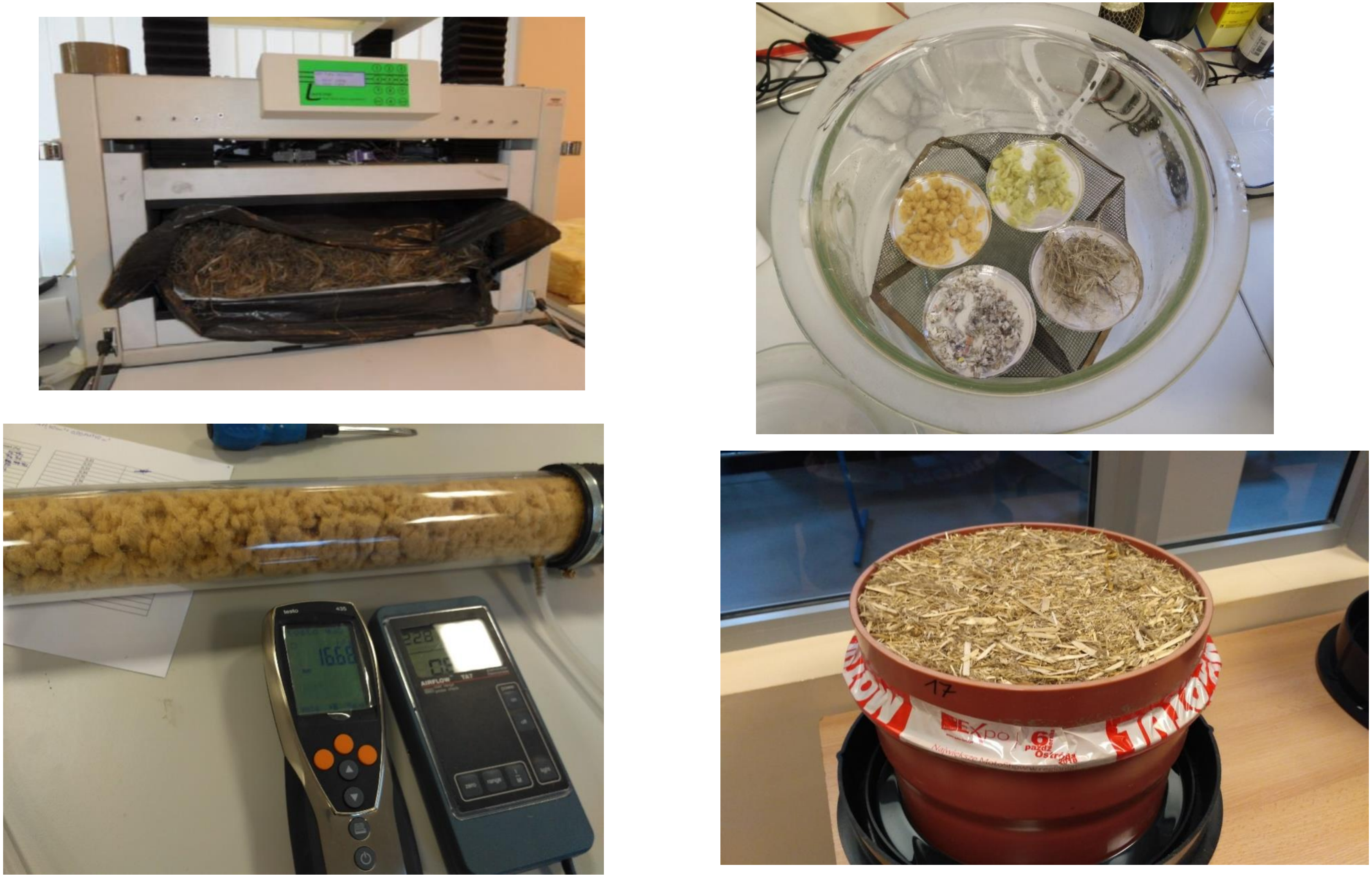


149 x

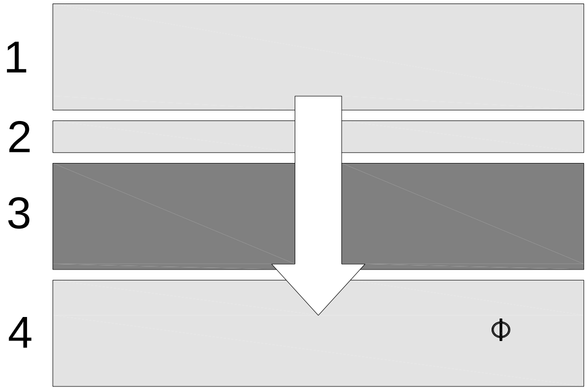


1 270 x

laboratory tests



Thermal conductivity

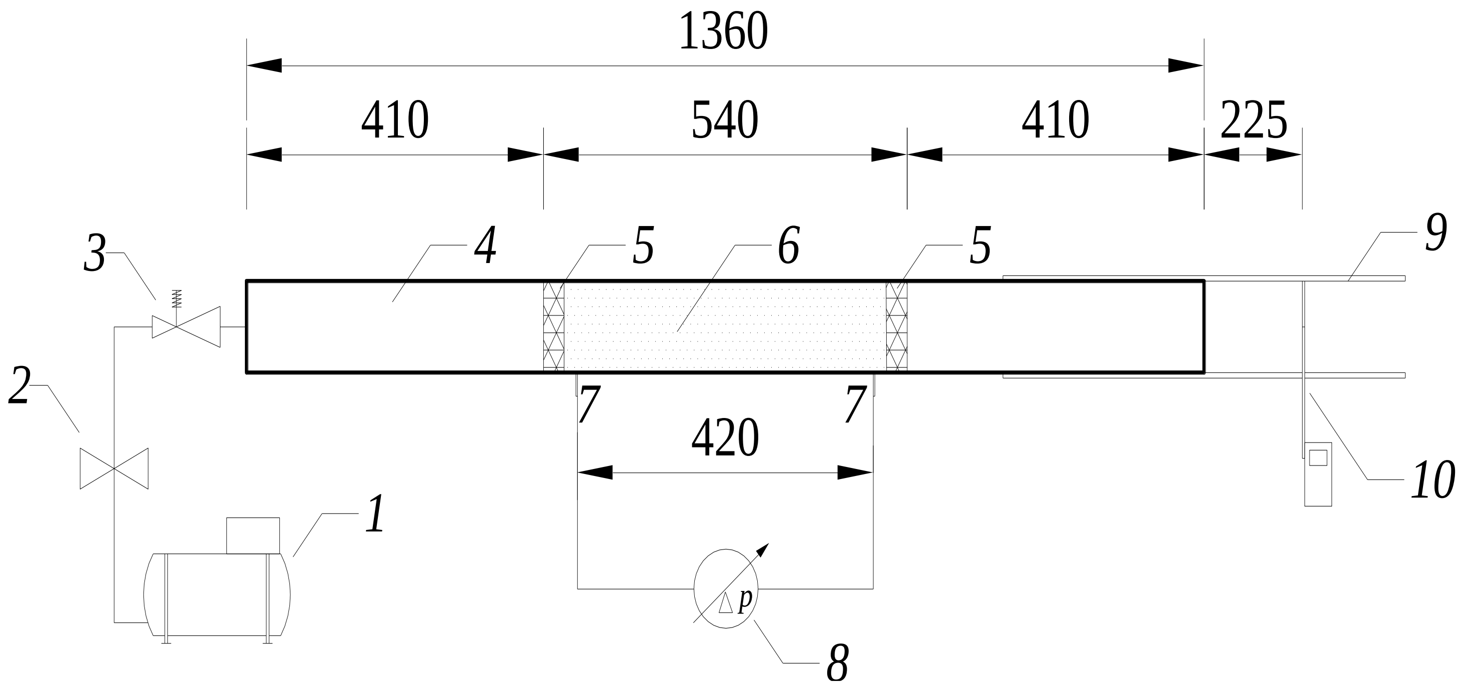


$$q = -\lambda \frac{dT}{dx}$$

1 – hot plate,
2 – heat flow meter,
3 – speciman,
4 – cold plate

q – heat flux (W/m^2),
λ – thermal conductivity coefficient (W/mK),
dT/dx – temperature gradient

Air permeability



The scheme of the test stand for the measurement of air permeability of loose fibrous materials: *1 – an air compressor, 2 – a valve, 3 – an air regulator, 4 – a plexiglass tube, 5 – strainers, 6 – test specimen, 7 – pressure taps, 8 – pressure gauge, 9 – nozzle, 10 – thermo-anemometer.*

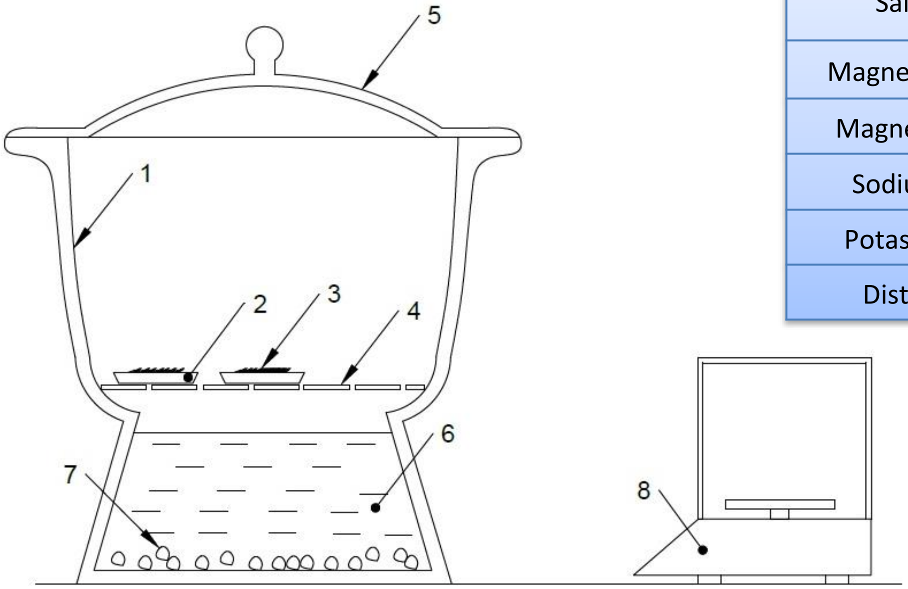
Air permeability

Forchheimer equation for flows characterized with Re > 1

$$-\frac{dp}{dx} = \frac{\mu}{\kappa} \cdot v + \beta \cdot \rho \cdot v^2$$

dp – the pressure difference between pressure taps (Pa),
dx – the distance between pressure taps (m),
μ – the dynamic viscosity (Pa·s),
κ – the air permeability coefficient (m^2),
β – the Forchheimer coefficient (1/m),
ρ – the fluid density (kg/m^3),
v – the velocity of fluid flow (m/s).

Sorption

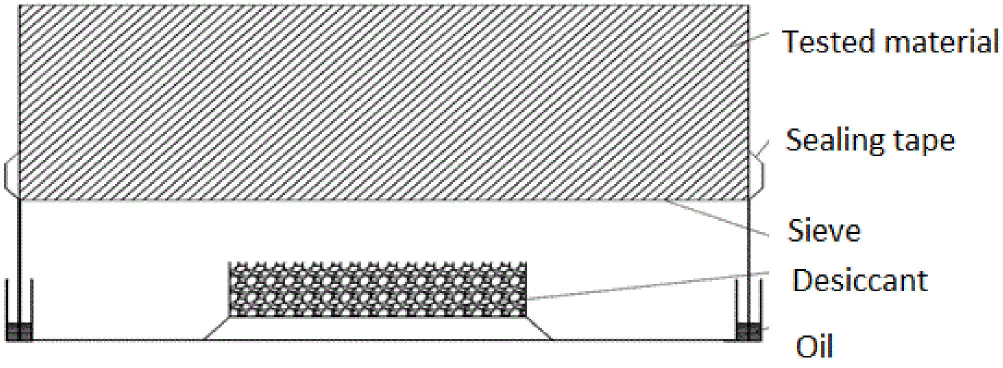


Salt solution	Salt formula	Relative air humidity (%)
Magnesium chloride	$MgCl_2$	32
Magnesium nitrate	$Mg(NO_3)_2$	54
Sodium chloride	NaCl	75
Potassium nitrate	$K(NO_2)_3$	95
Distilled water	H_2O	100

Test stand for measuring moisture sorption of loose fiber thermal insulation materials: 1 - desiccator, 2 - aluminium laboratory mold, 3 - sample material, 4 - metal mesh as a pad, 5 - cover of the desiccator, 6 - saturated salt solution, 7 - undissolved salt crystals, 8 - laboratory scale

Vapor permeability

$$\delta = \frac{d}{R_v}$$

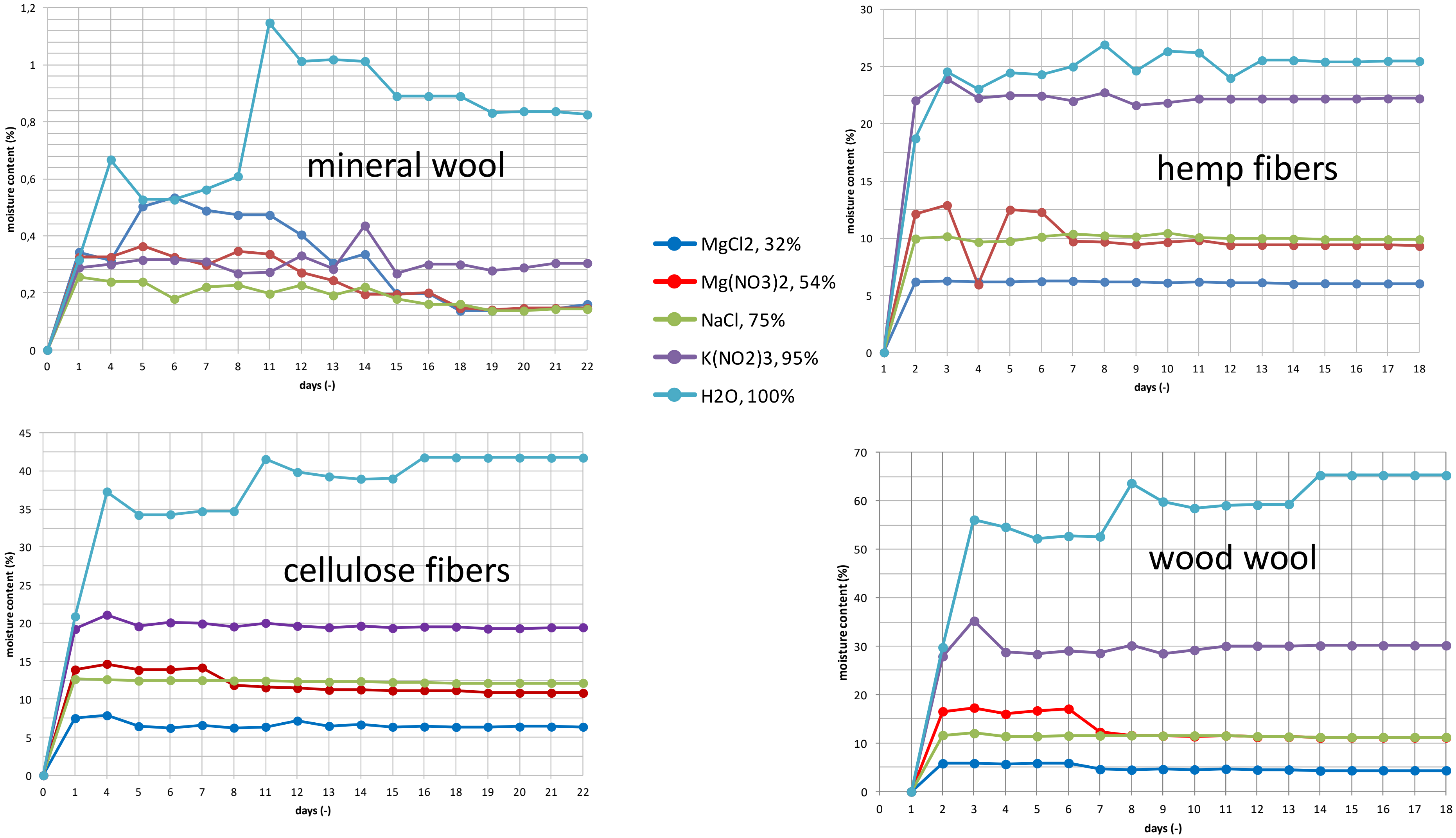


δ – vapor permability coefficient (g/mhPa)
d – sample thickness (m)
R_v – diffusion resistance of the sample (m^2hPa/g)

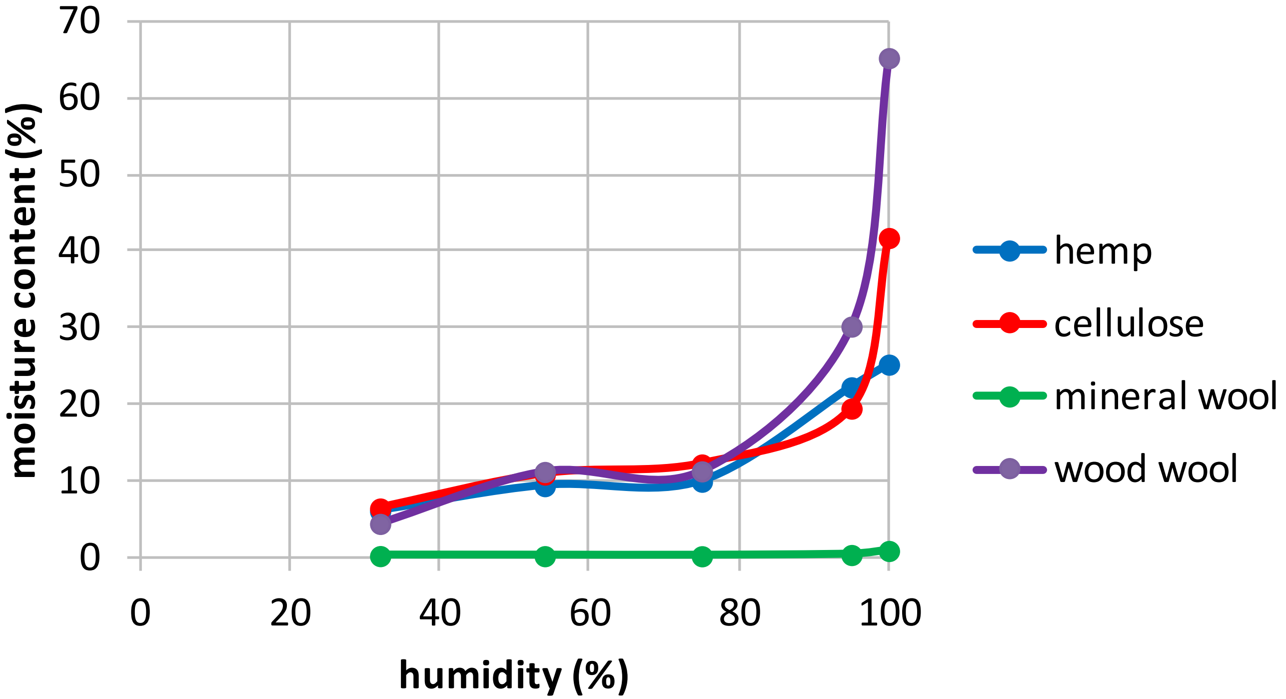
$$R_v = \frac{A \cdot P}{g - r}$$

R_v – diffusion resistance of the sample (m^2hPa/g)
A – sample area (m^2),
P – vapor pressure difference (Pa),
g – the amount of water vapor that passes through the sample within an hour (m^2hPa/g),
r – resistance of inflow and outflow of water vapor (m^2hPa/g),

Sorption results



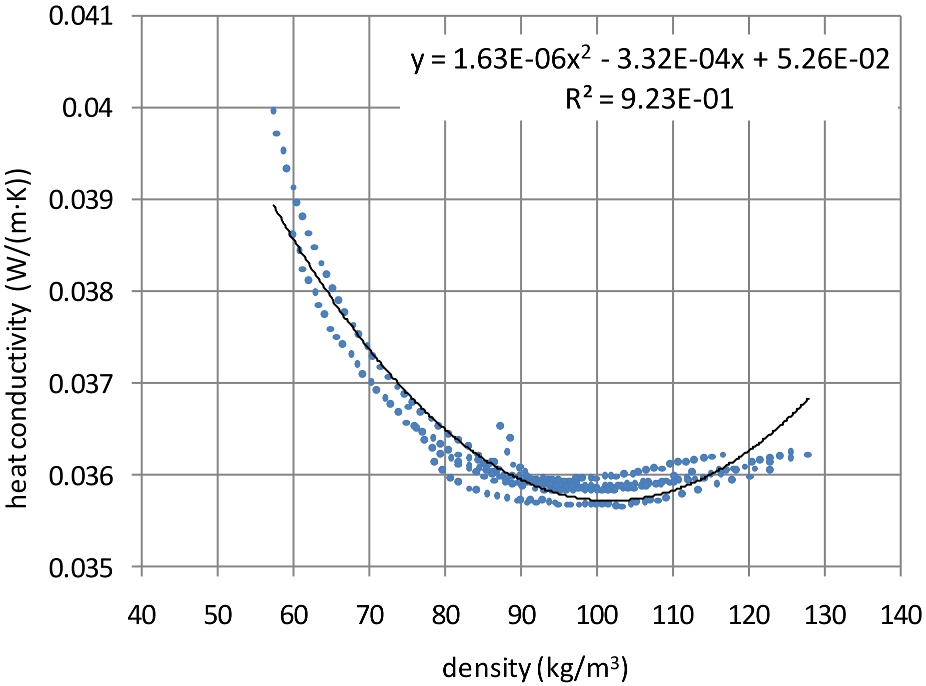
Sorption isotherms



Vapor permeability results

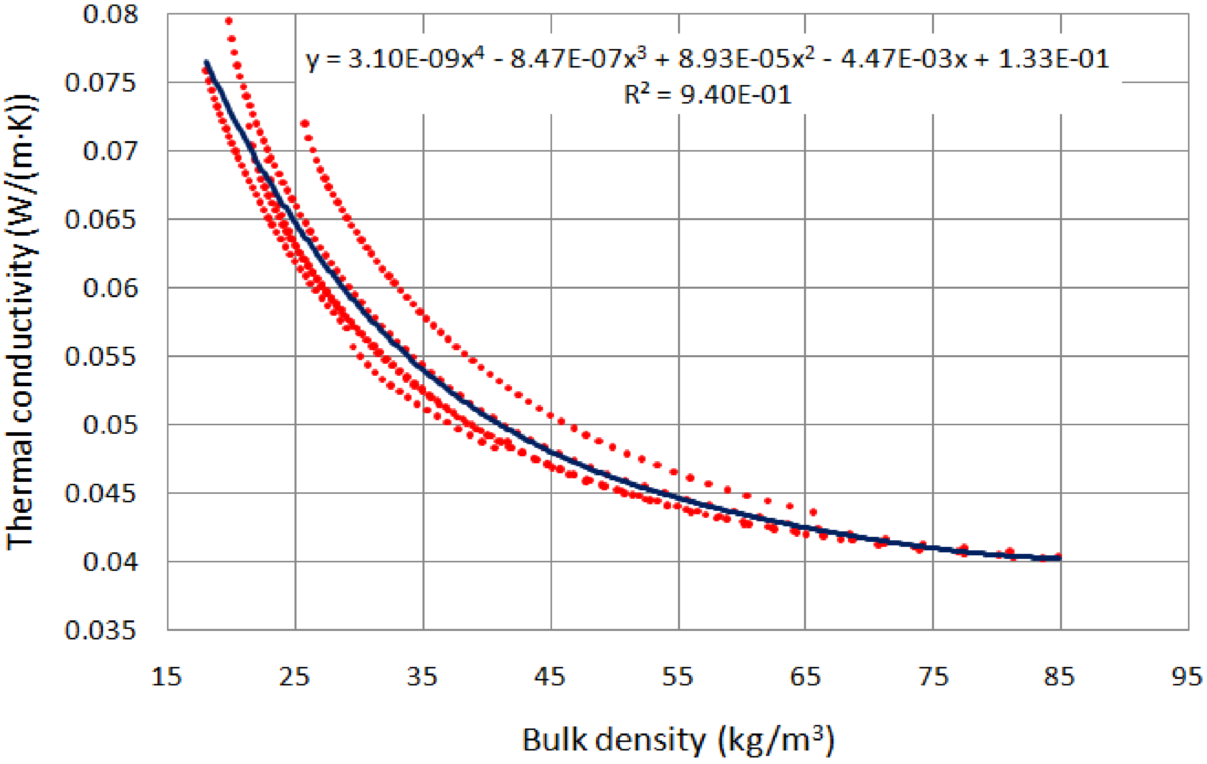
Thermal conductivity

- Mineral wool



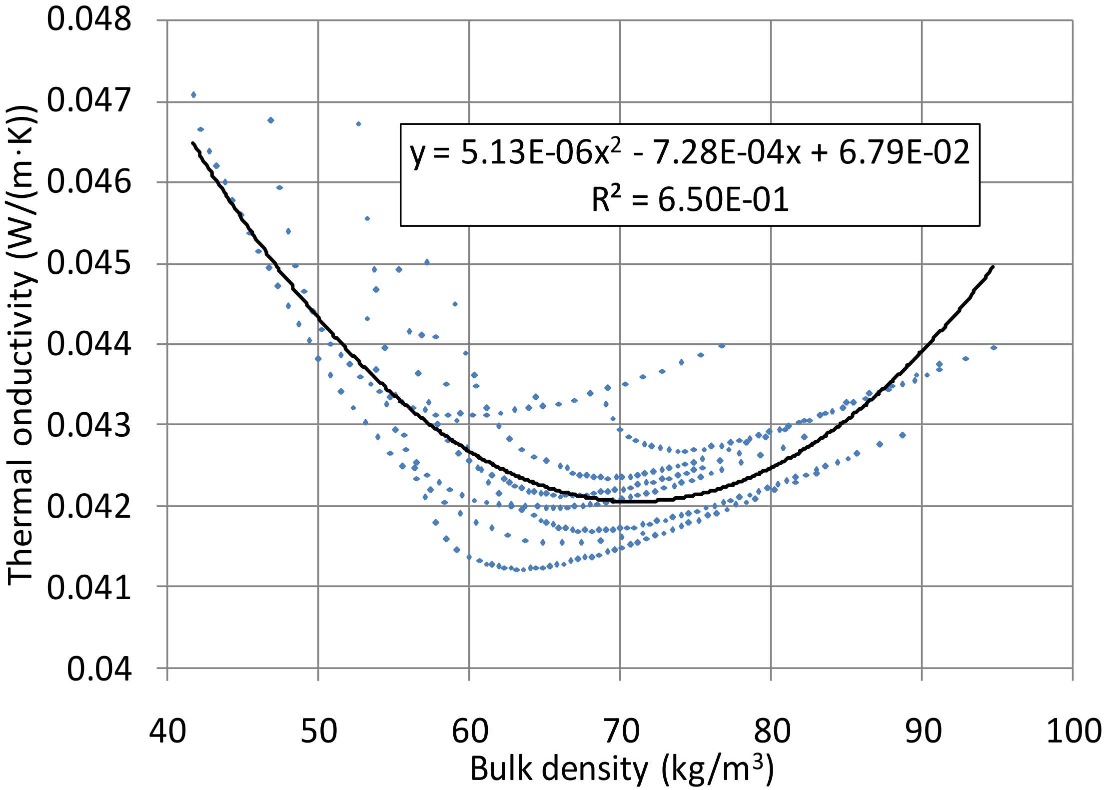
Thermal conductivity

- Hemp fibers



Thermal conductivity

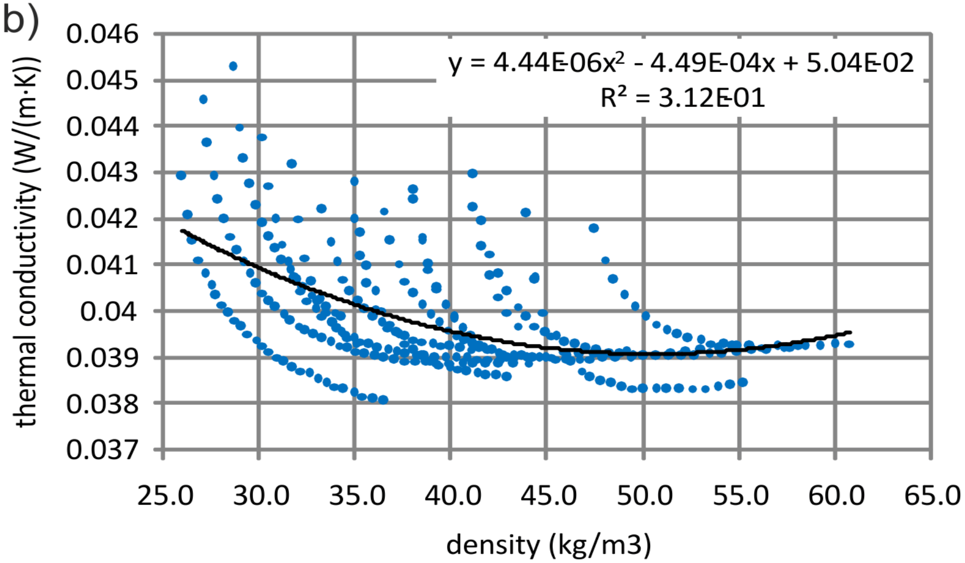
- Cellulose fibers



Thermal conductivity

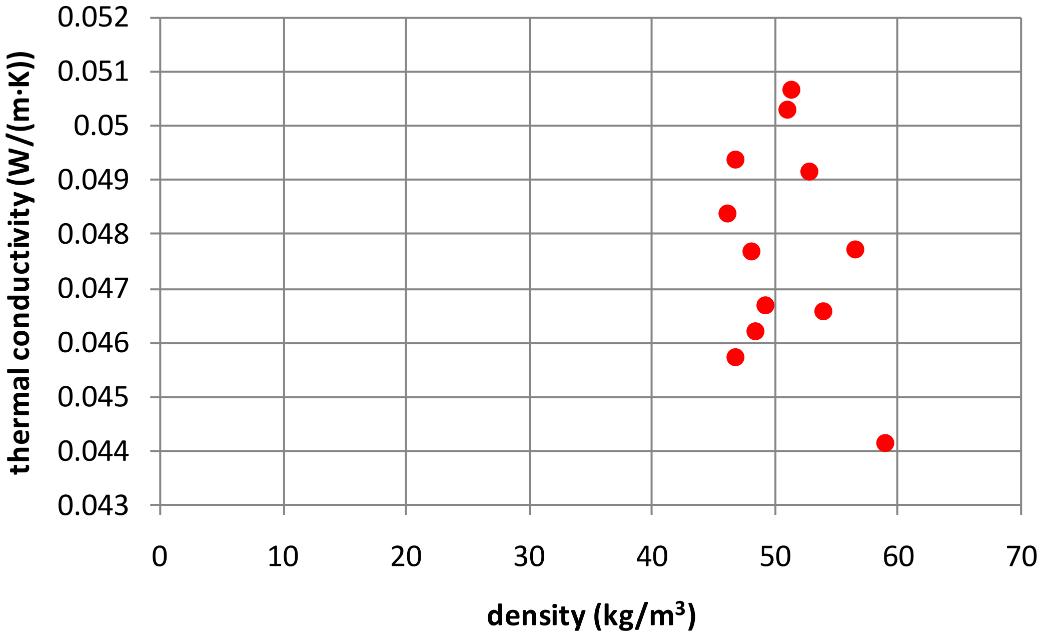
- Wood wool

b)



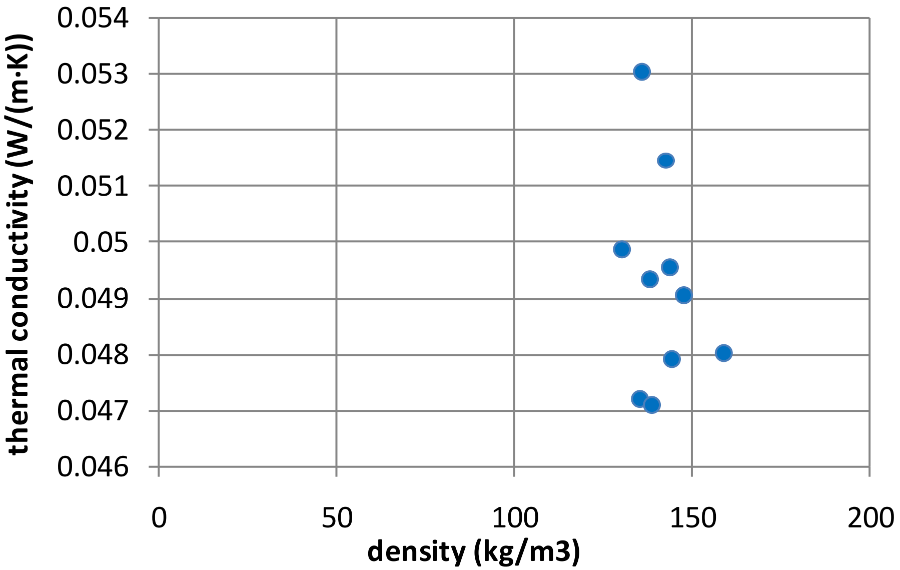
Thermal conductivity

- Straw

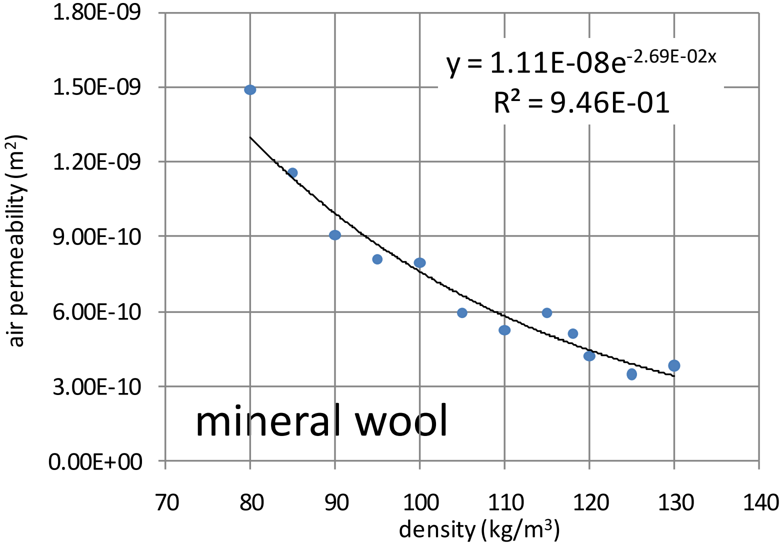


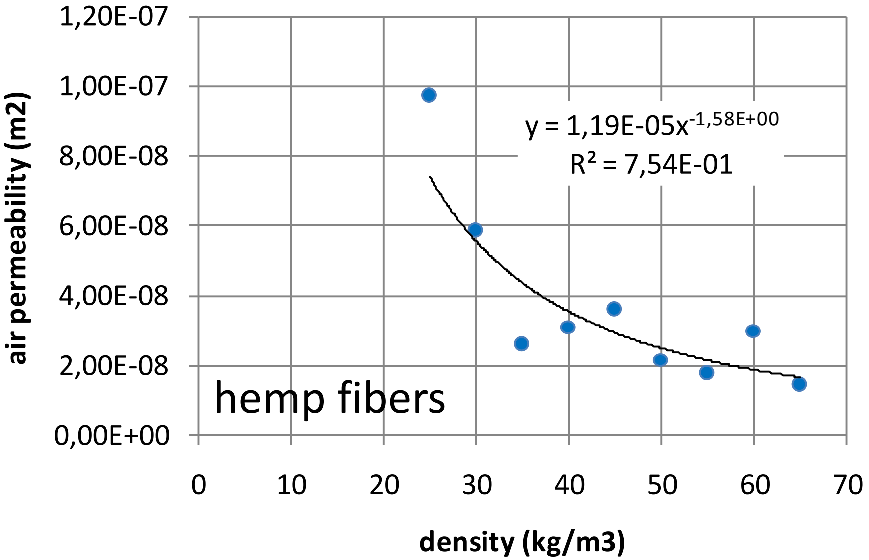
Thermal conductivity

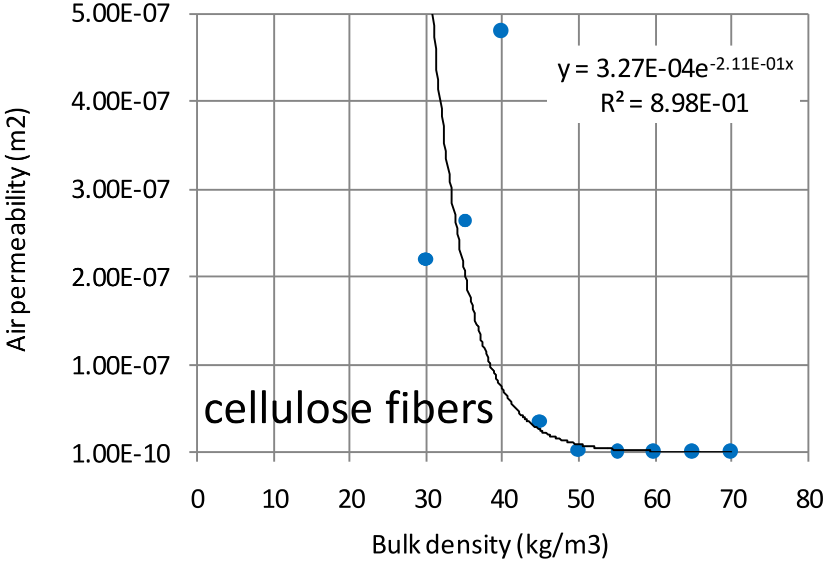
- Flaxshives

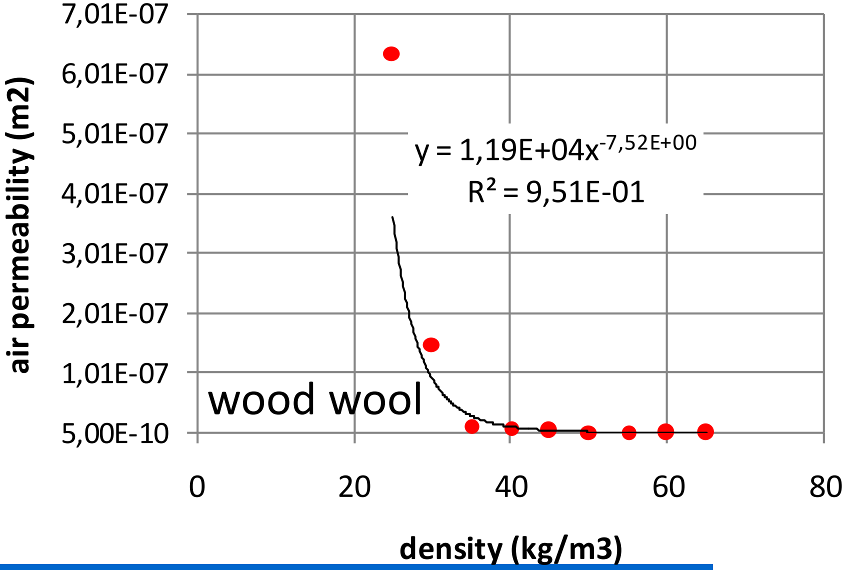


Air permeability

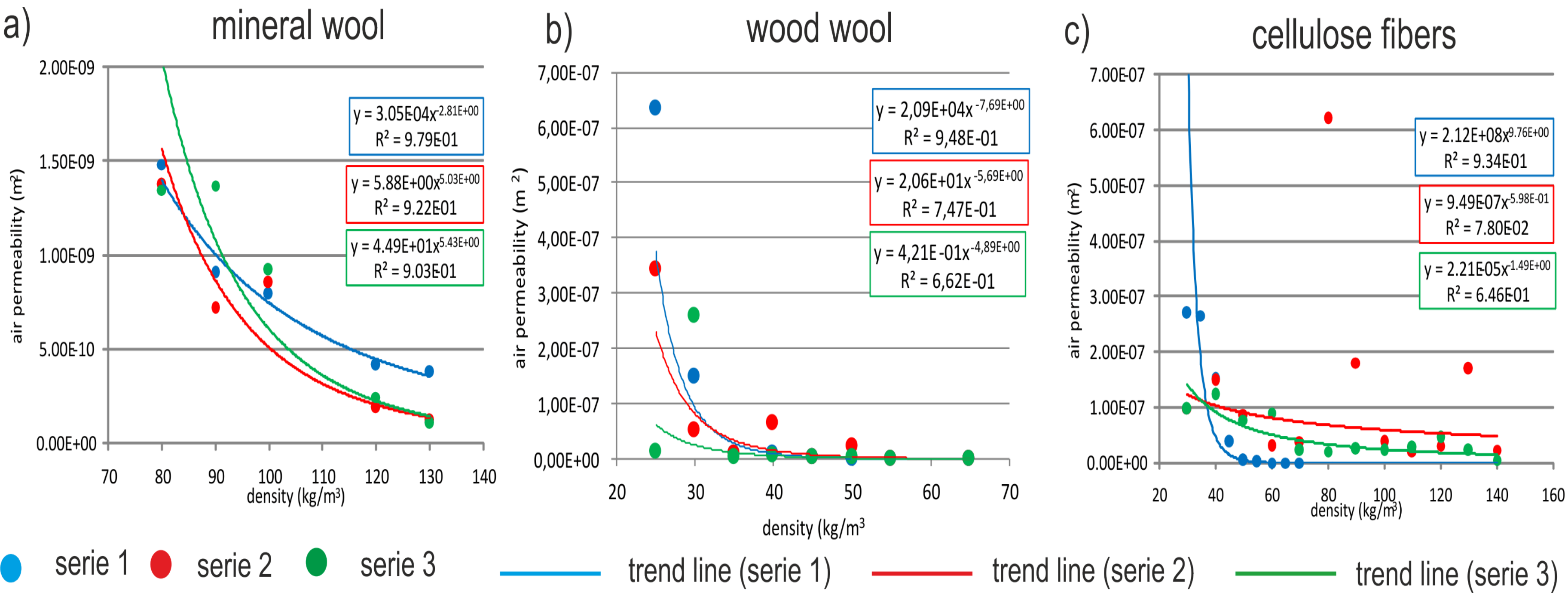








Air permeability of moistened materials

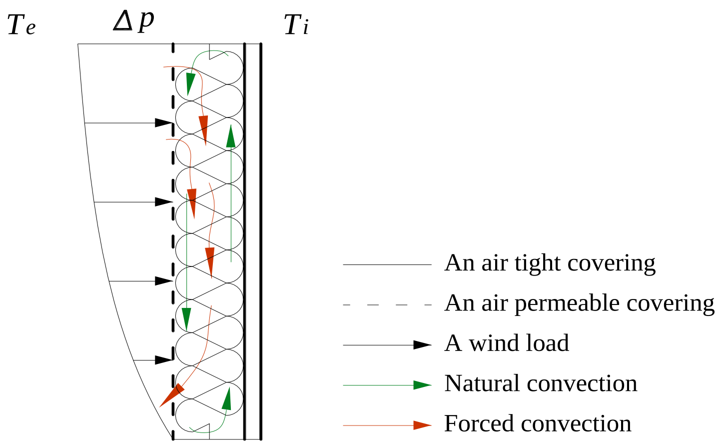


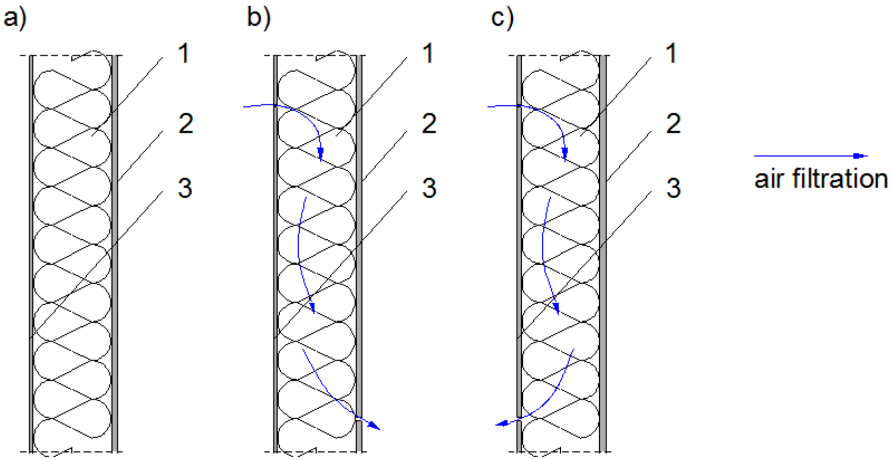
	Mean moisture mass (%) of tested materials before and (after) air permeability test		
	Serie 1	Serie 2	Serie 3
Mineral wool	0.0	0.94 (0.46)	2.53 (2.13)
Wood wool	0.0	12.78 (8.72)	20.81 (16.02)
Cellulose fibers	0.0	64.06 (61.43)	74.65 (72.34)

Kosinski, P., Wójcik R., Skoratko D., Attia, S., (2021) An impact of moisture content on the air permeability of the fibrous insulation materials, 8th International Building Physics Conference - IBPC2021 Copenhagen, Denmark, 25-28 August 2021

Thermal simulation on heat transfer

- Frame partition filled with cellulose fibers
- Delphin 5.8, Volume Control Method





Material	d (m)	λ (W·m⁻¹·K⁻¹)	κ (m²)
Gypsum board	0.0125	0.200	-
Loose cellulose fibers 45 kg/m³	0.25	0.046	3.696E-08
Loose cellulose fibers 55 kg/m³	0.25	0.043	1.214E-09
Loose cellulose fibers 70 kg/m³	0.25	0.042	2.897E-10

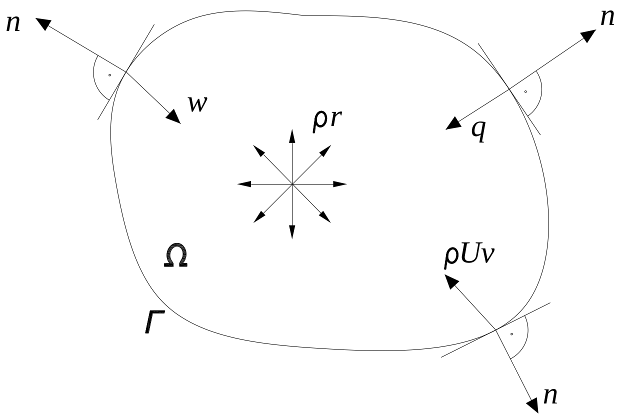
BC*:*
T_i = 20.00 °C, T_e = -20.0°C,
Δp = 5.00 Pa,
α_e = 25.0 W/(m^2·K),
α_i = 8.0 W/(m^2·K)

Brzyski P., Kosinski, P., Skoratko A., Motackii W., (2019) Thermal properties of cellulose fiber as insulation material in a loose state, AIP Conference Proceedings 2133 (1), 020006

Energy balance

Heat conduction including air filtration in a rigid heat conductor

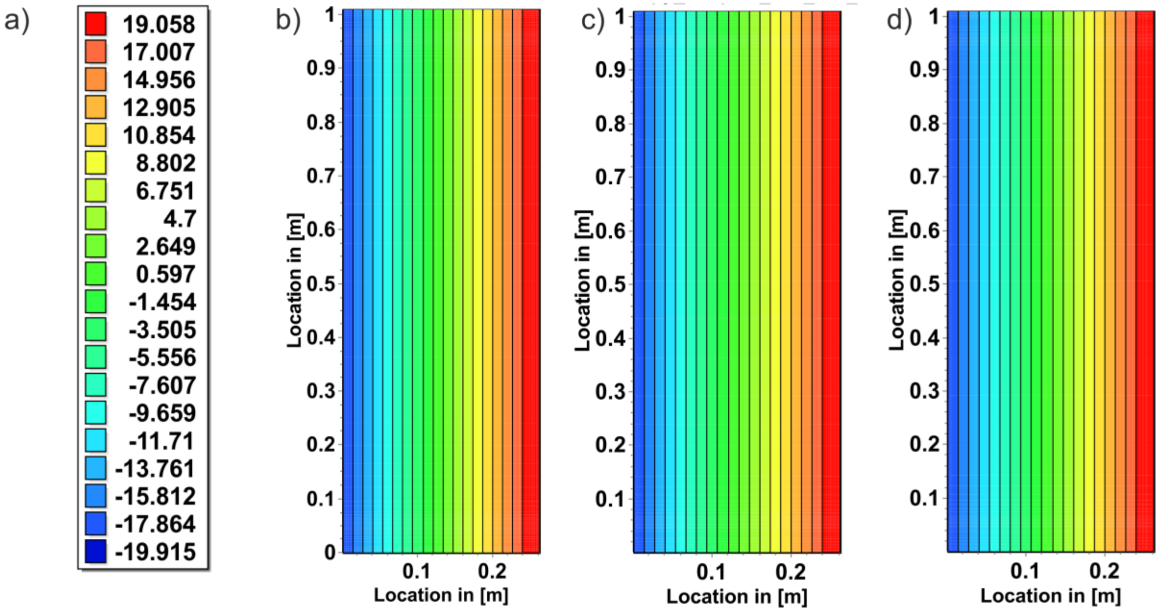
$$\frac{\partial}{\partial t}(\rho U) = \nabla\cdot\left(\lambda\nabla T + \kappa\frac{c_p\Delta T}{\nu}(\nabla p + \rho g)\right) + \rho r,$$



ρU – the internal energy density (J/m^3),
λ – the heat conduction coefficient (W/(m·K)),
κ – the air permeability coefficient (m^2),
c_p – the specific heat of dry air (J/(kg·K)),
ΔT – the temperature difference (K),
ν – the kinematic viscosity (m^2/s),
∇p – the pressure gradient (Pa/m),
ρ – the dry air density (kg/m^3),
g – the gravity acceleration (m/s^2),
ρr – the internal heat source density(W/m^3).

Thermal simulation on heat transfer

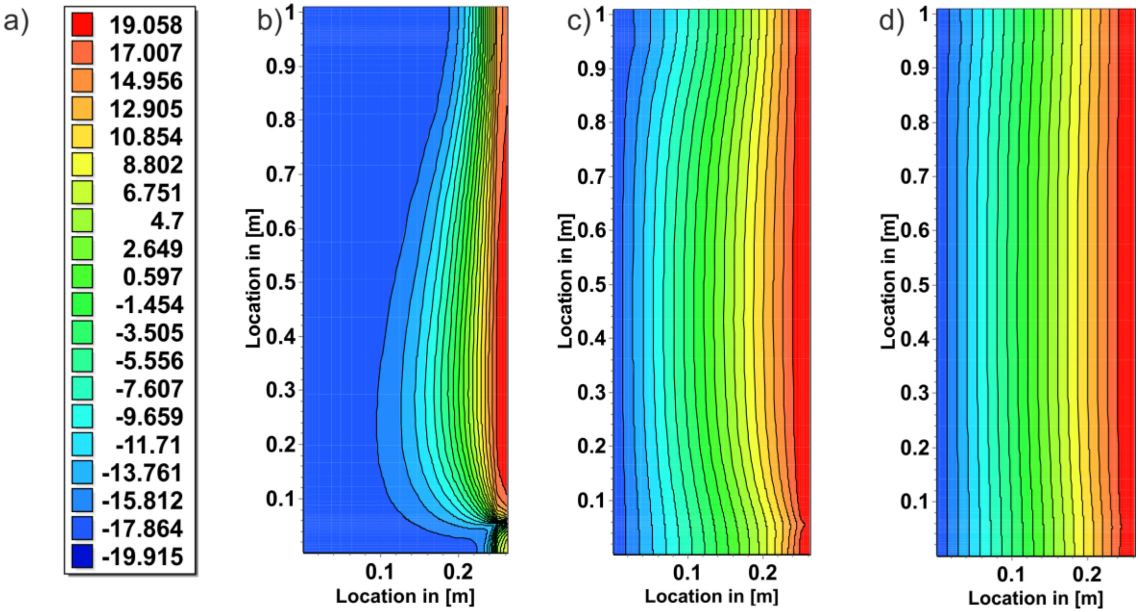
- Results for thermal equilibrium without air filtration of the model



45 kg/m^3 55 kg/m^3 70 kg/m^3

Thermal simulation on heat transfer

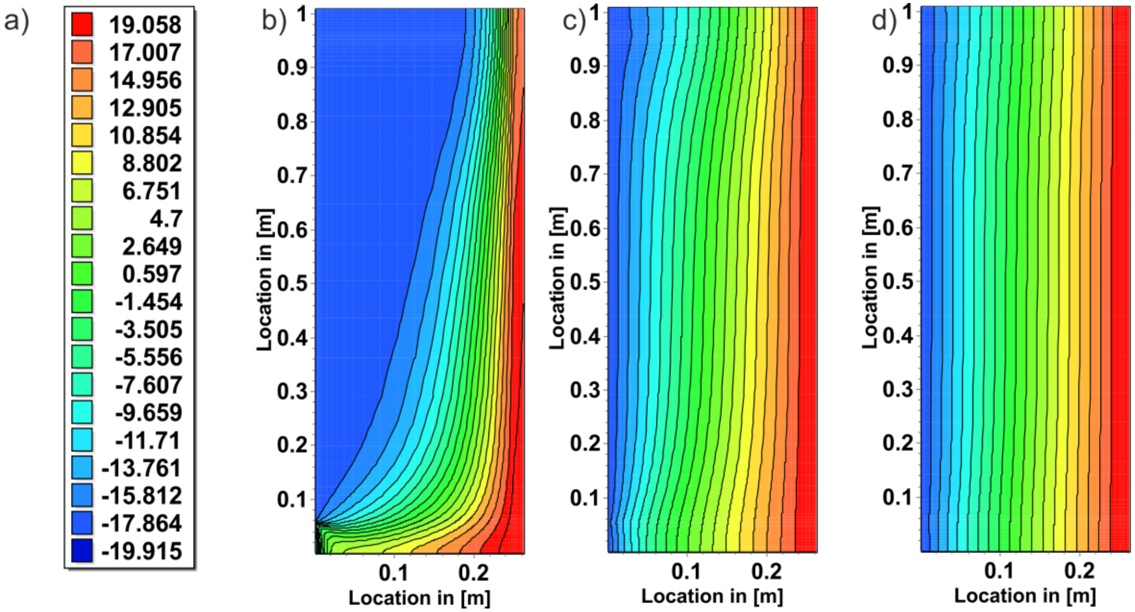
- Results for air infiltration effect



45 kg/m^3 55 kg/m^3 70 kg/m^3

Thermal simulation on heat transfer

- Results for windwashing of the model



45 kg/m^3 55 kg/m^3 70 kg/m^3

Conclusion

- Natural materials has a potential to use them as thermal insulations.
- Some properties of them are even better than for fabric materials.
- The investigation is in continue, like moisture state in long therm observation and thermal conductivity depending temperature.

Recent publications about natural materials

- Kosinski, P., Wójcik R., Skoratko D., Attia, S. 2021. *An impact of moisture content on the air permeability of the fibrous insulation materials*, 8th International Building Physics Conference - IBPC2021 Copenhagen, Denmark, 25-28 August 2021
- Kosiński P., Brzyski P., Suchorab Z., Łagód G. 2020. *Heat Losses Caused by the Temporary Influence of Wind in Timber Frame Walls Insulated with Fibrous Materials*. Materials 13 (23), 5514
- Kosiński P., Brzyski P., Suchorab Z., Łagód G. 2020. *Comparison of air permeability and thermal properties of loose mineral wool and hemp fibers*. AIP Conference Proceedings 2305 (1), 020007
- Kosiński P., Brzyski P., Duliasz B. 2020. *Moisture and wetting properties of thermal insulation materials based on hemp fiber, cellulose and mineral wool in a loose state*. Journal of Natural Fibers 17(2), pp. 199-213
- Brzyski P., Kosiński P., Nadratowska M. 2019. *Thermal bridge occurrence in straw-bale timber frame walls*. IOP Conference Series: Materials Science and Engineering 710(1),012029
- Brzyski P., Kosiński P. Skoratko A. 2019. *Thermal bridges occurrence analysis in timber construction walls filled with hemp fibers*. AIP Conference Proceedings 2133,020005 ▪
- Brzyski P., Kosiński P., Zgliczyńska A., Iwanicki P., Poko J. 2019. *Mass Transport and Thermal Conductivity Properties of Flax Shives for Use in Construction Industry*. Journal Of Natural Fibers (in press)
- Kosiński P., Brzyski P., Szewczyk A., Motacki W. 2018. *Thermal Properties of Raw Hemp Fiber as a Loose-Fill Insulation Material*. Journal of Natural Fibers 15 (5), pp. 717-730

Adoption of v4 building stocks to nZEB standard using natural and bio-based materials

- The project is co-financed by the Governments of Czechia, Hungary, Poland and Slovakia through Visegrad Grants from International Visegrad Fund. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe. Visegrad Grant No. 22010231

THANK YOU FOR ATTENTION

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www.uwm.edu.pl/zboifb