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ADVANCED MATERIALS, STRUCTURES AND TECHNOLOGIES

Examination of Thermal Technical Properties of Organic Based Fibre Insulation Core Materials under Low Pressure

J. Zach, J. Hroudova, V. Novak

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND
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2007–13
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Introduction

- ***Requirements*** *on*:
- reduction of CO_2 emission,
- energy consumption,

  ⟶ changes in the energy efficiency of buildings.

- ***Energy*** consumed on heating and cooling ***exceeds 50 %*** of total energy consumption.
- ***Near zero energy*** and ***passive buildings*** - new, modern energy requirements.
- ***Existing*** and ***historical buildings*** do not meet these requirements – solution?
- addition of building envelope insulation (EPS, MW),
- use of vacuum insulated panels (5−10 x greater thermal resistance - reduce the thickness of the wall insulation).
- Common ***core materials of VIP*****:** fumed and precipitated silica, open-cell polyurethane and several types of fibreglass.

Introduction

- ***Natural fibres*** - production of a core VIP insulator.
- ***Advantages*****:**
  - vascular fibres, composed of clusters of very fine fibres - must be only defibred, their length adjusted and again joined into materials,
  - low energy cost of production,
  - use of easily renewable resources.
- Research performed on this type insulator at normal pressure suggests to use ***fibres*** with the ***lowest*** possible ***thickness***.
- When ***organic insulators*** are used in the production of VIP, they are vacuum sealed in a vapour proof film → ***properties*** of the insulation ***cannot degrade*** and the insulator ***does not become contaminated*** or exposed to ***biotic attack***.

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Introduction

- ***New area*** of application of these materials; little knowledge available.
- The goal of the research being conducted at Brno University of Technology is to ***find alternative core materials based on natural fibres*** which are easy to recycle and do not put strain on the environment.

Specimens

- Specimens of thermal insulation materials based on organic were designed and made to be used in experiments. The following ***types of fibres*** were used:

• *Pure flax fibres* (flax fibres with low content of shives up to 5 %);

• *Raw flax fibres* (flax fibres with high content of shives up to 40 %);

• *Cleaned cotton fibres* from defibred waste textile (high content of cotton over 96 %);

• *Raw cotton fibres* from defibred waste textile – selected jeans textile (high content of cotton over 95 %);

• *Recycled PES fibres* from waste carpets.

Figure 1: *Photography of raw fibers (top left – flax fibers; top right – cleaned cotton fibers; bottom left – PES fibers; bottom right – raw cotton fibers)*

Specimens

- ***5 types of specimens*** were made from the fibres with bulk density of 70–130 kg.m^{-3} according to the type of fibres. The aim was to achieve higher bulk density to ensure the insulators' minimum mechanical properties necessary for vacuum sealing.

Table 1: *Overview of the composition of the specimens*

Specimen no.	***Flax 1***	***Flax 2***	***Cotton 1***	***Cotton 2***	***PES***	***BiCo***
1	80	-	-	-	-	20
2	-	80	-	-	-	20
3	-	-	40	-	40	20
4	-	-	-	-	80	20
5	-	-	-	45	40	15

- The specimens were made using bicomponent binding on a production line using the technology of making an air-lay mat. Thermo fixation was performed at +145 °C. In order to bind the specimens, 15–20 % of synthetic bicomponent fibres (ID BiCo) were used.

Test methods

- At first, the ***properties of the fibres were determined*** – their structure was microscopically analysed and subsequently their thickness measured.
- The insulation mats were cut into specimens sized 200 x 200 mm. ***Physical, mechanical and thermal insulation properties were determined*** for these specimens:

• determination of *thickness* in accordance with EN 823,

• determination of *density* in accordance with EN 1602,

• determination of *thermal conductivity* in accordance with EN 12667, ISO 8301 depending on volume weight,

• determination of *mechanical properties* - Determination of compression behaviour according to EN 826.

Test methods

- The key thermal insulation properties were determined using ***FOX 200 Vacuum*** at medium temperature +10 °C and temperature gradient 10 K at normal pressure and at reduced pressure down to vacuum ($p < 0.1$ mBar).

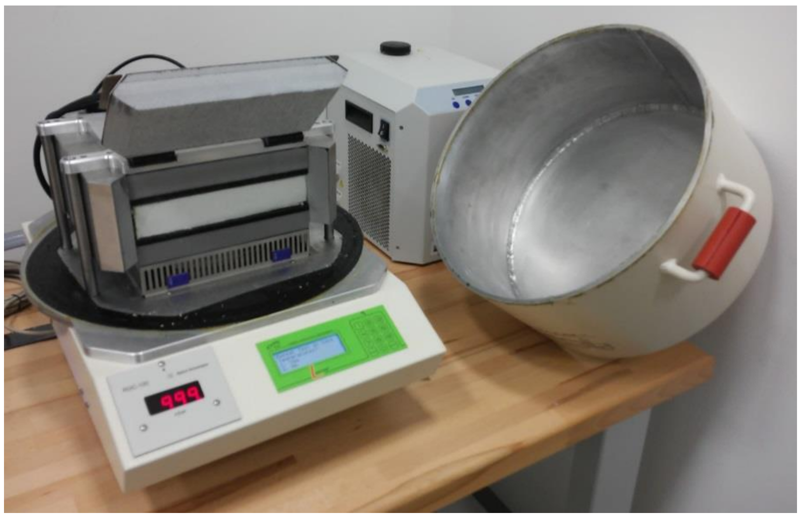

Figure 2: *Photography of apparatus FOX 200 Vacuum for determination of thermal conductivity*

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Test results

- ***Microscopic analysis*** of the ***fibres*** was performed and it was found that in none of the cases defibration down to primary fibres took place during basic processing.

Table 2: *Overview of the thickness of raw fibres*

Specimen no.	***1***	***2***	***3***	***4***	***5***
Type	Flax 1	Flax 2	Cotton 1	PES	Cotton 2
Thickness [μm]	19.8	120.1	25.9	21.1	20.1

- First, the specimens were measured for ***thickness***, ***bulk density*** and ***compressive stress at 10 % strain***. The measurement was performed for the maximum holding pressure enabled by the equipment for determining thermal conductivity. Holding pressure was 1.5 Pa.

Test results

Table 3: *Overview of physical and mechanical properties of the specimens*

Specimen no.	*1*	*2*	*3*	*4*	*5*
Thickness [mm]	22.49	**19.52**	20.08	23.09	**38.32**
Density [$kg \cdot m^{-3}$]	**98.3**	123.8	119.7	101.5	**128.6**
Tension at 10% [kPa]	**2.9**	**12.8**	4.2	**2.9**	3.7

Table 4: *Overview of thermal insulation properties at normal pressure and vacuum*

Specimen no.	*1*	*2*	*3*	*4*	*5*
λ_{Normal} [$W \cdot m^{-1} \cdot K^{-1}$]	**0.0352**	0.0386	0.0354	0.0360	0.0373
λ_{Vacuum} [$W \cdot m^{-1} \cdot K^{-1}$]	0.0078	0.0094	**0.0051**	0.0058	**0.0051**

- After the determination of thermal conductivity at extremely reduced pressure near vacuum, the tests continued by measuring ***thermal conductivity in dependence on pressure*** which was increased prior to each measurement up to 500 mBar.

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Test results

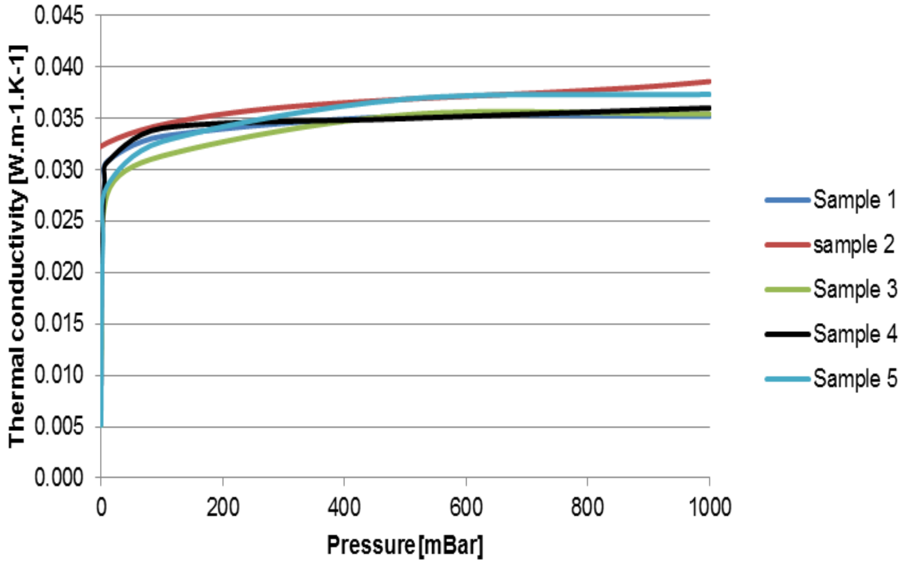

Figure 3: *Dependence of thermal conductivity of the specimens on pressure (*1000 mBar is normal pressure)*

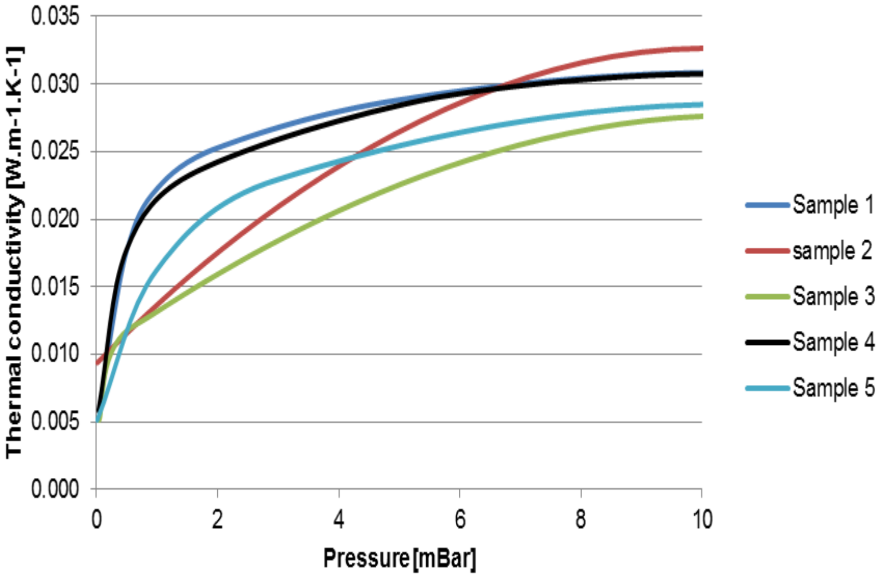

Figure 4: *Dependence thermal conductivity of the specimens on pressure (low pressure area)*

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Conclusion

- The measurements show that fibrous insulators based on organic waste fibres see a reduction of thermal conductivity at reduced pressure down to a value which is in most cases suitable for the production of VIP. The ***thermal conductivity*** of the materials was ***reduced*** by ***76–86 %*** down to ***0.0051*** $\boldsymbol{W \cdot m^{-1} \cdot K^{-1}}$ (in specimens no. ***3*** and ***5***).

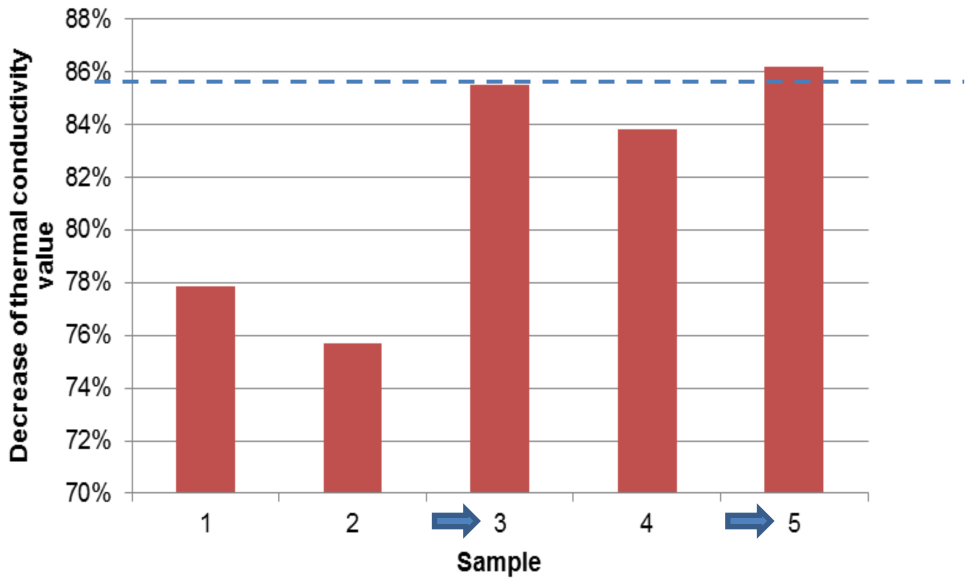

Figure 5: *Overview of percentage decrease of thermal conductivity*

Conclucion

- Development of ***core insulation based on organic fibres***;
- Organic fibres from ***easily renewable raw material sources*** and next ***fibres from recycled clothing and technical fabric***;
- Materials to be very promising, especially materials based on ***cotton*** appear interesting
- ***Advantages*** are:

• initial *raw material is widely available* (waste textile with a high portion of cotton is essentially available worldwide),

• that *secondary raw materials* are used,

• *production is energy and cost efficient*.

Acknowlegements

This paper was elaborated with the financial support of the project GA 13-21791S „Study of heat and moisture transfer in the structure of insulating materials based on natural fibres“ and project No. LO1408 "AdMaS UP - Advanced Materials, Structures and Technologies", supported by Ministry of Education, Youth and Sports under the „National Sustainability Programme I".

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Thank you for your attention

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