Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 78 (2015) 303 – 308

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Thermal and acoustic performance evaluation of new basalt fiber insulation panels for buildings

Cinzia Buratti[a], Elisa Moretti[a]*, Elisa Belloni[a], Fabrizio Agosti[b]

[a] *Department of Engineering, University of Perugia, Via G. Duranti 93, 06125 Perugia (PG), Italy*
[b] *Agosti Nanotherm s.r.l., Via San Giacomo 23, 39055 Laives (BZ), Italy*

Abstract

Thermal insulation of building envelope is very important in energy saving: a growing interest is focused on using insulating recycled and sustainable materials. The thermal and acoustic properties of innovative basalt natural fiber insulating panels were investigated. The thermal conductivity was evaluated by means of a Heat Flow meter apparatus: it is included in 0.030-0.034 W/mK range. The acoustic absorption coefficient was measured by means of Kundt's Tube. The results were compared to traditional solutions with similar chemical composition, but worse mechanical resistance. The easy application of this solution could be useful especially for refurbishments.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

Keywords: basalt fiber insulation panels; thermal performance; acoustic performance; Kund's Tube; refurbishment of buildings

1. Introduction

Thermal insulation in buildings contributes to reduce the size of air-conditioning systems and the annual energy consumptions. The periods of thermal comfort could be extended without depending on mechanical air-conditioning systems, especially during inter-season periods [1]. In Italy at least 90% of buildings were constructed before 1991 and the most part is not in compliance with the statutory requirements (the most recent norms date 2006). The application of innovative solutions can be a useful tool for the refurbishment of existing buildings, reducing the envelope heat losses . Optical, thermal and acoustic properties of innovative insulating systems for buildings have

* Corresponding author. Tel.: +39-075-585-3694; fax: +39-075-585-3697
E-mail address: elisa.moretti@unipg.it

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.648

been investigated at the University of Perugia since 2003, both with experimental campaigns and simulation codes [2, 3, 4]. The application of innovative insulating systems composed of basalt natural fibers can be a clever solution for decreasing heat losses. Basalt fiber combines ecological safety, natural longevity, and many other properties, such as mechanical strength and thermal insulation characteristics. It is not a new material but its applications are surely innovative in many industrial fields, in particular for buildings, constructions, and energy efficiency. The present study is focused on thermal and acoustic characterization of insulating panels composed of basalt natural fibers. Three panels different for density (145, 175, and 200 kg/m^3) and thickness (9 mm, 18 mm, and 27 mm) were investigated. The thermal conductivity was measured by a heat flow meter apparatus at the Labs of the Agosti Nanotherm Company. The tests for the evaluation of the normal incidence acoustic coefficients were carried out at the Labs of Building Physics of the University of Perugia.

2. State of art of basalt fibers insulation panels

2.1. Materials and applications

Basalt is a variety of volcanic rock, especially known for its resistance to high temperatures, strength, and durability. It is suitable for applications requiring resistance against high temperatures, insulation properties, acid and solvent resistance, durability, mechanical strength, low water absorption, etc. In particular, basalt fibers can be used for fire protective applications; it is also an eco-compatibility material, characterized by an easier recyclability when compared to rock or glass fibers. Furthermore, basalt fiber technology production is similar to glass fibers one, but it requires less energy. The large availability of raw material all over the world allows lower costs when compared to glass fibers. Basalt fibers are produced from basalt rock by using single component raw materials and by drawing and winding fibers from the melt. Once the basalt fibers have been produced, they are converted into a suitable form for particular applications [5].

The paper is focused on insulation basalt fiber panels as innovative materials for high energy efficiency in buildings (Fig.1). The chemical composition of the investigated samples shows a high percentage of alumina; it is completely composed by natural fibers, without additives. In this case, in particular, all the mineral fibers used for the construction of the panels are 100% recycled. These systems have a high mechanical resistance, excellent thermal and acoustic properties, and good breathable properties. They are available in different densities and thicknesses. Usually they can be applied as internal coatings, they can be glued to a wall surface and daubed with plasters or paints, without using reinforcing-mesh.

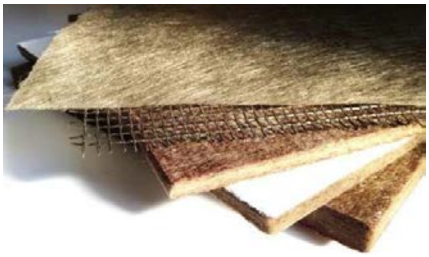

Fig. 1. Basalt fiber insulating panels.

2.2. Description of the samples

Square samples were realized for thermal characterization. They were assembled with external dimensions 300 x 300 mm (dimensions of the experimental apparatus). Three panels different for density were investigated (145, 175 and 200 kg/m^3). The names of the tested samples and their characteristics are reported in Tab. 1: only the panels with a total thickness of 9 mm were tested considering the three different densities (BF_9_a, BF_9_b and BF_9_c).

For acoustic tests, cylindrical samples with diameters 29 and 100 mm were manufactured. Three samples with different thicknesses (9 mm, 18 mm and 27 mm) were investigated: the densities of these samples are not uniform and vary in 145-200 kg/m^3 range. The control of the density during the manufacturing process of the panels with high thicknesses (18-27 mm) is very difficult. Moreover, only for the sample BF_9, three different densities of the panels were investigated in order to analyze the influence of weight. Fig. 2 shows the samples tested by means of Kundt’s Tube.

Table 1. Description of the samples for thermal and acoustic measurements.

Specimens name	Total thickness (mm)	Density (kg/m^3)	Characterization
BF_9_a		145	Acoustic and thermal
BF_9_b	9	175	Acoustic and thermal
BF_9_c		200	Acoustic and thermal
BF_18	18	175	Acoustic
BF_27	27	200	Acoustic

Fig. 2. Basalt fiber specimens for the acoustic experimental campaign.

3. Methodology

3.1. Thermal measurements

The Hot Plate apparatus establishes steady state one-dimensional heat flux through a test specimen between two parallel plates at constant but different temperatures. Fourier's law for heat conduction is used to calculate thermal resistance and thermal conductance. The main equipment used in Nanotherm Laboratory is the Fox 314 HFM apparatus [4], which measures the steady-state heat transfer through flat materials according to ASTM Standard C518 (2003) [6] and EN ISO 12667 [7]. The sample is placed between two flat plates controlled to a specified constant temperature. Thermocouples fixed in the plates measure the temperature drop across the specimen and wireless thermal flux meters (HFMs) embedded in each plate measure the heat flow through the specimen. The thermal conductivity (λ in W/(m·K)) is calculated by means of the heat flux, the temperature difference across the specimen, and the thickness of the specimen.

3.2. Acoustic characterization

The normal incidence absorption coefficient was measured by means of a two-microphone impedance tube (Brüel & Kjær, model 4206) using the transfer function method and cylindrical samples with diameters of 29 and 100 mm (combined frequency from 50 to 6400 Hz), according to ISO 10534-2 standard [8]. The normal incidence sound absorption coefficient indicates the part of the acoustical energy of the incident wave that is absorbed by the tested sample in a specific configuration; the not absorbed part is reflected back to the source side. The sound pressures are measured at the same time in two microphone positions and the transfer function between them is calculated. The samples inserted in the thermal and acoustic experimental apparatus are shown in Fig. 3.

Fig. 3. Samples inserted in the experimental apparatus: heat flow meter apparatus (left) and Kundt's Tube (right).

4. Results and discussion

4.1. Thermal performance

The samples BF_9_a, BF_9_b, and BF_9_c (Tab.1) were tested both for thermal and acoustic characterization by means of the heat flow meter apparatus and the thermal conductivity of the specimens was calculated. The obtained values are 0.0320, 0.0335 and 0.0345 W/mK, respectively for samples BF_9_a, BF_9_b and BF_9_C. Other samples with lower densities were also tested (115 and 130 kg/m^3): values of the thermal conductivities respectively of 0.0305 and of 0.0315 W/mK were found, but the results are not considered due to their not adequate mechanical resistance. A light increasing of λ with the density was in general observed.

4.2. Acoustic properties

Three samples for the each type of panel were tested (BF_9a, BF_9b, BF_9c, BF_18, and BF_27) (three for the large tube and three for the small one) and an average trend was analyzed. Several measurements were carried out also for the same disk, modifying the position of the sample inside the tube. Fig. 4 shows the average normal incidence absorption coefficient trend (combination of the large and the small tube measurements, 100-5000 Hz). In general, the normal incidence absorption coefficient increases when increasing both density and thickness; nevertheless for frequencies higher than 1600 Hz, higher values than BF_27 (Fig. 4 (a)) were found for BF_18.

Furthermore, by increasing both thickness and density, the greatest shift is at low frequencies, according to Literature data [9,10]. Fig. 4 (b) shows the average normal incidence absorption coefficient of the sample BF_9 for the different densities (145, 175 and 200 kg/m^3): the more the density, the more the absorption coefficient.

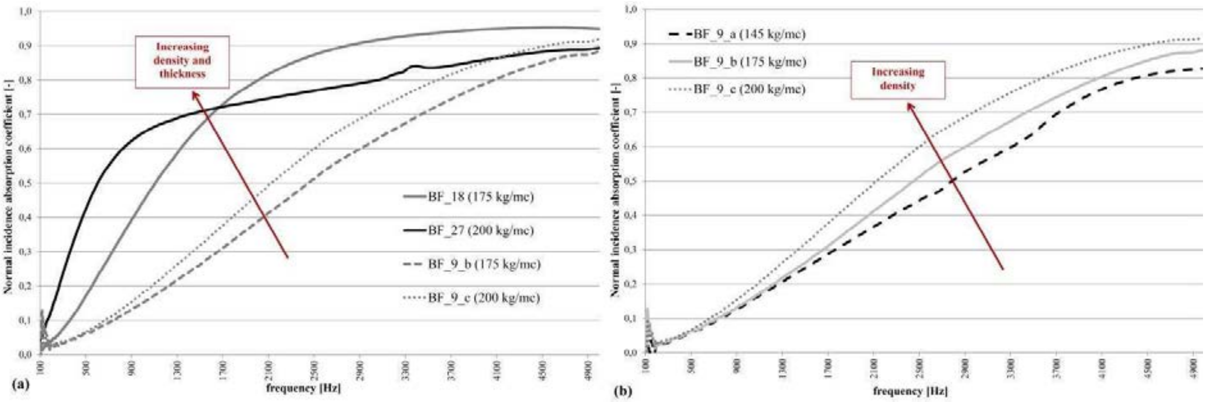

Fig. 4. Absorption coefficient at normal incidence: (a) comparison between BF_9_b, BF_9_c, BF_18, and BF_27; (b) BF_9a, b and c, considering the three densities.

5. Comparison with conventional solutions and benefit analysis

The basalt fiber innovative insulation panels could be an effective solution when compared to traditional ones, such as rock wool and glass wool panels. The advantage is their possible use in small thickness (≤ 3 cm), whereas the thickness of rock wool and glass wool panels vary in 3 – 10 cm range.

In order to evaluate the in situ performance of the proposed material, different existing buildings were supposed to be refurbished by using the panels: Tab. 2 shows the decreasing of the thermal transmittance of different kinds of wall, due to the internal application of the new insulating panels (λ = 0.032 W/m K) in the three different thicknesses (9, 18 and 27 mm, with a final coat of about 1-2 mm). They are compared to the same walls with the application of rock wool. It can be observed that the innovative panel is very effective for a stone wall with a thickness of about 60 cm (Type 1) (U = 2.14 W/m^{2}K). Applying only 9 mm of basalt fibers panel, the thermal transmittance of the wall becomes 1.34 W/m^{2}K (U-red. of about 38%), with a thickness increasing (Δs) of only 1.6%; comparable results (U-red. of about 63 - 64%) are obtained for the same wall by applying 27 mm of basalt fibers panel (s_{BF} = 0.027 m) or 30 mm of rock wool (s_{RW} = 0.030 m), but the thickness increasing is about 4.8 - 4.9%. The same trend should be observed for a brick wall and a cavity wall. Furthermore a support structure is necessary for rock wool panels, while fiber basalt panels can be directly glued on the wall, whatever the thickness due to their higher mechanical resistance.

The tensile strength of the basalt fiber panels is about 350 kPa, while the one of a rock wool panel with high density (about 120 kg/m^3) is of only 10 – 20 kPa.

Finally, a comparison between the acoustic coefficient trend of the basalt fiber panel BF_27 (200 kg/m^3, s=27 mm) and the values obtained for a rock wool panel 4 cm thick with three different densities were analyzed in Fig.5 (RW_40_a, RW_40_b and RW_40 _c). A similar trend was found, but the values for rock wool are 0.1 - 0.2 higher than basalt fibers for all the frequencies, due to the higher thickness [11, 12]. Future studies will focus on analyzing also the transmission loss properties of the panels, in order to evaluate the noise abatement properties.

The cost of the basalt fibers panels varies in 27 – 30 €/m^2 (s = 9 mm) and it is not very different from the cost of rock wool panels with thickness in the 40 - 60 mm range. The price of the new material is expected to decrease thanks to the reduction of the transport costs, considerable nowadays (Chinese factories): the target value is about 16 €/m^2.

Table 2. Thermal transmittance values of different types of conventional wall before and after refurbishment with different insulation materials.

	Before refurbishment		**After refurbishment (Basalt Fiber panels)**					**After refurbishment (Rook Wool panels)**			
Wall Type and description	s_{TOT} (m)	U (W/m^{2}K)	s_{BF}(m)	s_{TOT} (m)	U (W/m^{2}K)	U – red. (%)	Δs (%)	s_{RW} (m)	U (W/m^{2}K)	U – red.(%)	Δs (%)
1 - Stone wall (s = 600 mm), internal and external lime plastered (s = 15 mm)	0.63	2.14	0.009	0.64	1.34	38	1.6	0.03	0.80	**63**	4.9
			0.018	0.65	0.97	55	3.2				
			0.027	0.66	0.76	**64**	4.8				
2 - Brick wall (s = 300 mm), internal and external lime plastered (s = 15 mm)	0.32	1.61	0.009	0.33	1.11	31	3.1	0.03	0.71	**56**	9.5
			0.018	0.34	0.84	48	6.2				
			0.027	0.35	0.68	**58**	9.4				
3 - Cavity wall (s = 250 mm) (air brick wall 120 mm + 50 mm air gap + air brick wall 80 mm), internal and external lime plastered (s = 15 mm)	0.28	1.10	0.009	0.29	0.84	24	3.6	0.03	0.59	**43**	10.8
			0.018	0.30	0.68	38	7.1				
			0.027	0.31	0.57	**48**	10.7				

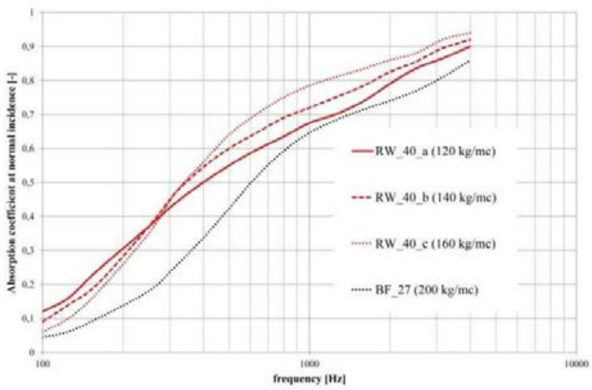

Fig. 5. Absorption coefficient at normal incidence: comparison between basalt fibers and rock wool panels [11].

6. Conclusions

Efficient insulating materials contribute in reducing the heat losses from buildings and allow energy and money saving for heating and cooling. Lately many innovative insulation products emerged on the market also thanks to good mechanical resistance and acoustic properties. In this context, thermal and acoustic properties of an innovative insulating system composed of basalt natural fibers were investigated. The eco-compatibility panel has a thermal conductivity included in 0.030 - 0.034 W/m K range, lower than the one of the rock wool panels; in the building refurbishment, the thermal transmittance of walls could be reduced by 20-40 % (depending on the existing wall type) using panels with very small thickness (9 mm). The acoustic performance of the innovative insulating material was evaluated in terms of absorption coefficient at normal incidence: the panels have high values of absorption coefficient (which increase considering higher thicknesses or densities) and the performance is comparable to the one of rock wool panels. This new material will be useful not only for its good acoustic and thermal behavior, but also because it is 100% recycled: future studies will analyze the Life Cycle Assessment of the innovative system in order to evaluate the Embodied Energy and the Global Warming Potential when compared with traditional materials.

References

[1] Papadopoulos AM. State of the art in thermal insulation materials and aims for future developments. Energy Build. 2005;37:77–86.
[2] Buratti C, Moretti E, Belloni E, Cotana F. Unsteady simulation of energy performance and thermal comfort in non-residential buildings. Build. Environ. 2013;59:482–491.
[3] Moretti E, Zinzi M, Belloni E. Polycarbonate panels for buildings: Experimental investigation of thermal and optical performance. Energy Build. 2014;70:23–35.
[4] Buratti C, Moretti E, Belloni E, Agosti F. Development of Innovative Aerogel Based Plasters: Preliminary Thermal and Acoustic Performance Evaluation. Sustainability 2014;6:5839-5852.
[5] Available online: http://www.enea.it/it/produzione-scientifica/EAI/anno-2011/indice-world-view-3-2011/basalt-fiber-from-earth-an-ancient-material-for innovative-and-modern-application//(accessed on 3 February 2015).
[6] ASTM C518–10. Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus; ASTM: West Conshohocken, PA, USA, 2003.
[7] EN ISO 12667. 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; ISO: Geneva, Switzerland, 2001.
[8] ISO 10534–2. Acoustics-Determination of Sound Absorption Coefficient and Impedance in Impedance Tubes-Part 2: Transfer-Function Method; ISO: Geneva, Switzerland, 1998.
[9] Kim HK, Lee HK. Influence of cement flow and aggregate type on the mechanical and acoustic characteristics of porous concrete. Applied Acoustics 2010;71:607–615.
[10] Asdrubali F, D'Alessandro F, Mencarelli, Horoshenkov KV. Sound absorption properties of tropical plants for indoor applications. The 21st International Congress on Sound and Vibration, 13-17 July 2014, Beijing/China.
[11] Wang CN, Torng JH. Experimental study of the absorption characteristics of some porous fibrous materials. Applied Acoustics 2001; 62:447-459.
[12] Pompoli F. Studio di modelli di previsione delle proprietà fisico-acustiche, di materiali in lana di roccia Rockwool, Relazione Tecnica 2004.