PAPER • OPEN ACCESS

An impact of moisture content on the air permeability of the fibrous insulation materials

To cite this article: Piotr Kosiski *et al* 2021 *J. Phys.: Conf. Ser.* **2069** 012205

View the article online for updates and enhancements.

An impact of moisture content on the air permeability of the fibrous insulation materials

Piotr Kosiński[1], Robert Wójcik[1], Dariusz Skoratko[1] and Shady Attia[2]

[1]Department of General Construction and Building Physics, University of Warmia and Mazury in Poland, ul. Jana Heweliusza 4, 10-724 Olsztyn, Poland

[2]Sustainable Building Design Lab (SBD), University of Liège, Quartier Polytech 1, Allée de la Découverte 13A, 4000 Liège, Belgium

Piotr.kosinski@uwm.edu.pl

Abstract. Fibrous materials are characterized by good thermal properties, but are susceptible to air filtration. Effective air and wind protection of the building envelope eliminate the problem of air penetration of fibrous materials, but there are still many buildings where this protection has not been applied. Authors investigated the effect of moisture content on the air permeability of chosen loose fibrous materials: mineral wool, wood wool and cellulose fibers. The presented results may be used to simulate and calculate heat loses in existing buildings.

1. Introduction

Fibrous thermal insulation materials differ in structure, origin, thermal and humidity properties. However, they all have one thing in common: they are porous and therefore prone to convective heat transfer [1]. The air permeability coefficient κ which characterize the air flow capacity of material, depends primarily on the porosity of the material (and thus on its density), but it is also influenced by the structure of the fibers and the presence of dust. The authors investigated the effect of wetting the mineral wool, wood wool and cellulose fibers on their air permeability.

2. Method and materials

2.1. Method

The scheme of the research device is presented in detail in [2], inspired by [3].The apparatus (Figure 1) used to determine the air permeability coefficient of loose fibrous materials was constructed with plexiglass tube (inner diameter 60 mm, wall thickness 3 mm) divided into three sections to enable disassembly of the inner section filled with the test sample. During experiment the pressure difference between two taps in the central section and corresponding air speed of the exhaust were recorded. The standard measurement uncertainty of the pressure difference is ±2 Pa in the measuring range, while the uncertainty of air velocity is ±0.04 m/s. Pressure uncertainty can be practically neglected in the achieved range (up to 6,000 Pa) of the pressure difference, but the uncertainty of air velocity is very important. We estimated this influence: underestimation of air velocity can result in up to 29% overestimation of air permeability, while overestimation of air velocity can lead up to 55% of underestimation of air permeability.
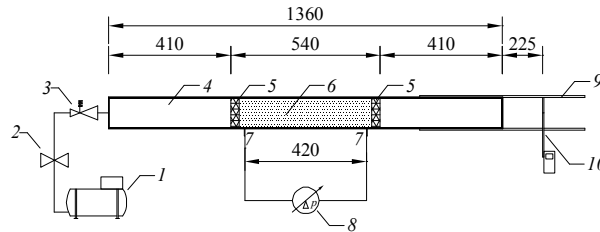
Figure 1. The scheme of the test stand for the measurement of air permeability of loose fibrous materials: 1 – an air compressor, 2 – a valve, 3 – an air regulator, 4 – a plexiglass tube, 5 – strainers, 6 – test specimen, 7 – pressure taps, 8 – pressure gauge, 9 – nozzle, 10 – thermo-anemometer.

The mechanism of the measurements is as follow: air is compressed in the screw compressor, equipped with the filter and dryer, and delivered to the apparatus by pressure reducer. The pressure difference between two taps, located in central part of the apparatus is registered. Simultaneously, air velocity on the exhaust is registered. In order to avoid discrepancy of the density and viscosity of the air during investigation, a constant temperature and humidity of air: +20 °C, 55% was maintained in laboratory environment. Temperature of compressed air was also constant +20 °C. Samples for measurements were prepared carefully in order to filled the central section evenly. The air permeability coefficient values were determined by approximating the Forchheimer equation (1):

$$-\frac{dp}{dx} = \frac{\mu}{\kappa} \cdot v + \beta \cdot \rho \cdot v^2,$$
(1)

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

2.2. Materials

Three materials were tested in a loose state: mineral wool, wood wool and cellulose fibers. For each material one measurement serie was conducted with dry material and two series with wet material. In each of the series at least 5 different densities of material were used. Table 1 presents the moisture content of tested materials before and after measurements. Mineral wool is characterized with small sorption tendency, while natural origin materials, especially cellulose fibers were saturated in a very high level. The wet materials were conditioned for 5 weeks in desiccators over demineralized water. After the measurements, they were stored again in desiccators to continue conditioning for another 6 weeks. The time of conditioning was set on the basis of previous sorption investigations. Despite systematic mixing the materials, uniform moisture level of the samples has not been achieved.

Table 1. Moisture content of the tested 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)

3. Results and discussion

Authors prepared the same volume of each material. It can be clearly seen in Figure 2 that for cellulose more samples were tested. This is due to the fact that this material is easy to create samples of desired density. In the case of dried fibers of each of tested materials, a good fit can be seen

between the results and the regression - power function. The presence of moisture in mineral wool reduces the air permeability of the material, so the fit function decreases more sharply. It should be noted, that it is not a big difference between the series 2 and 3 in this case. Moisture appearance in the wood wool samples also reduces the air permeability with visible tendency that the more wet is sample the more reduced is air permeability. It can be seen that there are few out-of trend results in each of the wet series. Cellulose fibers reached the highest moisture level amongst tested materials, but its influence on air permeability is not visible. More important is that wet cellulose fibers do not react predictably on the air flow. Many samples deviate from the trend as shown by the regression fit. It might be affected by high moisture content of cellulose and local condensation of water on the surface of the fibers and dust. In that point questionable are the recommendations of cellulose insulation producers to not use vapor barrier.
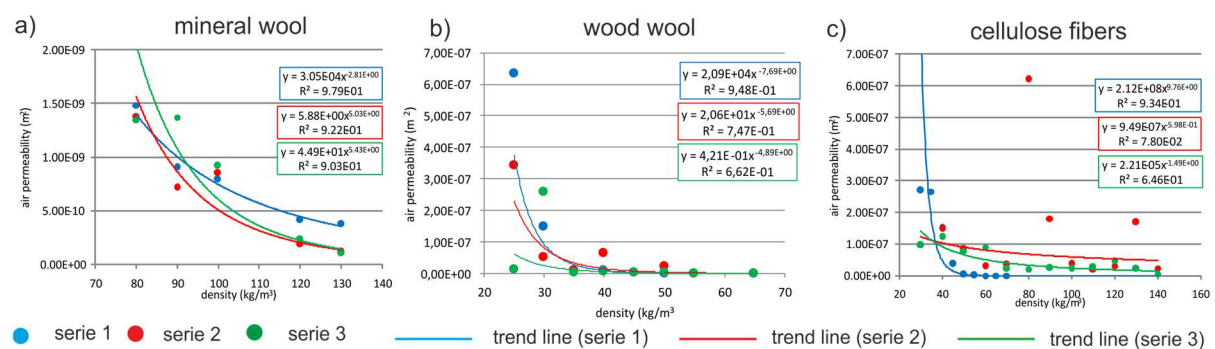
Figure 2. Measured air permeability of: a) mineral wool, b) wood wool, c) cellulose fibers.

4. Conclusions

It can be concluded that the tendency to reduce air permeability along with the density occurs regardless of whether the sample is dry or wet. However, moisture amount in the material affects the value of air permeability. Different fibrous materials conditioned in the same environmental conditions achieve varying wetness level. Materials of natural origin tend to get higher wetness. Interestingly, mineral wool, which has low water absorption due to the hydrophobization of the fibers, shows a greater reduction in air permeability than wood wool and cellulose fibers. Wet wood wool for densities up to 50 kg/m^3 also achieves lower air permeability in comparison to dry material, but for higher densities almost the same. In case of wet cellulose fibers, lower air permeability was measured for densities up to 40 kg/m^3 in comparison to dry material. Importantly, the cellulose fibers underwent the least drying during the air flow. Examination of the structure of dry and wet fibers under a microscope revealed that in the case of mineral wool moisture remains only on the fiber surfaces, while in natural materials, moisture remains both on the surface of the fibers and inside them. Perhaps that was why wet mineral wool lost (in percentage) more moisture during the air flow than natural materials. Current research is directed towards determining heat losses by air filtration in different moistened fibrous materials.

References

[1]   Straube J and Smegal J 2018 *Literature Review and Research Summary on Wind Washing of Air Permeable Insulation.* Technical Report. RDH Building Science Laboratories, Waterloo, ON

[2]   Kosiński P and Wójcik R 2017 An Impact of Air Permeability on Heat Transfer through Partitions Insulated with Loose Fiber Materials. *Appl. Mech. and Mat.* 861 p 190-197

[3]   Sobieski W and Trykozko A 2011 Sensitivity Aspects of Forchheimer's Approximation *Trans. in Por. Med.* 89 p 155–164