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ScienceDirect

Procedia Engineering 151 (2016) 368 – 374

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Ecology and new Building materials and products, ICEBMP 2016

Studying the properties of particulate insulating materials on natural basis

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Abstract

Recently, materials based on secondary raw materials have been the focus of attention of building companies and end users as well. The reason for this are mainly the low material costs, easy manufacture and application in building structures. Despite the lower cost compared to existing insulation materials, strict requirements are put on these thermal insulation materials.
In response to the constantly increasing need for insulation materials and given the general requirement of sustainability in the use of natural resources, the Faculty of Civil Engineering in Brno has for many years been engaged in the development of insulation materials made from natural fibres of agricultural origin. These materials show great promise in civil engineering. They have a low carbon footprint and low primary energy input. Experimental testing conducted in the past has revealed that the properties of these materials are comparable to those of the synthetic insulations available on the market. However, in terms of thermal insulation properties, the natural-fibre materials have different hygrothermal behaviour, which is due to the different structure of the insulations as well as the low value of thermal conductivity of the natural fibres (compared with e.g. glass or mineral fibres). The paper deals with the development of particulate insulation based on natural fibers, their behavior under different conditions and mainly with the examination of the thermal properties depending on moisture and bulk density. The paper also presents the results of research in the dependency of thermal insulation, acoustic and mechanical properties of the experimentally manufactured insulations on their bulk density.

Peer-review under responsibility of the organizing committee of ICEBMP 2016

Keywords: Natural fibers; thermal conductivity; dynamic stiffness; moisture content

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Peer-review under responsibility of the organizing committee of ICEBMP 2016
doi:10.1016/j.proeng.2016.07.390

1. Introduction

Currently, strict requirements are put on energy cost savings in civil engineering, the lowest possible manufacturing costs of building materials and constructions. At the same time, the comfort of the building users is also subject to a high standard. Concerning the thermal insulation of buildings, materials based on natural and secondary raw materials, obtainable by the recycling of agricultural products, are being used still more frequently. Their undisputed advantage is the immediate availability of local resources. Not only does this reduce the list price, but it also accelerates the delivery. However, these materials suitable for the production of advanced insulation materials fall under a number of requirements. Primarily, these are the thermal properties of the fibers, which should be comparable with conventional fibers commonly used in the manufacture of insulating materials. For example the thermal insulation materials made of EPS, XPS have thermal conductivity values between 0.030 – 0.040 $W \cdot m^{-1} \cdot K^{-1}$, the cotton board with a density of 150–450 $kg \cdot m^{-3}$ have the thermal conductivity values ranging from 0.0585 to 0.0815 $W \cdot m^{-1} \cdot K^{-1}$, Recycled textile fibers reached values between 0.041 and 0.053 $W \cdot m^{-1} \cdot K^{-1}$ [1,2,3]. A thermal characterization of the straw bales material was performed by Goodhew et al.; they measured a thermal conductivity of 0.067 $W \cdot m^{-1} \cdot K^{-1}$ for a 60 $kg \cdot m^{-3}$ dense sample [4]. Yarbrough et al. evaluated the thermal insulation performance of particleboards made of rice hulls, an important by-product of rice cultivation. The thermal conductivity at 24 °C was between 0.0464 and 0.0566 $W \cdot m^{-1} \cdot K^{-1}$ the lowest value was measured for a 154 $kg \cdot m^{-3}$ dense sample [5]. Another important property of thermal insulating materials is their bulk density, which also closely influences their insulating properties water vapor resistance factor. The ability of a material to be not permeable to water vapor is measured by water vapor resistance (μ-value). The lower the value the higher the material vapor permeability. The μ-value value of 1 is assigned to air. EPS building insulators are characterized by a μ-value between 20 and 70, while coir-based materials are between 5 and 30. Mineral wools are characterized by very low values (under 5) whereas vapor barriers can reach values over 100,000 [6].

The paper examines the thermal properties of experimental materials at a different relative humidity. Furthermore, it aims to find the density of water vapor resistance factor, the dynamic stiffness and acoustic properties in dependence on bulk density.

2. Materials and methods

The test samples of thermal insulating materials were made from three kinds of natural fibers, namely straw, hemp and cellulosic fibers.

Cellulosic fibers – obtained by recycling commonly available waste paper. The paper is processed in production lines, where it is thoroughly pulped into cellulosic fibers.

Straw fibers – obtained by defibring the stalks and stems of dried cereals, mainly wheat.

Hemp fibers - this is industrial hemp, which was determined to be most suitable due to its good durability, stability and good thermal insulation properties.

The above-described fibers were used in four types of text mixtures:

1. Hemp fibers + cellulose fibers in the ratio of 60:40
2. Cellulose fibers 100%
3. Cellulose fibers + straw in the ratio of 30:70
4. Straw 100%

Samples of three bulk densities were made from each mixture. The samples from mixtures 1 through 3 had the bulk densities of 30, 45 and 60 $kg \cdot m^{-3}$, mixture number 4 was made into samples with the densities of 95, 110 and 120 $kg \cdot m^{-3}$ according EN 1602 [7].