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Thermal conductivity of heat insulation material made from coniferous needles with potato starch binder

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Abstract

In previous experiments made by authors of this research about the possibilities to produce thermal insulation material from coniferous greenery (needles and thin branches), it was found that there is not enough natural resin in coniferous greenery to make sufficiently strong thermal insulation material plates. Therefore it is necessary to add some binder. Potato starch glue was selected as a natural and environmentally friendly binder. For that reason, the aim of the experiments in this study is to evaluate how the quantity of potato starch binder influences the thermal conductivity coefficient of the coniferous needle thermal insulation material. In this study two experiments were performed investigating two factors – proportion of the binder and the coniferous species (pine or spruce). In the first experiment milled fresh coniferous greenery with potato starch binder was used. In the second experiment potato starch was used to band dried needles without the branches. Granulometric content of the raw material was determined in both cases. A total of 14 different samples were prepared and tested in this study, the thermal conductivity coefficient was determined in laboratory conditions for all of the samples. The results are compared with thermal conductivity coefficients of other thermal insulation materials. The possibility to use coniferous greenery to produce thermal insulation material is evaluated.

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Keywords: needles; coniferous; heat insulation; potato starch

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1. Introduction

The demand for environmentally friendly and healthy products is steadily increasing. This also applies to building materials, which can have great effect on human health. It is therefore not surprising that new, environmentally friendly construction materials including thermal insulation materials are still actively studied. Demand for thermal insulation materials is increasing due to the growing costs of energy resources. Obtaining natural and environmentally friendly thermal insulation materials is an especially topical issue nowadays, when thermal insulation materials have become an extensively used product. This study is focussed on an ecological thermal insulation material made from coniferous forestry residues.

Plate-like thermal insulation material from coniferous greenery prepared without any additional adhesives or binders has been studied and described previously by the authors of this article [1]. The authors arrived at the conclusion that the resin naturally occurring in coniferous forestry residues is not enough to provide the firmness and particle adhesion necessary for insulation plates from coniferous greenery. Therefore it is necessary to find a solution in the form of a natural, environmentally friendly adhesive.

The use of various herbal origin adhesives for binding thermal insulation materials has been studied by various authors. For example, Palumbo M. et al. used corn starch and sodium alginate to produce thermal insulation materials from rice husk, corn pith and barley straw [2]. In other studies a raw rice husk thermal insulation material has been produced using a lime based binder [3]. Plaster and epoxy has been used as a binding material for thermal insulation materials from sunflower stalk, textile waste and stubble fibres by Hanifi Binici [4]. A common plant-based construction material adhesive is concrete [5–8].

The adhesive material obtained from mixture of potato starch and water was selected for this study. Up until this moment the potato starch adhesive has not been studied sufficiently as only few papers can be found in scientific databases [9, 10]. To our knowledge potato starch has not been evaluated in the context of its potential as adhesive material for plant-based thermal insulation materials. Therefore, the aim of this research is to evaluate if and how the quantity of potato starch binder influences the thermal conductivity coefficient of coniferous needle thermal insulation material.

2. Materials and methods

A two-factor experiment plan was performed before manufacturing and testing the coniferous greenery thermal insulation material with potato stark adhesive, thus ensuring an efficient determination of the effect and values of the set factors and the acquisition of qualitative results. The thermal conductivity coefficient was selected as the main response factor. The proportion of the selected adhesive is one of the factors that have to be assessed in order to reach the aim of this study. The second factor is the species of coniferous tree (spruce or pine). The previous studies confirmed that freely poured spruce and pine needles have different thermal conductivity coefficients [11], however the impact of the species for ground needles has not yet been determined [1]. In order to determine the effect of separating needles from other woody parts in the greenery on the thermal conductivity coefficient, it is necessary to obtain raw material that would consist only of single species needles of coniferous trees. This is technically possible if coniferous greenery is dried and the needles are falling off the branches. However, if the dried needles are minced, a mass of fine particles are formed. These fine particles were proved to have lower capacity to retain heat [12]. Therefore it was decided to carry out 2 experiments with a board-type insulation material (made using potato starch adhesive) with 2 unchanged factors, but varying the preparation methods.

Potato starch adhesive prepared in ratio 1:10 (1 part dry potato starch, 10 parts water) was used to bind the needles in the form of a plate-type thermal insulation material. In the first experiment (see Table 1) raw, coarse grind coniferous greenery is used. Milling machine (PM120 Vibrotehnik) with a sieve mesh size of 10 mm was used to grind the greenery. The minimal value of the adhesive part by weight to coniferous greenery mass was 1/2, maximal 1/1 and medium 1/1.5. This proportion was chosen based on laboratory experiments with small size (~10x10 cm) samples. From the small samples it was recognized that these proportions are proper to keep the needles together. But it is not based on the mechanical strength of the material.

To describe the species of the coniferous trees, it was assumed that the minimal value was pine greenery and maximal – spruce greenery, average value of this factor is a mix of both pine and spruce greenery with the ratio 1/1.