Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 172 (2017) 586 – 594

Procedia Engineering

www.elsevier.com/locate/procedia

Modern Building Materials, Structures and Techniques, MBMST 2016

Investigations on physical-mechanical properties of effective thermal insulation materials from fibrous hemp

Arūnas Kremensas[a]*, Rūta Stapulionienė[a], Saulius Vaitkus[a], Agnė Kairytė[a]

Vilnius Gediminas Technical University, Scientific Institute of Thermal Insulation, Laboratory of Thermal Insulating Materials, Lithuania

Abstract

Depletion of fossil fuels resources and large amounts of pollutants emitted to the atmosphere enforce searching for alternative renewable resources. One of these resources is fibred hemps. The main components obtainable during the processing of fibred hemp biomass – fibres and shives, they are characterised by low density and porous structure; thereby, they are suitable for the production of thermal insulating composites. The research is based on investigation of two types composites produced from hemp fibres and hemp shives as well as biologically divisible binders. The investigation covers the impact of different amounts of binders and hydrophobizers on physical-mechanical properties.

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

Keywords: Hemp fibres, hemp shives, biodegradable binders, thermal conductivity, compressive strength.

Nomenclature

d	thickness of specimen
Greek symbols	
ρ	density (kg/m^3)
λ	thermal conductivity (W/(m·K))
σ	strength (kPa, MPa)

* Corresponding author. Tel.: +370 52512344.
E-mail address: arunas.kremensas@vgtu.lt

Peer-review under responsibility of the organizing committee of MBMST 2016
doi:10.1016/j.proeng.2017.02.069

Introduction

Nowadays energy saving is becoming more relevant. Depletion of fossil fuels resources and large amounts of pollutants emitted to the atmosphere which occur during their processing enforce searching for alternative renewable resources. One of the possible solutions – cultivation of fibred plants (fibred hemps, flax and etc.) and usage of products from the processing as alternative raw material in various industrial fields.

Hemps – annual plants which under the favourable conditions may grow up to 4 metres in height [1], and in southern regions, even up to 10 metres [2]; therefore, fibred hemps are characterized by large amount of biomass (4-6 tonnes of dry mass from 1 ha) [3]. During the processing of hemp raw material, fibre is separated and chopped woody part remains. This part is called hemp shives. Hemp fibres may be used for the production of thermal insulating materials, composite parts for automotive industry, in paper production, textile, and hemp shives are widely used as litter for animals [4]. One of the possibilities is their wider application in building sector.

Hemp shives are characterised by low density and high porosity [4] (air accounts approximately 60 % [5]) what determine sufficient thermal insulating properties. For this reason, it would be appropriate to bind hemps with binding material and the obtained mixture could be used as pour in place material or as a mixture for the formation of blocks and slabs.

The research of "hemp concrete" has begun in the eighties [5]. Using different types of binding materials and mixing different amounts of them with hemp shives, mixtures with various physical-mechanical properties and wide application areas are obtained (e.g. load bearing, thermal insulating, sound absorbing structures and elements [5]).

Scientists [6] have conducted a research and obtained results show that compressive strength of specimens from hardened mixture of MgO based cementitious binder, hemp shives and water ranges from 1.86 MPa to 6.94 MPa, thermal conductivity– from 0.085 W/(m·K) to 0.065 W/(m·K), when the density of specimens varies from 910 kg/m^3 to 1200 kg/m^3. Due to low density of hemp shives and high thermal insulating properties when cementitious binder is used, material which is characterised by low density, thermal conductivity and sufficient acoustical properties can be obtained [4].

Another widely used binder is lime. Concrete from hemp shives and lime has one interesting characteristic: 1 m^2 of wall, produced from such material, in 100 years of exploitation eliminates 14-35 kg of CO_2 due to reactions occurring during lime carbonization process [7]. This material is characterised by porous structure which determines low thermal conductivity value (depending on forming parameters of mixture, thermal conductivity varies from 0.06 W/(m·K) to 0.12 W/(m·K), however, the material is not mechanically strong [5]). The research of Evrard [8] concluded that compressive strength of formed mixtures ranges from 0.2 MPa to 0.5 MPa and Arnaud et al. [9] obtained it ranging from 0.4 MPa to 1.2 MPa [4]. Due to low compressive strength, this material cannot be used in the production of bearing structures, consequently it should be combined with wooden or other type bearing carcass or used as ordinary thermal insulating-acoustical material [10]. Other inorganic and organic binder may be used for the production of forming mixtures, i.e. clay dust, lime and cementitious mixtures [11,12].

In seventies when the research and development of bio-composites has begun, starch is used as a binder [13]. This is biologically divisible material which is low cost, used in paper, cardboard, textile production industries as well as production of thermoplastic composites and films [13].

The most saleable and widely used product from hemp raw material is hemp fibres which consist of cellulose, hemicellulose, lignin, wax and other water soluble materials. Chemical composition and structure determine properties of natural fibres [14]. Natural fibres have lots of advantages such as low density, ecology, sufficient acoustical and thermal insulating properties and low cost, still they have disadvantages: absorb moisture, properties are dependent on harvesting conditions, limited temperature in the production processes and they are not fire resistant [15]. Hemp fibres are characterised by good strength properties (tensile strength (550–900) MPa, modulus of elasticity – 70 GPa) [15], accordingly, they are used to strengthen composite materials, frequently they replace glass fibres [16].

Ochi (2006) [17] has conducted a research on a composite from starch based emulsion type biologically divisible binder and revealed that composite's tensile strength when 70% of hemp fibres are used is 365.4 MPa and bending strength – 222.7 MPa. Lopez et al. (2012) [18] have investigated the impact of hemp fibres on strength properties of biopolymer based on starch. Experimental results have shown that tensile strength of non-reinforced biopolymer is 30.6 MPa, bending strength – 55 MPa. The obtained results for composite with 30% of hemp fibres show that tensile strength has increased to 54.3 MPa and bending strength to 102.6 MPa. These results show that due to high mechanical strength