INCREASING FIRE PROOFNESS OF SAPROPEL AND HEMP SHIVE INSULATION MATERIAL

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Abstract. Sapropel and hemp shive insulation material has been presented in the research. Raw materials sapropel and hemp shives are extracted in Latvia. Hemp shives is the waste of hemp processing, which is not being used at the moment. The most recent research works testify that the resources of sapropel in Latvia's lakes have been estimated to approximately 800-900 million m^3 and they can be used during several hundreds of years. The only disadvantage of the recently extracted composite material is its comparatively low fire-resistance. Several solutions have been offered in order to increase the fire-resistance of sapropel-hemp shive insulation plates. They are coating of the material with different fire-smothering liquids, fire retardants and the formation of different protective coatings. It is essential to choose a protective coating that is made of ecological, renewable and local raw materials. Clay, lime and gypsum plasters have been offered as protective coatings in the publication of the research work. The aim of the research is to increase the fire-resistance characteristics of the recently extracted insulation material and its prospective usage in construction according to the existing normative documents regarding construction in Lavia.

Keywords: sapropel, hemp shives, thermal insulation materials, fire resistence, ecological building materials.

Introduction

Nowadays the most topical environmental problems are climate change and global warming resulting in rebalancing of natural complexes, as well as extreme weather conditions in the areas where it has not been typical [1].

At the end of 2015, the United Nations Climate Change Conference took place in Paris. At this conference governments agreed on long-term goals to keep the global average temperature increase below 2 ºC in comparison with the pre-industrial level and to try to limit temperature increase to 1.5 ºC. These objectives are also binding for our country.

The Latvian Parliament adopted the National Medium-Term Development Plan 2014-2020 (Latvian National Development Plan – NDP 2020), which provides the growth model for the country in order to ensure long-term predictability in decision making. This development plan pays attention to the renewable energy resources and energy saving providing the use of local raw materials in various economic sectors [10].

On October 1, 2014 a new Construction law entered into force in Latvia, which clearly defines the basic principles of construction. Paragraph 5 of the construction basic principles stipulates that the following should be observed in construction: sustainable construction principles, according to which a high-quality living environment for the present and future generations has to be developed during the construction process by increasing the use of renewable energy resources and by promoting the efficient use of other natural resources for this purpose [2].

In the circumstances of energy resource deficits it is important to limit energy consumption and to use local renewable energy resources, as well as to use building materials made from local renewable natural resources.

Ecological construction development provides an opportunity for energy-saving during the production of building materials, as well as reducing environmental pollution. Ecological building materials are fully recyclable and they decompose relatively quickly [9].

The study proposes to develop insulation materials from hemp shives as fillers and sapropel as a binder. Both these raw materials are local and renewable. Such solution is very timely, as the sapropel stocks in Latvia's lakes has reached 700 to 800 million m^3 [3] and in the swamps under the peat layer it is 1.5 billion m^3 [4].

Sapropel is organogenous sediments of a lake and it develops from aquatic debris mixed with mineral particles (sand, clay, calcium carbonate and other compounds). It is brown, black, grey, greenish or yellowish jelly-like mucilaginous or colloidal mass, which can be found in most of Latvia's lakes and in more than one third of the swamps. The thickness of sapropel deposits varies from a few centimetres to about 20 meters [5]. There are 1327 total of such lakes in Latvia where sapropel stocks can be found.

Hemp shives – residues obtained during hemp processing – are used as the filler. The woody part of the hemp or shives makes about sixty-five percent of the hemp, which is not fully used [6].

Laboratory experiments show that it is possible to get qualitative, ecological and advanced insulating building materials from such local, renewable raw materials like sapropel and hemp shives [8]. One of the most serious disadvantages of this newly obtained composite material is its relatively low fire resistance.

The study provides several solutions for the increase of fire-resistance of insulation plates made of sapropel – hemp shive mixture. It is important to choose the coverage of the material with different non-combustible protective coatings from ecological, renewable and local raw materials. This paper deals with the research of various coatings – clay, lime and gypsum.

Materials and methods

Natural raw materials were obtained from different local companies for the research. Sapropel was obtained from Ubagova Lake in Makoņkalns rural territory of Rezekne municipality, where LATPOWER Ltd is operating. Hemp shives were obtained from Latgale Agricultural Science Centre Ltd and processed in flax pre-treatment workshop in Preili.

Sapropel-organogenous lake sediments – is used as a binder in the light sapropel hemp shive concrete. G. Liberts innovative microscopy centre of the Daugavpils University tested sapropel samples with an electronic microscope VEGA. The results are provided in Table 1, where min and max measurements are % of weight [7].

Table 1

Sapropel chemical element min and max values % by weight

Chemical elements	C	O	Mg	Al	Si	S	K	Ca	Fe	Mo
Max	89.53	31.18	0.66	1.88	3.29	0.39	1.35	2.67	1.27	0.49
Min	53.06	35.40	0.66	1.55	2.86	0.40	0.52	1.07	0.94	0.49

Sapropel obtained in Ubagova lake consists of 92.6 % of water.

Hemp shives derived from the hemp seed varieties (Cannabis sativa L.) have been used as a filler of light sapropel hemp shive concrete. Hemp shives are residues derived from the processing of hemp with low density (from 40 to 90 $kg \cdot m^{-3}$). Shives are in 60 -75 % of hemp stems. The size of hemp shives is 5 to 40 mm, humidity 12.14 %.

As a result of the experiments optimal proportion of sapropel and hemp shives and water mixture was obtained due to the experiment [8]. The obtained material was tested in the physics laboratory of the LUA using the equipment HFM 436 and a thermal conductivity coefficient λ has been determined, which ranged from 0.049 to 0.054 $W \cdot (mK)^{-1}$, as well as the volume mass of the material, which ranged from 152 to 183 $kg \cdot m^{-3}$. Sapropel hemp shive plates with dimensions of 270x270x50 mm were made for laboratory studies, where 30 mm was sapropel hemp shive mixture and fire resistant coatings of 10 mm on both sides. Refractory coatings were made of plaster, lime plaster and clay-sand mixture coating. The samples obtained at the beginning were dried in a ventilated oven at +51 ºC for 24 hours, after that for 15 days under natural laboratory conditions at +21 ºC and with room humidity of 22 %. It should be noted that the density of the samples with coatings increased to 534 $kg \cdot m^{-3}$. The obtained samples were used for fire reaction and fire resistance tests.

Fire-reaction tests were conducted in the laboratory of the Forest and Wood Products Research and Development Institute in Jelgava, 41 Dobeles Street, but fire resistance tests were conducted in the laboratory of the Latvia University of Agriculture, Faculty of Environment and Civil Engineering in Jelgava, 19 Academy Street.

The fire resistance tests were performed on the uncoated sapropel hemp shive mixture by determining the maximum instantaneous combustion power, the total amount of the exuded heat in the first 5 minutes, the total amount of exuded heat per area unit, the average maximum heat emission and combustion capacity of the material using a conic calorimeter method according to ISO 5660

(Figure1). The test for the sample with a size of 100x100x50 mm and a mass of 67g was carried out at thermal radiation of 50 kW·m^{-2}, air temperature at 23 ºC and relative humidity of 50 % .

Fig. 1. **Sapropel hemp shive mixture test in the conic calorimeter**

Fire resistance of the produced sapropel hemp shive mixture plates with a non-combustible coating was determined by a small-scale fire resistance test [14] by determining the increase of the temperature on the surface of the sample on the fire unexposed side.

The temperature is measured in the furnace, on the fire side, on the surface of the sample with K-type thermo-couples Omega XC-20-K-12, with an accuracy of ± 0.5 %. On the opposite side of the fire four K type thermo-couples Omega 5TC-GG-KI-20-1M were fitted with an accuracy of ± 0.5 %. The parameters of thermo-couples are recorded by the data recorder OM-DAQPRO-5300 every 10 seconds.

The computer programme "DaqLab", version 1.40.01 was used for data processing.

Results and discussion

A number of material burning parameters have been defined for sapropel hemp shive mixture. The maximum instantaneous combustion power of sapropel hemp shive mixture is 223 kW·m^{-2} and it can be achieved in 25 s, while the average instantaneous combustion power is 80 kW·m^{-2}.

As shown by the results in Figure 2, sapropel hemp shive mixture ignites quickly and can lead to rapid fire development and therefore it is necessary to consider the ignition time reduction of the material. Despite the fact that the sapropel hemp shive mixture plates are coated with a non-combustible coating – gypsum, clay and lime, it only slightly reduces the mixture ignition time, since the increase in the temperature is sharp, as shown in Figure 3.

As shown by the results in Figure 2 (c), the total heat release amount during the first 300 s is 30 MJ·m^{-2}, which is a very low parameter and it does not accurately describe the properties of the material, sincethe material had already lost 70 % of its mass in 345 s and the total mass loss is 3659 g·m^{-2}.

The defined total amount of heat per area unit of the sapropel hemp shive mixture 48 MJ·m^{-2} can significantly increase the fire load in the place where the material has been used, but the effective amount of the combustion is 13 MJ·kg.

The amount of released fumes for sapropel hemp shive mixture was also determined with the conic calorimeter method which was 212 m^{2}·m^{-2} during 10 s to 615 s of the flaming phase, but during the entire test from 0 s to 615 s the total amount of released fumes was 222 m^{2}·m^{-2} that would lead to a significant amount of smoke during the fire and would complicate the evacuation of the persons from the building.

In further studies it could be recommended to develop and research the thermal insulation materials in several layers, separated by a load-bearing fire barrier layer. Then the smouldering of one layer would not achieve critically high temperature and flames could not move to the next eco insulation layer. During the eco insulation smouldering process fumes would exude only from the layer in which ignition took place by limiting their quantity. Gypsum plasterboard should be used for finishing of the lightweight sapropel and hemp shive concrete wall, which would also serve as a finishing material and directly protect the material from ignition. Fire properties of the newly developed light concrete can be improved with the use of various flame retardants. Thus, the overall fire protection parameters of the layers would increase significantly.

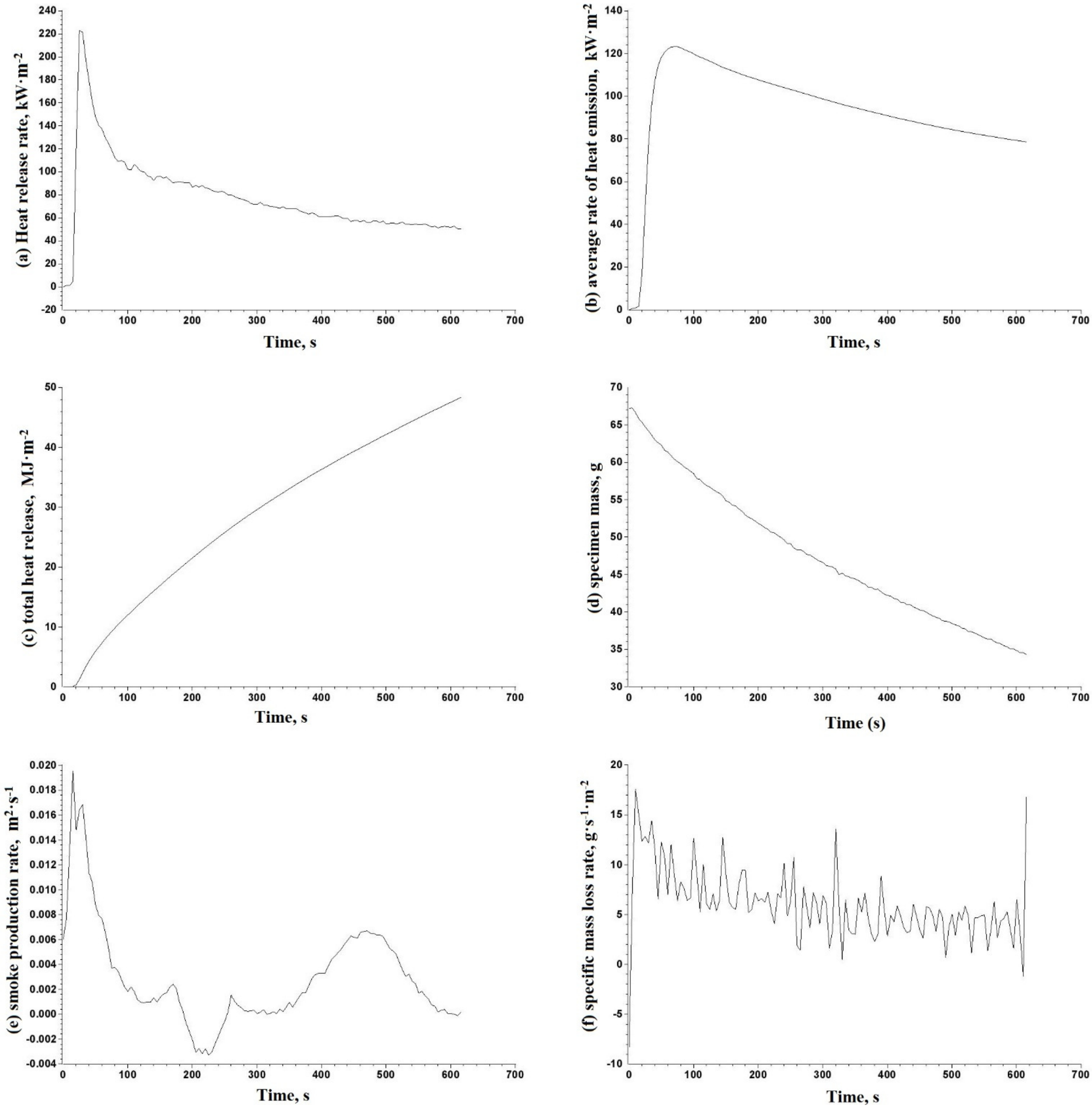

Fig. 2. **Results of the conic calorimeter tests**

Figure 2. The results of the conic calorimeter tests: (a) heat release rate, (b) average rate of heat emission, (c) total heat release, (d) specimen mass, (e) smoke production rate, (f) specific mass loss rate.

By determining the fire resistance of the produced sapropel hemp shive mixture plates covered with a non-combustible material with small-scale experimental equipment, a temperature increase was specified for the plates on the opposite side of the fire. Three types of coatings were used – lime, clay and gypsum. The plates with a gypsum coating showed the best results, in which the surface temperature on the opposite side of the fire after 2000 s did not exceed 70 ºC. An increased release of smoke was observed during all tests from the sapropel hemp shive mixture layer, which had burnt out after the completion of the test.

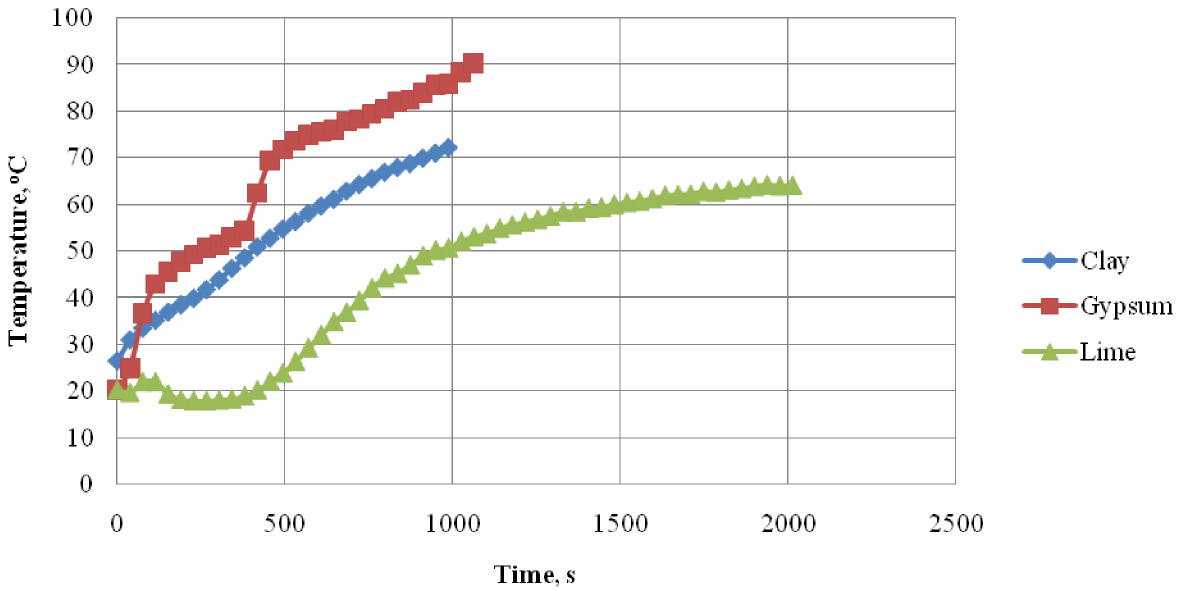

Fig. 3. **Temperature increase of the plates on the opposite side of fire**

Conclusions

1. Taking into account the previous experiments it can be concluded that the thermal conductivity coefficient λ of the light-weight sapropel and hemp shive concrete ranges from 0.049 to 0.054 $W \cdot (mK)^{-1}$ at the volume mass of the material within the range of 152-183 $kg \cdot m^{-3}$, therefore, this new composite material can be used as a good insulation material.
2. The above-mentioned fire resistance tests show that production of the thermal insulation plates from light 50mm thick sapropel and hemp shives with a variety of fire protection coatings (clay, lime, gypsum) is of low effectiveness, while increasing the thickness of the non-combustible coating will significantly increase the thermal conductivity coefficient. The use of the protection coating retards the spreading of fire to the protective cover of the opposite side, but it does not eliminate smoke.
3. The results of the research lead to the conclusion that it is necessary to consider the development of a complex construction system with coatings from non-combustible materials and the use of fire retardants.

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