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Research on Foam Gypsum with Hemp Fibrous Reinforcement

Raitis Brencis*, Juris Skujans, Uldis Iljins, Imants Ziemelis, Normunds Osits

Latvia University of Agriculture, Liela 2, Jelgava, LV-3001, Latvia
raitis.brencis@llu.lv

Energy saving for housing and building materials' production is an important issue in Latvia and other countries. Huge primer energy consumption and CO_2 emission is characteristic for production of various modern isolation materials. Natural resources have been widely used for building materials' production in many countries the entire world. The use of local materials, for example, gypsum in building materials' production and insulating of building constructions, would be a significant input in Latvia's national economy. Gypsies rock - gypsum is a local resource and its usage in Latvia's national economy is economically beneficial. Foam gypsum is one of the possible gypsum types, for which it is possible in wide range to vary the density and also such important parameters of building materials as mechanical strength, sound absorption, heat conductivity etc. (Skujans et al., 2010). Previous research (Skujans et al., 2007) on foam gypsum showed that foam gypsum can be similar to other well known thermal and sound insulation materials as mineral cotton, polystyrene, perlite, clay, etc. Gypsum obtains a high fire-resistance – the fire reaction class A in accordance with the European regulations (Ministry of Economics, 2008). Fragility of the material could be mentioned as a certain disadvantage, that's why reinforcement of the material is necessary. Natural fibrous plants growing in the region could be used as reinforcement. For example, palm plants in southern regions (Bacellar and D'Almeida, 2009) and hemp in Latvia (Allin, 2005). Fibrous plants are relatively widely used in building, production of industrial products, in vehicle production sphere, agriculture and others. A special attention is paid to the use of fibrous hemp in various sectors of national economy. The research on this topic is developed in Germany, France, Great Britain (Ulme and Freivalde, 2009). At present the usage of various fibrous plants in foam gypsum production, as well as production costs and ecological efficiency has not been evaluated. The purpose of the research is to develop the production technology for a new energy resources saving composite building material – foam gypsum with fibrous hemp reinforcement, as well as research on mechanical and sound absorption qualities.

1. Materials and methods

1.1 Production technology of the foam gypsum sample

The foam gypsum was produced using dry mineralization method (Skujans et al., 2007), mixing water, gypsum, surface active stuff (SAS), and adding hemp's reinforcement. The concentration of hemp's fiber is the amount of fiber in grams per 1 kg dry gypsum

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raw material (c, g/kg). The hemp's fiber concentration was varied within the limits of 15÷50 g/kg. Fibers of two lengths were used in sample production, and they were added to the foam gypsum during its production process. Fibers were prepared by chopping and sifting in order to get two different lengths - 2.5÷5.0 mm (hereinafter – short fibers) and with length 5÷10 mm (hereinafter – long fibers). Beams of size 40x40x160 mm were produced from the foam gypsum, which were farther used for testing the bending and pressure resistance, by pressing the material to the utter rupture. Foam gypsum beams were processed using a round shape knife, and a cylinder type sample with Ø 40 mm and length 160 mm were produced for tests in acoustic tube.

1.2 Research methodology of the foam gypsum sound absorption

The sound absorption measurements had been carried out using the company's "Sinus" impedance tube produced by the industry. By the tube it was possible to measure the sound absorption coefficient in the range of frequencies from 250 Hz up to 4000 Hz, when the sound reflects from the sample. The impedance tube has two different diameters Ø100 mm and Ø40 mm. In the tube part of Ø100 mm the sound source was placed, but in the part of Ø40 mm, two measure-microphones and a sample of Ø40 mm, to be measured, were located. The sound muffle coefficient (α) was determined by formula:

$$\alpha = \frac{I_{abs}}{I_{fal}} \tag{1}$$

where I_{abs} – intensity of absorbed sound; I_{fal} – sound intensity falling on the sample.
For all range of frequencies the mean value of the absorption coefficient was determined according to the standard of the European Union (EN ISO 11654:1997).

1.3 Research methodology of the foam gypsum bending and pressure resistance

Research on bending and pressure resistance of the composite material (foam gypsum + hemp's fiber) was carried out using a device Zwick Roell 2.5 TS (Figure 1.),

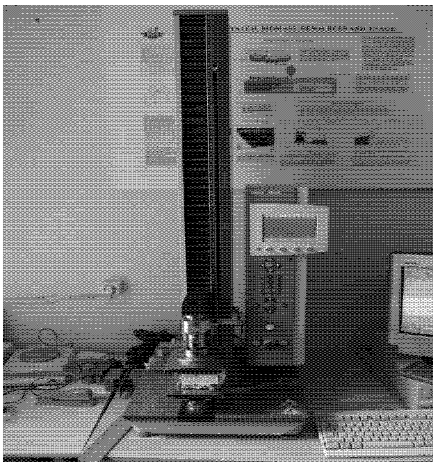

Figure 1: Company „Zwick" device for testing bending and pressure resistance.

The results were processed by a computer program Test Xpert V9.01. As a result of the research, the maximum bending and pressure stresses of the material had been determined depending on fibers' length and concentration in foam gypsum. Samples were tested in three points bending with 100 mm distance between supports.

2. Experimental results

Varying the producing technology (water gypsum ratio/surface active stuff ml), it is possible to obtain foam gypsum with density from 380 kg/m³ to 1100 kg/m³.

Figure 2 reflects that when the volume of surface active stuff is increased, the foam gypsum density value decreases.

The common sound absorption coefficient (α) tendency depending on the density is that α increases if the foam gypsum density decreases (Skujans et al., 2010). This tendency has been observed also when modifying foam gypsum with hemp's reinforcement. It is possible to obtain a better sound absorption coefficient of the material at equal foam gypsum density (Figure 3). This index is better for the foam gypsum with long fibers. Foam gypsum sound absorption coefficient with short fibers is higher than for the foam gypsum without fibers, but lower than for the foam gypsum with the long fibers at equal density value.

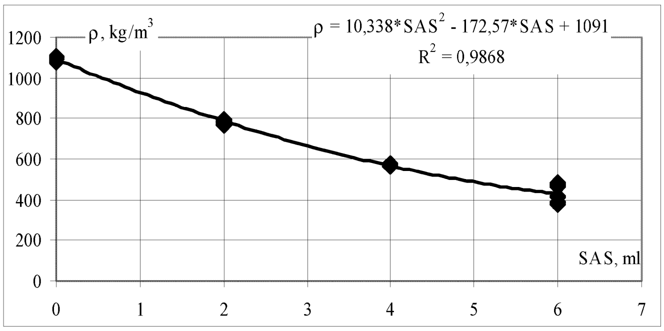

Figure 2: The density depending on amount of surface active stuff (SAS) at water gypsum ratio 0.7.

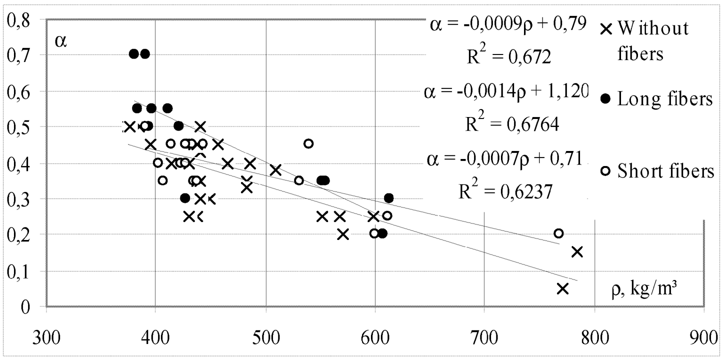

Figure 3: The value of sound absorption depending on the density.

Sound absorption coefficient within the limits of 0.6 – 0.3 is equal to the European standard (EN ISO 11654:1997) C, D class requirements, and that's why the foam gypsum with hemp's reinforcement within density value 380 – 550 kg/m^3 can be used as a sound absorbing material.

In order to specify the fibers' length and quantity impact on mechanical qualities within the density value 380 550 kg/m^3, samples with two types of hemp's fibers with length 2.5÷5mm and with length 5÷10 mm were produced. Increasing short fibers' concentration in the foam gypsum, its density value increases, but this coherence is opposite when producing foam gypsum with long fibers' reinforcement (Figure 4).

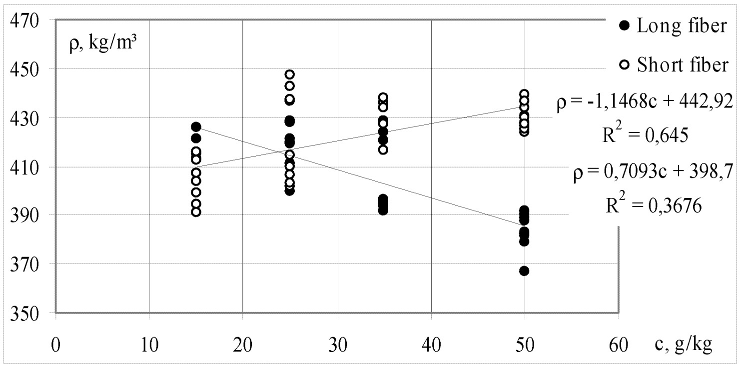

Figure 4: The density of the composite material depending on short and long fibers.

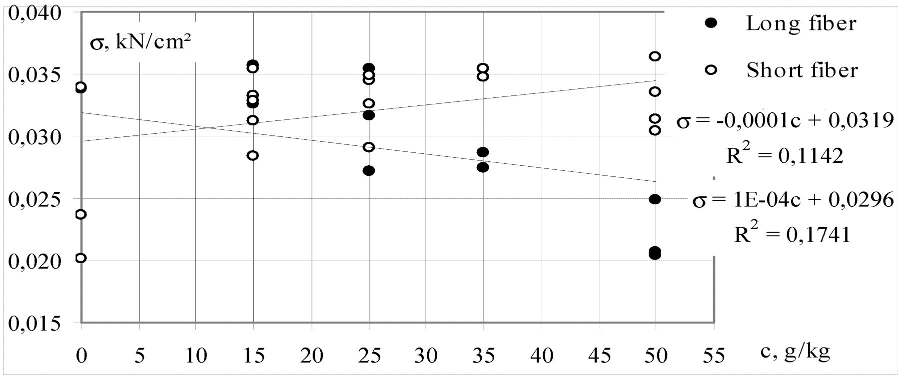

Figure 5: The value of bending stresses in the composite material depending on concentration of long and short fibers.

Figure 5 reflects the bending stresses of samples with long and short fibers. Increasing short fibers' concentration, the bending stresses prevalently increases. Increasing long fibers' concentration, the bending stresses decreases. This coherence correlates with the density influence on material strength (Figure 4), where increasing short fibers'

concentration, the density increases, but for the foam gypsum with long fibers, the density value decreases.
A similar bending stress is observed in research on pressure strength (Figure 6). Increasing hemp's reinforcement concentration increases the pressure strength of the foam gypsum with short fibers, but decreases the pressure strength of the foam gypsum with long fibers.

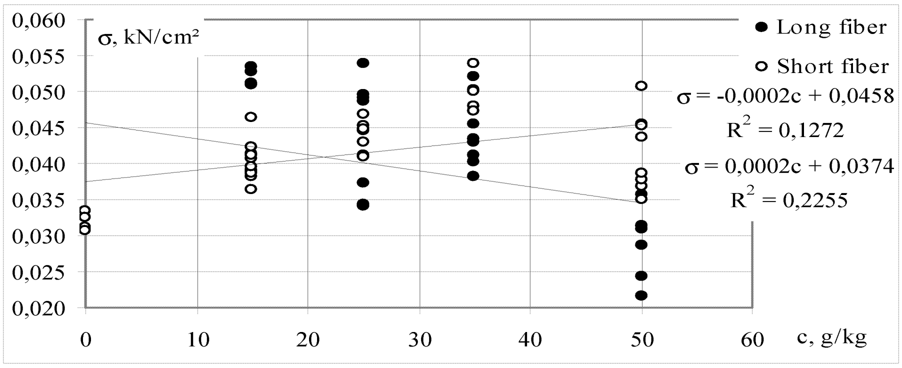

Figure 6: The value of pressure stresses in the composite material depending on concentration of long and short fibers.

3. Discussion

Foam gypsum and hemp fibers' reinforcement density dependence on fiber concentration (Figure 4) is still an unaccountable and debatable issue. It is possible that hemp fibers influence the growth of pores in foam gypsum, and foam gypsum density value is changed, when modified with hemp fibers. The issue of hemp fibers and foam gypsum structure correlation will be developed by further research on pore structure in foam gypsum modified with hemp fibers. Differences of sound absorption coefficient for the samples with hemp fibers and without it at equal density value, is still an unanswered issue. Possible, it is connected with the fact that hemp fibers have ability to transfer sound waves deeper into material, in such a way increasing sound absorption ability.

4. Conclusions

1. Foam gypsum with hemp's reinforcement of the density within 380 – 550 kg/m^3 by its acoustic qualities corresponds with the standard EN ISO 11654:1997 C, D level requirements, and it can be used as a sound absorbing material.
2. The sound absorption coefficient at equal density value is higher for foam gypsum with hemp's reinforcement, but long fibers' reinforcement increases the foam gypsum absorption coefficient (α) more than short fibers' reinforcement.
3. Increasing the concentration of short (2.5÷5 mm) fibers' reinforcement in the foam gypsum increases its density, but decreases the density for the foam gypsum with

long (5÷10 mm) fibers. The change of the density, in its turn, determines the bending and pressure stresses.

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