RESEARCH OF HEMP FIBROUS REINFORCEMENT EFFECT TO BENDING STRENGHT AND SOUND ABSORPTION OF FOAM GYPSUM

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ABSTRACT

Natural resources have been widely used for production of building materials in many countries in the entire world. Use of local minerals, such as materials on foam gypsum basis, in construction material production and usage in sound and heat isolation in building structures, is a significant benefit in national economy. The current research in foam gypsum shows that such possibilities exist (Skujans et al., 2010). Varying at the process of manufacturing with the ratio of gypsum and water, as well as the volume of the surface active stuff, foam gypsum of different volume density can be obtained but it has to be noted that the low bending strength of foam gypsum is a disadvantage. Material modification with fibrous reinforcement (hemp reinforcement) can serve as improvement of foam gypsum bending strength but it depends on the measure and amount of hemp reinforcement. Shorter fibers of hemps increase the material strength but longer fibers increase the sound absorption coefficient. Both fiber types have an impact on the pore structure of foam gypsum as it is on foam gypsum without fibrous reinforcement manufactured with the same technology.

Key words: foam gypsum, hemp reinforcement, pore structure.

INTRODUCTION

The authors research in the qualities of foam gypsum and hemp reinforcement and its usage as a heat and sound isolation material in building structures. Hemps as a building material are used in lot of building structures in Europe countries (Allin, 2005; Kymalainen et al., 2008). Fibrous plants are relatively widely used in building, production of industrial products, in vehicle production sphere, agriculture and others. Special attention is paid to the use of fibrous hemp in various sectors of the national economy. The research in this topic is developed in Germany, France, Great Britain (Ulme and Freivalde, 2009).

Hemps as fibers have been used (Madsen et al., 2007) in a lot of composite materials, for example, in composition with lime and mortar (Elfordy et al., 2008). At present the usage of various fibrous plants in foam gypsum production, as well as the production costs and ecological efficiency have not been evaluated. Hemps as heat insulation are similar with rock wool (Timber… 2010) and hemp fibers increase the bending strength and sound absorption of foam gypsum (Brencis, 2011).

The foam gypsum pore structure has influence on the material volume density and its physical and mechanical properties (Skujans et al., 2010). The hemp reinforcement influence on the foam gypsum pore structure has not been investigated. The purpose of the research is to develop the technology of production of new energy resources saving the composite building material – foam gypsum with fibrous hemp reinforcement, as well as research in the mechanical and sound absorption qualities of this material. The research coincides with the EU objectives of environment protection and is directed to construction of ecological dwelling houses in the future.

MATERIALS AND METHODS

Production technology of the foam gypsum sample

The foam gypsum was produced using the dry mineralization method (Skujans et al., 2007), mixing water, gypsum, surface active stuff (SAS), and adding hemp reinforcement. The concentration of hemp fiber is the amount of fiber in grams per 1 kg dry gypsum raw material (c, g/kg). The hemp 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. The fibers were prepared by chopping and sifting in order to get two different lengths - 2.5÷5.0 mm (hereinafter – short fibers) and with the length 5÷10 mm (hereinafter – long fibers).

Beams of size 40x40x160 mm were produced from the foam gypsum, which were further used for testing the bending and pressure resistance, by pressing the material to the utter rupture. The foam gypsum beams were processed using a round shape knife, and a cylinder type sample with Ø 40 mm and the length 160 mm was produced for tests in acoustic tube.

Methodology of the foam gypsum sound absorption properties

The sound absorption measurements were carried out using the company "Sinus" produced impedance tube (Fig. 1). With 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 absorption coefficient (α) was determined by formula (Skujans et al., 2010):

$$\alpha = \frac{I_{abs}}{I_{fal}} \quad (1)$$

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 (EN ISO 11654:1997).

Research methodology of the foam gypsum bending and pressure resistance

The research in the bending and pressure resistance of the composite material (foam gypsum + hemp fiber) was carried out by the device Zwick Roell 2.5 TS (Fig. 2.).

Investigation methodology of foam gypsum pores

The structure of pores was investigated by the digital microscope VNX-100. Before the investigation of the pores under the microscope, the samples have been grinded with following cleaning of the surfaces from the dust.
The measurements of the pores for each of the samples were done in five places with 50 times magnification. The disposition of the spots of the measurements made a cross on the sample surface. In each of 5 positions the picture, seen in the object-glass, has been divided in 1x1 mm squares. From this three regions were chosen. Each sample at 15 reiterations was measured. The pores making the porous structure of the samples do not have ideally round shape.

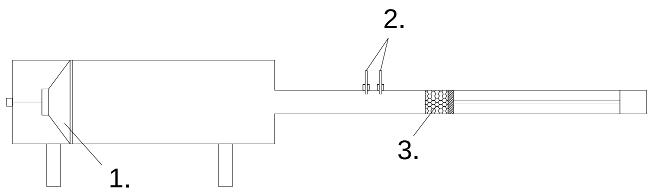

Figure 1. Device produced by the company "Sinus" for measuring sound absorption: 1-sound source, 2-measuring microphones, 3-measurable sample.

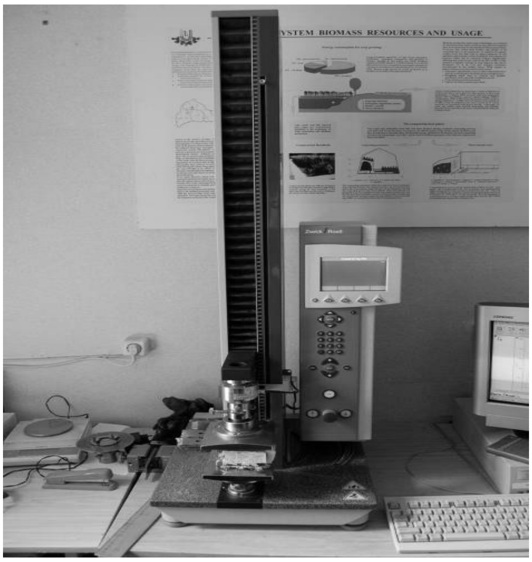

Figure 2. Company „Zwick" device for testing bending and pressure resistance.

Therefore, the area of pores per 1 mm² instead of its diameter has been determined. A large amount of pores are linked with adjacent ones. The cross-sectional area of these joint pores is distinctive for different samples and depends on its volume density, amount of the surface active stuff, added during the production process of the sample, as well as other reasons related with the technology used in production of foam gypsum.

RESULTS AND DISCUSSION

Varying at the process of manufacturing with the gypsum - water ratio, as well as the volume of the surface active stuff (SAS) and concentration of hemp fibers, samples of volume density from 380 kg/m³ to 1000 kg/m³ have been obtained. In further investigations samples with the volume density range from 380 kg/m³ to 500 kg/m³ were chosen. It was found that the sound absorption coefficient (α) increases with decrease of the volume density of the foam gypsum (Skujans et al., 2010). This tendency was observed also when the foam gypsum was modified with hemp reinforcement. It is possible to obtain a better sound absorption coefficient of the material at equal foam gypsum volume density (Fig. 3). By increasing the short fiber concentration in the foam gypsum, its volume density value increases, but this coherence is in the opposite when producing foam gypsum with long fiber reinforcement (Fig. 4). Fig. 5 reflects the dependence of the bending stresses of the samples with long and short fibers. Increasing of the short fiber concentration, the bending stresses prevalently increase. By increasing the concentration of long fibers, the bending stresses decrease.

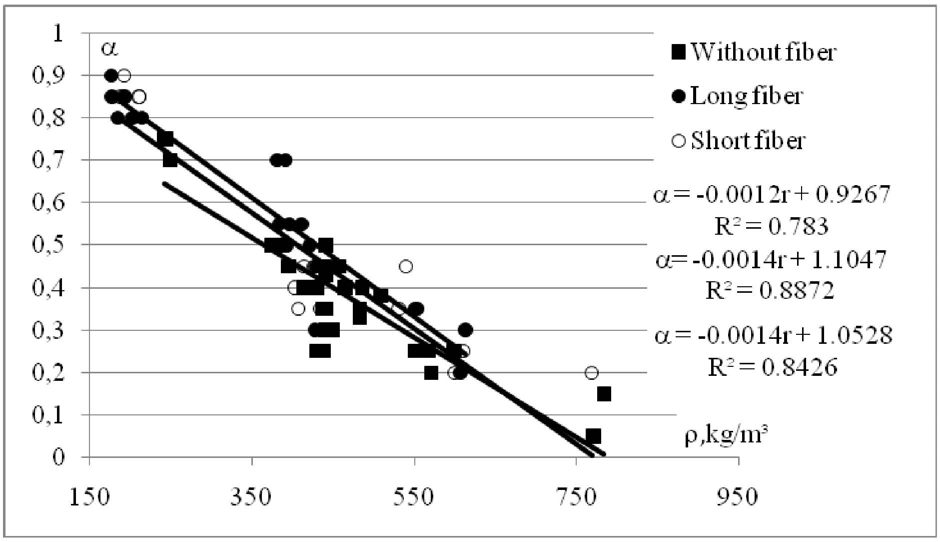

Figure 3. Value of sound absorption depending on volume density (Brencis, 2011).

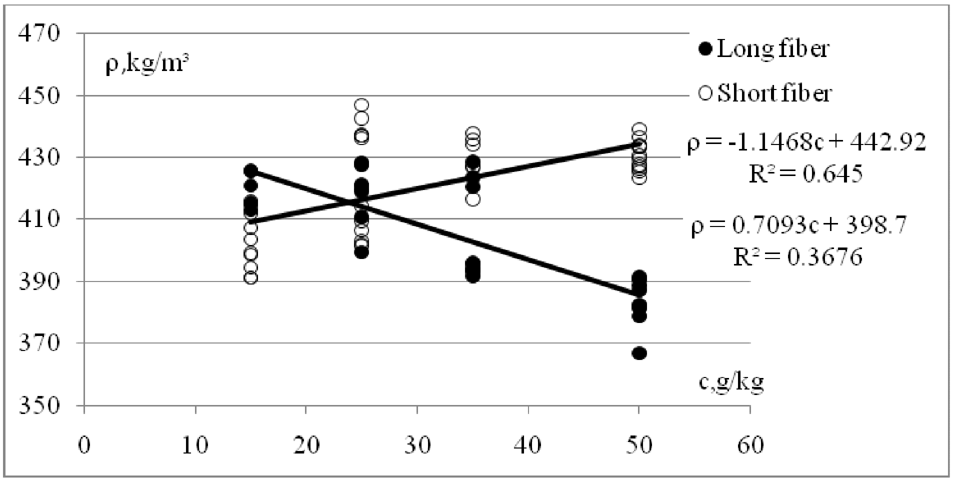

Figure 4. Volume density of composite material depending on short and long fibers (Brencis, 2011).

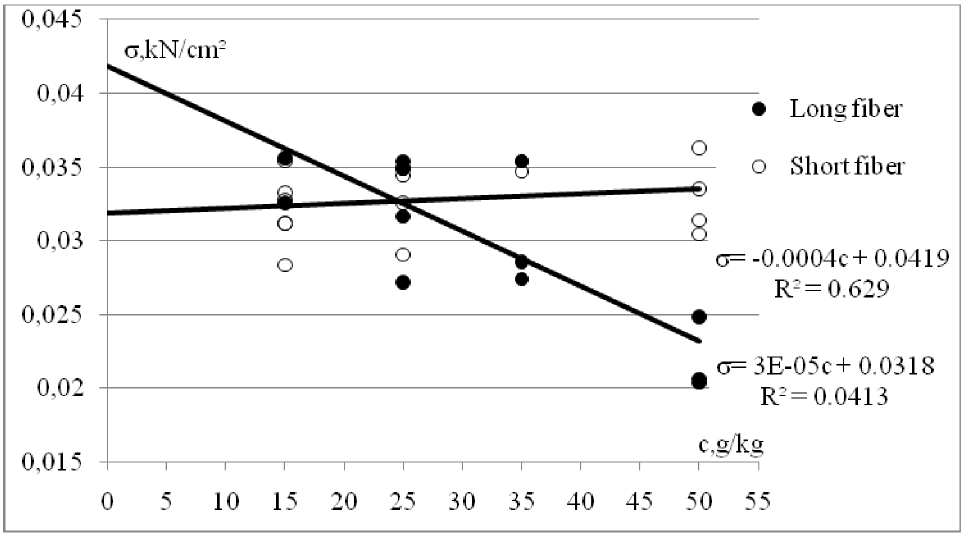

Figure 5. Value of bending stresses in composite material depending on concentration of long and short fibers (Brencis, 2011).

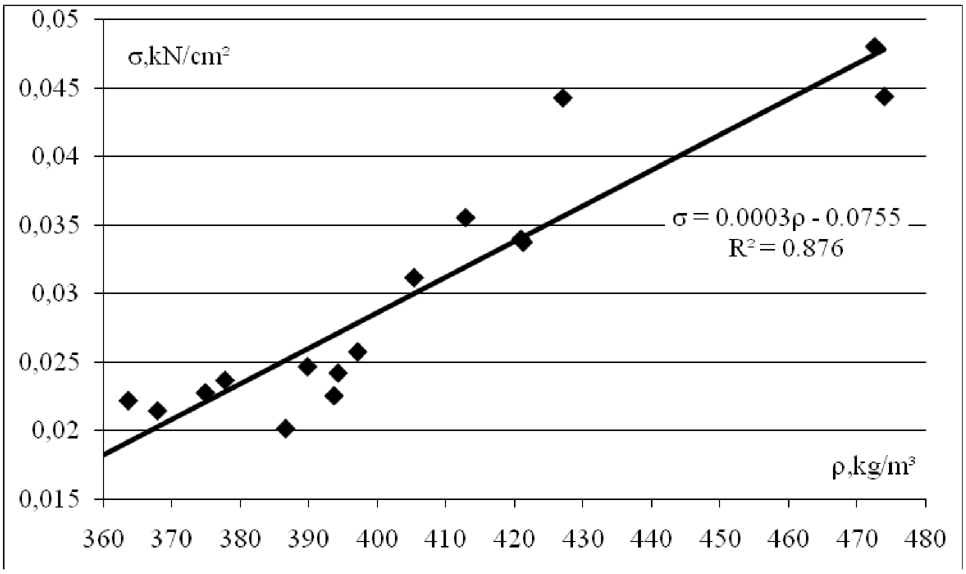

Figure 6. Value of bending stresses in foam gypsum without fibers depending on its volume density.

This coherence correlates with the volume density influence on the material strength (Fig. 4), where increasing the short fibers concentration, the volume density increases, but for the foam gypsum with long fibers, the volume density value decreases.

The values of the bending resistance of foam gypsum without fibers are shown in Fig. 6. The volume density of foam gypsum increase correlates with the bending resistance. In the volume density range between 360 - 450 kg/m³ the bending resistance is 0.02-0.045 kN/cm².

Fig. 7 shows the porous structure of foam gypsum with hemp reinforcement. Pores have not ideal round shape and some of them are linked with the adjacent ones. Around the hemp reinforcement the amount of pores is higher. In foam gypsum modified with hemps the amount of pores decreases (Fig. 8), but the fiber influence on the pores is not so relevant (Fig. 9). Joint pores and normal pores have the same inherence with different concentration of hemp fibers.

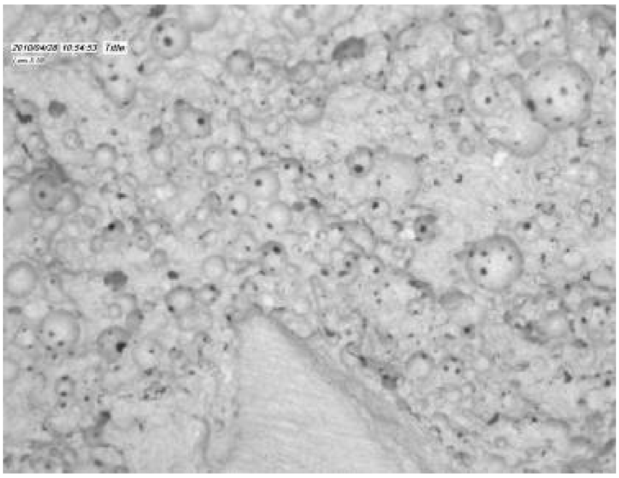

Figure 7. Foam gypsum porous structure with hemp reinforcement at 50 times magnification.

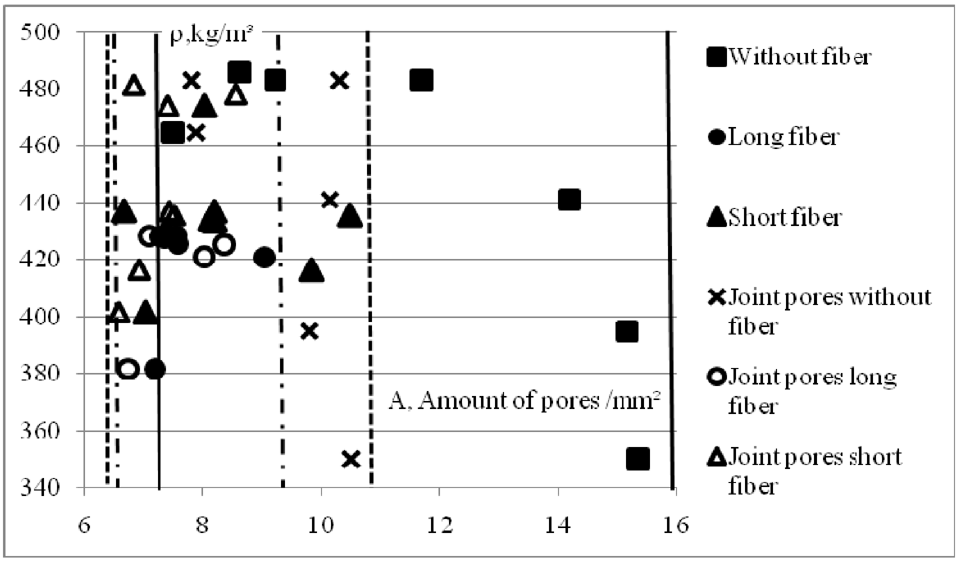

Figure 8. Volume density of reinforced foam gypsum depending on amount of pores in 1mm².

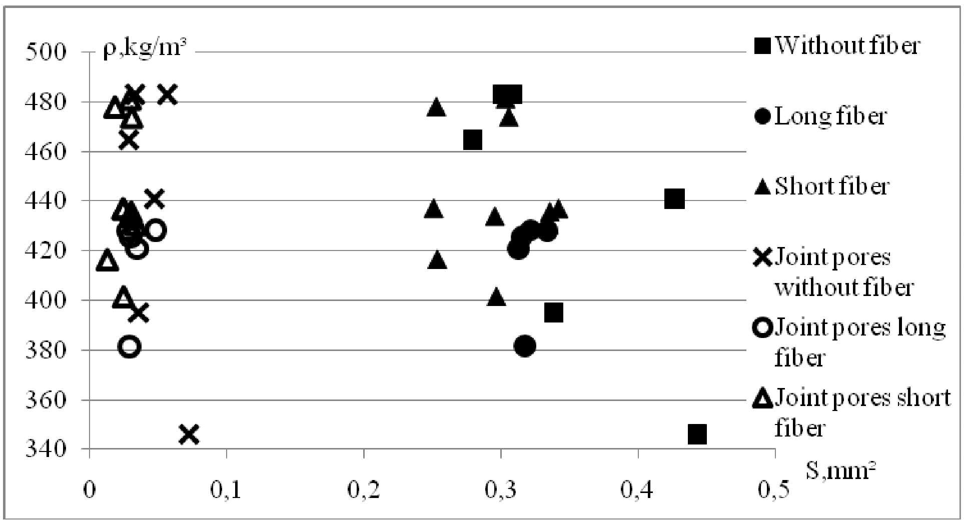

Figure 9. Volume density of reinforced foam gypsum depending on pore area in 1mm².

CONCLUSIONS

1. The results of the reported research demonstrate that hemp fiber reinforcement is affecting the macrostructure and bending strength, as well as the sound absorption characteristics of foam gypsum.
2. Applying of long hemp fibers of the length 5...10 mm and short fibers (2,5...5,0 mm) as reinforcement of foam gypsum, the amount of the pores of 1 mm² is decreasing but their size is increasing. The volume density of the material remains the same as the hemp fibres are substituting the volume of the pores..
3. Hemp reinforcement increases the sound absorption coefficient of foam gypsum in the range of the volume density form 340 to 500 kg per m3.
4. Increasing of the concentration of short fibers increases the volume density of foam gypsum, but increasing of the concentration of long fibers very opposite – decreases the volume density. Alteration of the volume density in its turn determines the bending resistance of foam gypsum.

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