POSSIBILITIES OF SILICA AEROGEL APPLICATION FOR FOAM GYPSUM COMPOSITIONS

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ABSTRACT

The current situation, when energy rates are increasing constantly and fossil fuel resources are decreasing, furthermore, energy-efficiency and acoustic standards for buildings become increasingly stringent, using a traditional insulation material often means having to accept increasingly thick layers of insulation. The solution to this can be the use of advanced and innovative materials. One of these is silica aerogel. The purpose of this study was to investigate the impact of silica aerogel granules and silica aerogel blanket on the thermal and acoustic properties of foam gypsum. To achieve this, seven different specimen types were prepared. Five specimens of each type were prepared. Summary 35 specimens were tested. The specimen coefficient of thermal conductivity λ was determined by applying specially developed equipment and software. The specimen sound absorption coefficient α was determined by applying the acoustic tube. The results obtained from the tests show that there are some advantages and disadvantages of silica aerogel application. It was discovered that as silica aerogel granules interfere with formation of foam gypsum, a different production technology should be used. However, experiments need to be continued for new results. The authors recommend that further research should be carried out with different types of aerogel and different volumes of aerogel granules. The authors of this study leave the research field open for further investigations.

Keywords: aerogel granules, aerogel blanket, thermal insulation, thermal conductivity, foam gypsum, sound absorption.

INTRODUCTION

Gypsum is a significant local resource of Latvia. Its usage for Latvia's national economy is economically beneficial. Gypsum is the main raw material for foam gypsum, therefore, the foam gypsum usage as presented by researches (Iljins et al., 2009; Skujans et al., 2010), creates additional outlets for gypsum and extends the product assortment of construction industry.

The purpose of this study was to investigate the impact of silica aerogel granules (adding 5%, 15% and 30% of mould capacity) and silica aerogel blanket (attached to one side of the specimens) on the coefficient of thermal conductivity λ and the sound absorption coefficient α of foam gypsum.

It was hypothesized that adding silica aerogel granules, the coefficient of thermal conductivity λ of foam gypsum decreases. The hypothesis was based on the assumption that silica aerogel granules encapsulate in the pore walls of foam gypsum, thereby slowing the flow of heat, which is due to the wall thermal conductivity (coefficient of thermal conductivity of silica aerogel granules is 0.018 W/m.K; coefficient of thermal conductivity of foam gypsum is 0.109 W/m.K at volume density 388.2 kg/m^3).

Previous research (Skujans et al., 2007) on foam gypsum showed that foam gypsum could be similar to other thermal insulation and sound absorption materials.

MATERIALS AND METHODS

The basic materials that were used for preparation of the specimens: water (drinking quality), gypsum (powder), surface active stuff (SAS, liquid), silica aerogel granules (CABOT Nanogel TLD 100, particle size 0.2 to 4.0mm, volume density 90 to 100 kg/m^3, Fig. 1), silica aerogel blanket (ASPEN AEROGEL SPACELOFT, thickness=5mm, Fig. 2).

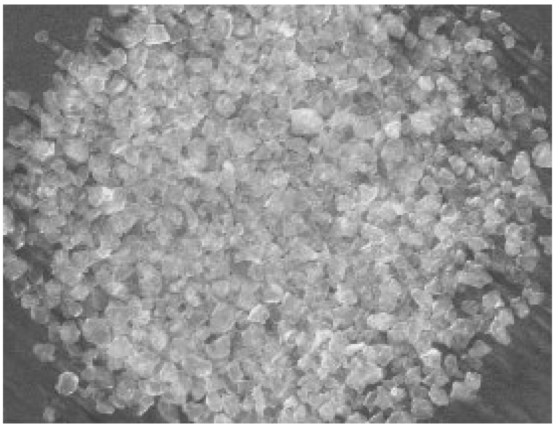

Figure 1. Silica aerogel granules “CABOT Nanogel TLD 100”.

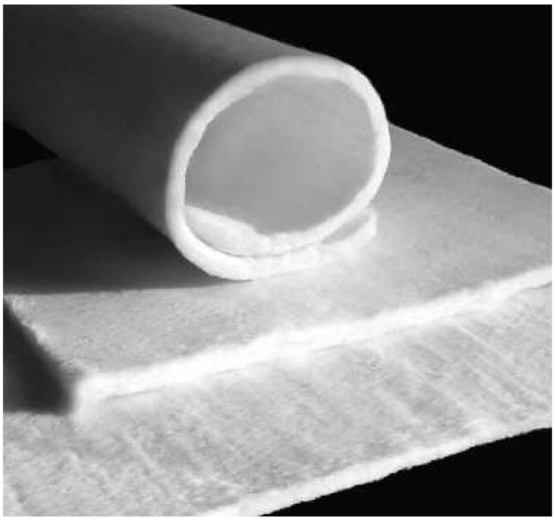

Figure 2. Silica aerogel blanket ”ASPEN AEROGEL SPACELOFT”.

The specimens were produced using the dry mineralization method (Скуянс, 1984) mixing water, gypsum, surface active stuff and adding silica aerogel granules. Silica aerogel blankets were attached to one side of the specimens.

All specimens were based on the ratio of water and gypsum 0.8. The silica aerogel granules were added at 5%, 15% and 30% of the mould capacity.

The silica aerogel blankets were attached to one side of the specimens. In total 35 specimens were tested to determine the coefficient of thermal conductivity (specimen dimensions were thickness=40mm, width=400mm, length=400mm): 6 solid gypsum specimens (BĢ), 6 foam gypsum specimens (PĢ), 5 foam gypsum +5%AG, 6 foam gypsum +15%AG, 6 foam gypsum +30%AG, 2 solid gypsum specimens +P, 4 foam gypsum +P. 93 specimens were tested to determine the sound absorption coefficient (specimen dimensions were thickness=40mm, diameter=39mm): 15 - BĢ, 15 - PĢ, 12 - PĢ+5%AG, 9 - PĢ+15%AG, 9 - PĢ+30%AG, 9- BĢ+P, 15 – PĢ+P, 9 – P. The volume density for BĢ+P and PĢ+P was calculated by equation:

$$\rho = \frac{m_1 + m_2}{V_1 + V_2} \qquad (1)$$

In equation (1) ρ is the volume density for the whole specimen (kg/m^3), m_1 and m_2 are the masses (kg) of each layer, V_1 and V_2 are the volumes of each layer. The test specimens for the determination of the coefficient of thermal conductivity were prepared by pouring gypsum (and other composites) into a mold. The specimens for the determination of the sound absorption coefficient were obtained by cutting the material to specific sizes (cylinders) and then grinding the surface of the materials.

The measurements were carried out using commercially available instruments. All specimens were dried at ambient air pressure and temperature (~20^{0}C) for 1 month before testing to drive off free moisture. Weight invariability was used as control of the specimen dryness (specimens were weighed weekly, but at the fourth week - daily) (Iljins et al., 2009). To gather the data presented in this paper, the following methods and instruments were used. The specimen coefficient of thermal conductivity was determined by applying specially developed equipment and software (k type wires for surface temperature measurements, Ahlborn Heat Flow Plates Type FQ90xxx for heat flow measurements; as a control device LaserComp FOX 600 Heat flow meter was used - the guarded hot plate test, for one correct measurement at each type of specimens). The sound absorption measurements had been carried out using the company “Sinus” impedance tube produced by the industry (device was calibrated before each measurement). The sound absorption measurements were made in the temperature ~23°C (for each measurement determined).

For the materials tested, the following information will be presented in detail:

The graph showing the dependence of the coefficient of thermal conductivity, λ, on the volume density ρ. The coefficient of thermal conductivity, expressed in W/m°K, is defined as the proportionality constant between the rate of heat transfer and the product of temperature gradient across the solid and the area through which the heat is transferred. The volume density expressed in kg/m^3. The graph showing the dependence of the coefficient of sound absorption, α, on the volume density ρ.

RESULTS AND DISCUSSION

In the following paragraphs, a brief discussion of the trends in the data obtained in the coefficient of thermal conductivity and coefficient of sound absorption tests is presented. The thermal and acoustic properties are also discussed and compared to each other to show the influence of the type of material. Thermal conductivity is very sensitive to the microstructure of the material. It is strongly influenced by such factors as mineral composition, impurities in the crystal structure, average grain size, grain orientation, and porosity. The sound absorption coefficient is very sensitive to the volume density, type of surface (smooth or rugged) and porosity (also surface porosity) (Горлов, 1989). The different specimens of foam gypsum composites (with and without silica aerogel granules dispersion) were obtained and tested (Fig. 3., 4., 5., 6., 7.). Fig. 5., 6., 7. indicate that adding silica aerogel granules to foam gypsum, the porosity decreases.

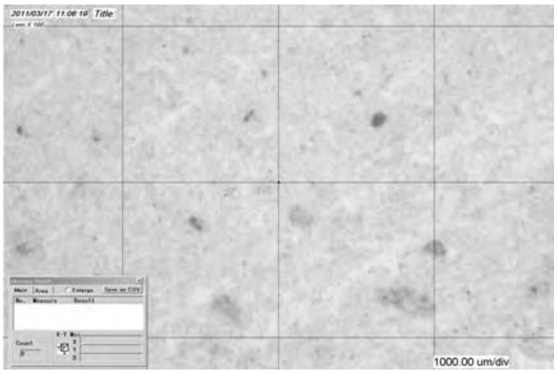

Figure 3. Solid gypsum zoomed 100x, where size of square 1x1mm.

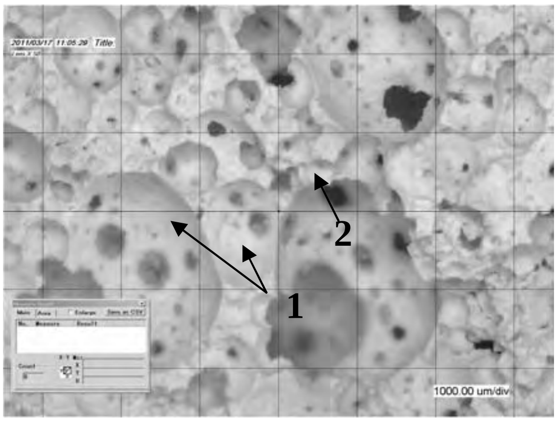

Figure 4. Foam gypsum, zoomed 50x, where size of square 1x1mm, where 1 – pores; 2 – gypsum matrix.

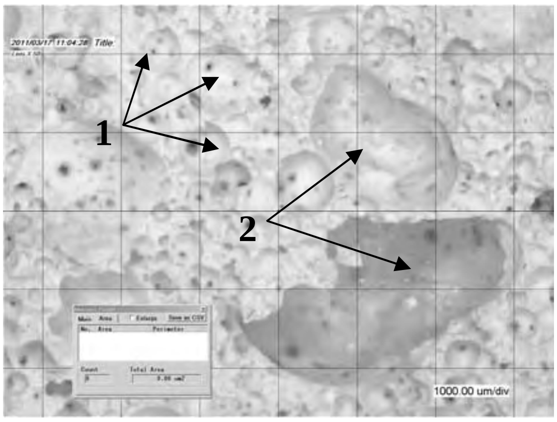

Figure 5. Foam gypsum +5%AG, zoomed 50x, where size of square 1x1mm, where 1 – pores; 2 – silica aerogel granules.

The hypothesis that adding silica aerogel granules to foam gypsum, the coefficient of thermal conductivity decreases, did not prove as it was expected and was not supported by the data. The tendency of the coefficient of thermal conductivity of foam gypsum is illustrated in Fig. 8 to 9. The tendency of the coefficient of sound absorption is illustrated in Fig. 10 to 11.

Fig. 8 indicates that the coefficient of thermal conductivity of solid gypsum is believable (Otto, 2004). Moreover, Fig. 8 shows that the silica aerogel blanket reduced the greatest part of the coefficient of thermal conductivity by itself.

As we can see in Fig. 10 to 11, adding silica aerogel granules to foam gypsum decreased the coefficient of sound absorption for the both values (1000Hz frequency and rated).

Fig. 10 to 11 show that usage of the silica aerogel blanket for foam gypsum did not increase the value of the coefficient of sound absorption, but it did for solid gypsum.

The results presented that foam gypsum is a sound absorption material of class D (EN ISO 11654), other tested materials are not classified. The data presented in this study can be used for further investigations.

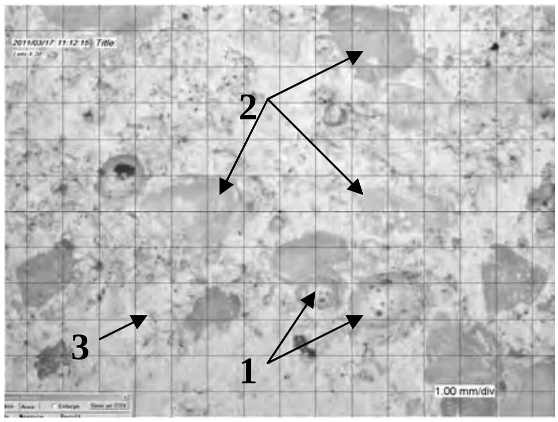

Figure 6. Foam gypsum +15%AG, zoomed 20x, where size of square 1x1mm, where 1 – pores; 2 – silica aerogel granules; 3 - gypsum matrix.

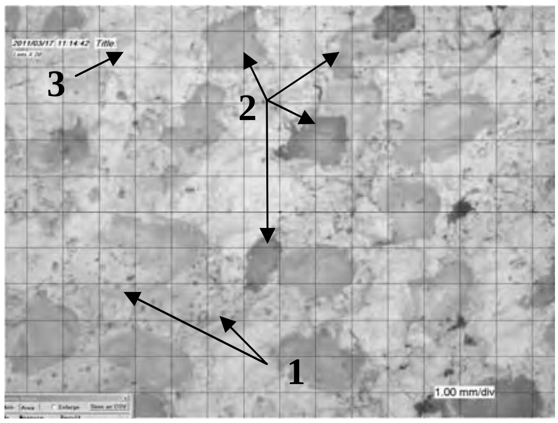

Figure 7. Foam gypsum +30%AG, zoomed 20x, where size of square 1x1mm, where 1 – pores; 2 – silica aerogel granules; 3 - gypsum matrix.

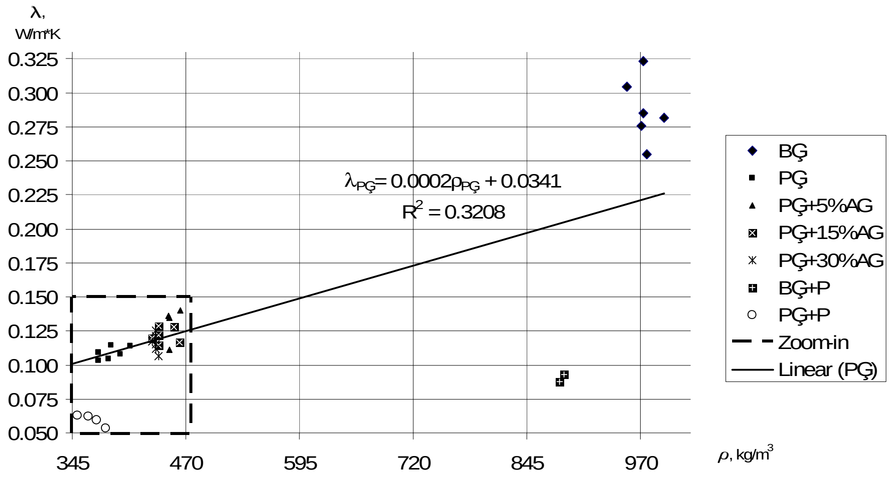

Figure 8. Coefficient of thermal conductivity depending on volume density.

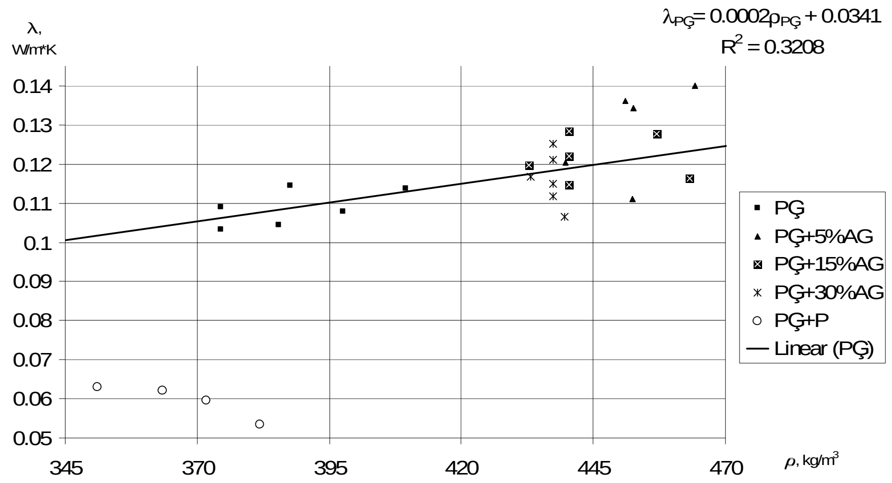

Figure 9. Zoomed. Coefficient of thermal conductivity depending on volume density.

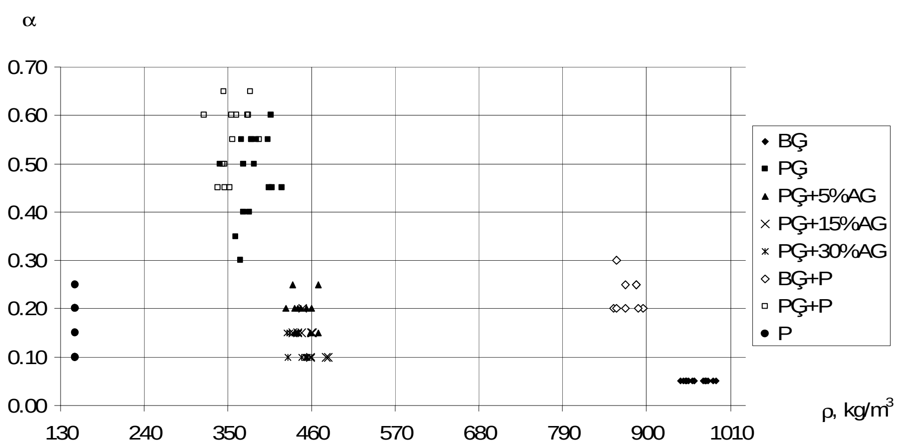

Figure 10. Sound absorption coefficient in one third octave mid band 1000Hz frequency depending on volume density.

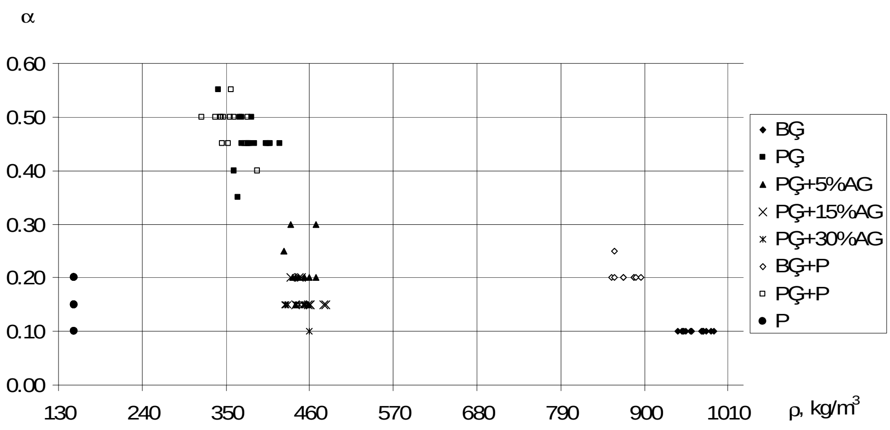

Figure 11. Rated sound absorption coefficient depending on volume density.

CONCLUSIONS

Based on the experimental data presented, the following conclusions can be summarized:

1. Composite materials, which were made by the method of dry mineralization described above, with the concentration of silica aerogel granules as defined, did not decrease the coefficient of thermal conductivity ($\lambda_{PĢmin}$=0.103 W/m.K, $\lambda_{PĢ+30AGmin}$=0.106 W/m.K).
2. The experiments showed that attaching the silica aerogel blanket to one side of the specimen, the coefficient of thermal conductivity of the composite decreases, that indicates on the influence of the silica aerogel blanket on the thermal conductivity (without blanket $\lambda_{PĢmin}$=0.103 W/m.K, with blanket $\lambda_{PĢ+Pmin}$=0.054 W/m.K).
3. Addition of the silica aerogel granules decreases the sound absorption coefficient at the measured frequency range compared to foam gypsum with no additives ($\alpha_{PĢmax1000Hz}$=0.55, $\alpha_{PĢ+30AGmax1000Hz}$=0.15).
4. Attaching of the silica aerogel blanket to one side of the foam gypsum specimen, did not lead to the increase of the sound absorption coefficient.
5. Attaching of the silica aerogel blanket to one side of the solid gypsum specimen leads to the increase of the sound absorption coefficient ($\alpha_{BĢmax1000Hz}$=0.05, $\alpha_{BĢ+Pmax1000Hz}$=0.30).
6. It was observed that silica aerogel granules significantly reduce the amount of persistent foam (Figures 4., 5., 6., 7.), possibly it increases the volume density. Moreover, the volume density increase promotes that the coefficient of thermal conductivity increases and the sound absorption coefficient decreases.

NOMENCLATURE

BĢ – solid gypsum;
PĢ – foam gypsum;
PĢ+5%AG - foam gypsum with silica aerogel granules 5% of mould capacity;
PĢ+15%AG - foam gypsum with silica aerogel granules 5% of mould capacity;
PĢ+30%AG - foam gypsum with silica aerogel granules 5% of mould capacity;
BĢ+P – solid gypsum with silica aerogel blanket;
PĢ+P – foam gypsum with silica aerogel blanket;
P - silica aerogel blanket (“ASPEN AEROGEL SPACELOFT”, thickness=5mm).
AG - Silica aerogel granules – „CABOT Nanogel TLD 100“

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