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Effect of Autoclaved Aerated Concrete Modification with High-Impact Polystyrene on Sound Insulation

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Abstract. Autoclaved aerated concrete is one of the most commonly used building materials. Its advantages include low density, high thermal insulation capacity and high fire resistance. It has a relatively high compressive strength, though not high enough to be able to compete with other building materials in this respect.
One of the directions leading to the improvement of physical and mechanical properties of autoclaved aerated concrete is the modification of its composition. A noticeable effect of pulverized high-impact polystyrene (improved compressive strength and water absorption) was relevant for the decision to continue the study of its effects. This paper discusses the effect of high-impact polystyrene on sound insulation in AAC products. The tests demonstrated a positive influence of the modifier on AAC sound insulation enhancement. Results from the tests performed on HIPS-modified AAC products were showed and compared with the properties of conventional products. The effect of the polymer on the microstructure of the products obtained was described briefly.

1. Introduction

The importance of sound controls to building quality and occupant satisfaction, in particular in multi-family dwellings, is currently receiving more attention. Noise pollution is defined as sound of excessive intensity that can have deleterious effects on human wellbeing and health, leading to reduced concentration and productivity and to increased tension. To limit the spread of noise in buildings, appropriate sound insulation needs to be provided. Protection against noise should start at the wall material selection stage. Although autoclaved aerated concrete (AAC) blocks have a small mass and may seem to be unsuitable for walls of high sound insulation, AAC partitions meet most requirements set out for wall sound protection. The negative impact of noise on human health and comfort urged the authors of this paper to determine the sound insulation of modified AAC products.

Autoclaved aerated concrete (AAC) is the most often used material for wall assembly. It accounts for about 40% of all wall materials on the domestic market and meets over 30% of the European demand [1]. Developed in Sweden in the 1920s, the material emerged in response to energy crisis and increasing demands for structural timber. In 1923 Axel Erikkson started to produce the new material under the name Ytong on a commercial scale. AAC combines the properties of wood such as being a natural material easy to cut and shape, lightweight, with high thermal insulation but without typical disadvantages of wood, i.e., it does not burn or rot. These properties and the advancement of the new technology were the basis for the attempts to modify the composition of AAC mass [2,3]. The improvement of AAC properties (compressive strength and water absorption) relied on the use of the polymer, selected based on the previous studies, as a modifier. The ecological aspect of the experiment was reflected in the use of the recycled additive.

In terms of hazardous substances content, AAC is a safe material, creating a user-friendly environment and posing no threat to the natural environment. It is obtained from hydraulic and air binders (cement and/or lime), fine, silica-based materials, water and expansion agents. Additions improving rheological properties of the mass can also be used. Some doubts may arise with the use of aluminum powder or paste as a pore-forming agent. Aluminum powder or paste responsible for expansion is added at a very low rate of maximum 0.5 kg per 1 m^3 of the material at the most lightweight variant [1]. Its reaction with the lime in the mixture produces calcium aluminates, harmless to people and environment, and hydrogen, responsible for the porous structure, which is finally replaced by air. Also, compared with other building material technologies, AAC is produced with no waste or pollution, from small quantities of raw materials and Energy. From a perspective of a sustainable product, modern AAC production processes and its physical and mechanical properties offer relevant benefits [1,4].

2. Materials and methods

The modification of the autoclaved aerated concrete with high-impact polystyrene (HIPS) increased the compressive strength of the material by 27% and decreased the water absorption factor by 28% as compared to a conventional product. This paper aims at showing the results of further studies concerning the effects of the addition on airborne sound insulation.

The AAC was modified with high-impact polystyrene, one of the oldest styrene polymers. HIPS is obtained through graft copolymerization of polystyrene (PS) in the presence of polybutadiene (PB) ensuring improved impact resistance compared to conventional PS. It is a dense and rigid material highly resistant to cracking [5,6], commonly used in a variety of applications, including refrigerator liners, ice-cream cups, TV cabinets, office furniture and many others. The material used in the tests was a regranulate pulverized to 630 μm particle size, with a density of 1.05 g/cm^3.

The tests were performed on HIPS-modified AAC cube specimens of 100 mm edge length made under semi-industrial conditions in an aerated concrete manufacturing plant according to slow-setting silicate technology (SW*)* as a 500 variant. The SW technology involves producing a slurry from adequately proportioned components (sand and gypsum jointly account for about 72% of the product mass, cement and lime – about 20 % and water – about 7%). At this stage, appropriate quantities of the HIPS were added. After mixing, the slurry was placed in tripartite moulds and stored in initial curing chambers at 60°C for three hours. After that, the specimens were placed in autoclaves for 13 h at a temperature of 190°C and a steam pressure of 1.2 MPa. The performance of the finished products was tested in laboratories of Kielce University of Technology. The results from the tests were compared with those obtained for the conventional AAC samples and shown as arithmetic means from both concrete types. Sound insulation measurements were performed on a patented test facility [7] consisting of a rectangular wind tunnel shown in Figure 1.

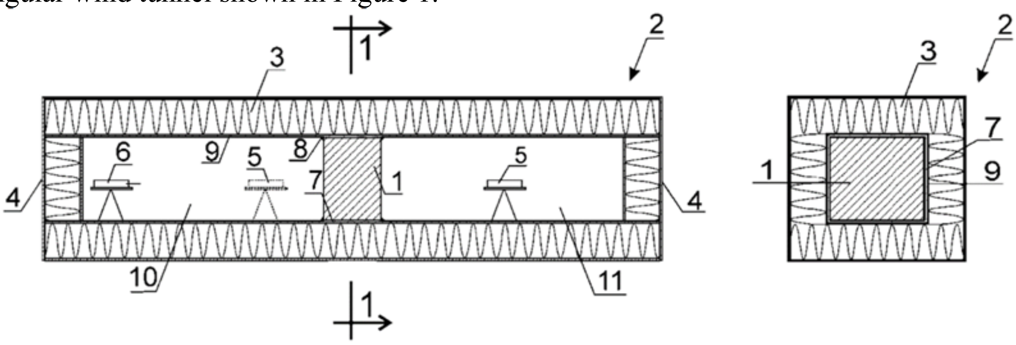

Figure 1. Acoustic tunnel schematic diagram; longitudinal cross-section; transverse cross-section [8]

The tunnel has two channels: a receiving chamber (10) and a source chamber (11) covered with lids (4), built of OSB-3 from external and internal sides, separated with an insulating layer of mineral wool. In the source chamber, a sound generator emits high frequency sound measured by a sound intensity meter in the receiving chamber.

3. Results and discussions

3.1. Sound insulation

The Z-10 sound generator and DT-8852 sound level meter were used in the tests. Average frequency value ranged from 31.5 to 8000 Hz. For sound insulation measurement, the specimens (A-D) were placed in the tunnel and the sound intensity was measured individually for each of them. The sound level measured in the empty tunnel was used to determine the differences between the measured intensities confirming the acoustic insulation of the specimen being tested. Table 1 summarizes results of the measurement. The percent content of HIPS in each specimen was as follows A-0%; B-10%; C-20%; D-30% relative to the joint content of sand and gypsum. The results are represented as arithmetic means of the records.

Table 1. Test results

	Sound level in the receiving chamber [dB]	Sound level in an empty tunnel [dB]	Sound level difference [dB]
A	77.0	92.0	15.0
B	73.5	92.0	18.5
C	72.2	92.0	19.8
D	71.2	92.0	20.8

Analysis of the results indicates that the addition of HIPS increases the sound insulation of the material under test. The highest insulation was recorded for the specimen containing 30% of HIPS. This result was 39% higher than that of the reference specimen. The specimens containing 10% and 20% of HIPS had sound insulation values 23% and 32% respectively higher than that demonstrated by the reference specimen.

3.2. Microstructural analysis

SEM and XRD examinations were performed to analyze the microstructure of the specimens. According to the literature [1,9], the basic components of autoclaved aerated concrete include the C-S-H phase and tobermorite, with smaller quantities of hydrogrossular and anhydrite. Pectolite and xonotlite may occur in minor quantities. The C-S-H phase has a positive effect on the ACC strength. According to [10,11], four morphological types of the C-S-H phase exist: fibrous particles of C-S-H I, honeycombs of C-S-H II, flattened/isometric particles of C-S-H III, and spherical agglomerates of C-S-H IV. Tobermorite has three phases varying by interlayer distances of 1.4; 1.13; and 0.97 nm. (A1+Na)-substituted tobermorite structure shows a habit with well-developed hexagonal plates that may occur in spherical agglomerations [1].

The SEM analysis of the microstructures of specimens produced from modified AAC revealed the presence of the C-S-H phase and tobermorite. In the specimen of the highest sound insulation (and the highest compressive strength according to the findings of the previous study [3]) i.e., the one containing 30% of the HIPS (Photo 1 and Photo 2), C-S-H I fibers were observed. Other observations included the presence of tobermorite in the form of spherical agglomerations and characteristic forms of hydrogrossular.

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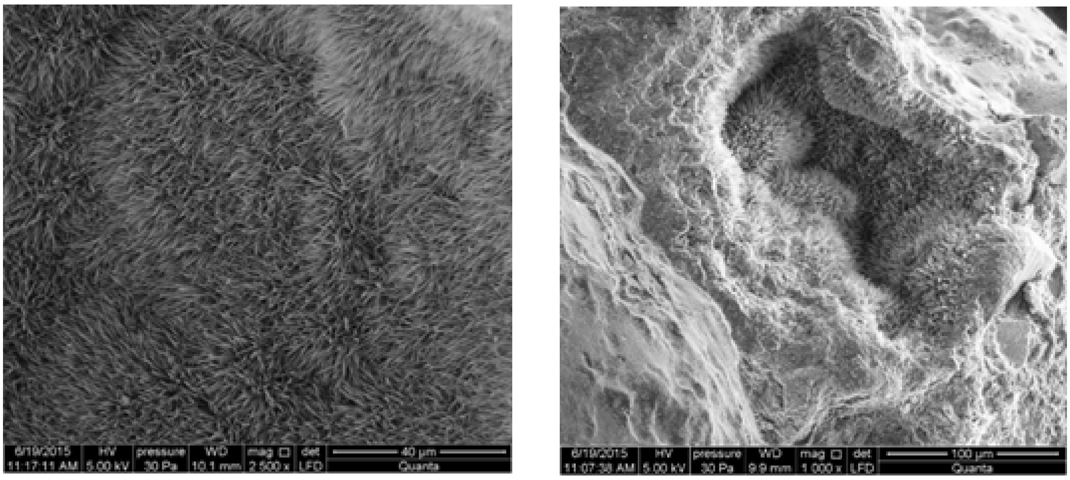

Figure 2. Photo of microstructure of specimen D

The results of the XRD phase composition tests showed the presence of numerous tobermorite phases and crystalline phases of calcite and quartz, Figure 2. Minor amounts of anhydrite were also found. In the conventional AAC, xonotlite phases were detected but as this phase is not dominant, this does not confirm the improvement of the product properties.

4. Conclusions

The findings from this study indicate that the addition of the processes plastic in the composition of AAC products contributes to the improvement of their sound insulation. The addition 30% high-impact polystyrene increased the sound insulation by 39% as compared to the conventional product. Another aspect of using such a polymer is the possibility of utilizing recycled consumer items. This study encourages further research and assessment of high-impact polymer on properties such as frost resistance and non-combustibility.

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