Sound-Absorbing Polymer Composite Materials for Construction Purposes

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Abstract. The paper presents the results of a study of the influence of the nature of fillers (wood flour, wood dust, vermiculite, expanded vermiculite, organoclay) and a polymer matrix (elastomer and thermoplastic) on the sound-absorbing and physico-mechanical characteristics of polymer composite materials. As a result of the studies, it was shown that sound absorption depends on the polymer matrix used - the sound absorption coefficient in the frequency range 2500-5000 Hz is greater for an elastomer-based composite material. It was also found that the nature of the studied fillers, as well as their content, practically does not affect the level of sound absorption of the polymer composite material. Differences appear only at a frequency of 6300 Hz. At high frequencies, expanded vermiculite has shown itself to be the most effective filler in terms of improving sound insulation properties. In the case of using, as a polymer-based thermoplastic, the introduction of a filler does not affect the values of the sound absorption coefficient in the entire frequency range.

1. Introduction

Currently, more and more place in the world is given to the creation of new composite materials used in various fields of human activity. Along with the development of science and technology, problems arise related to the impact on nature and man of various harmful factors, including noise. The development of new polymer acoustic materials will reduce the negative impact of ubiquitous noise on humans [1-7].

Noise - sounds caused by random causes that do not carry useful information and interfere with a particular life process. The noise in the premises belongs to the category of sanitary and hygienic hazards, as it irritates the human nervous system and reduces its performance. Noise levels are an acute problem for the city. The main sources of noise exposure in the city are: vehicles, rail, metro, construction equipment, industrial enterprises, engineering equipment of buildings, as well as household noises in the territories inside residential buildings. It is impossible to eliminate the source of noise, but it is possible to absorb, reduce the impact of noise and bring it to safe using acoustic materials. In this regard, the development of sound-absorbing building composite materials is relevant.

This paper presents the results of a study of the nature of fillers and a polymer matrix for sound-absorbing and physico-mechanical characteristics of composite materials [8-21].
2. Experimental part
The sound-absorbing properties of composite materials were studied on the basis of model compositions based on a vulcanized elastomer - butyl rubber grade BK-1675n (manufactured by Nizhnekamskneftekhim, Nizhnekamsk, Russia). In this case, a standard sulfuric vulcanizing system was used. Polymer composite materials of a thermoplastic type based on a copolymer of ethylene with vinyl acetate (with a vinyl acetate content of 28%) of the Sevilen brand 11808-340 (manufactured by NefteKhimSevilen, Kazan, Russia) were also obtained.

As fillers were selected:
- wood flour brand A560 (manufactured by PF Lignum-Resource, Kazan, Russia);
- wood dust (DP) collected by grinding the front surface of birch plywood of the Zelenodolsk plywood factory (absolute humidity 5%, arithmetic average of the length of wood particles 2 mm);
- vermiculite is a mineral from the hydromica group having a layered structure. We took vermiculite with the following elemental composition (%): SiO$_2$ - 42, Al$_2$O$_3$ - 13, Fe$_2$O$_3$ - 17, FeO - 3, MgO - 25 (fraction 2 mm);
- expanded vermiculite from the Potaninsky deposit with a bulk density of 150 kg/m$^3$ is a loose granular material of a scaly structure, obtained by firing natural hydrated mica (fraction 1 mm);
- Cloisite 15A is an organoclay manufactured by Rockwood (USA), modified with quaternary ammonium salts with the general formula $[\text{RN(CH$_3$)$_2$}]R^-\text{Cl}^-$, where $R$ is the C$_{16}$-C$_{18}$ alkyl radical. Cation-exchange capacity of 125 mg-eq / 100 g of clay, density - 1660 kg/m$^3$.

Samples were obtained in a Brabender mixer, which is a Banbury-type laboratory enclosed rotary mixer. Mixing of the samples was carried out according to the previously worked out mode. After mixing, the samples were rolled on cold rollers. After that, the finished mixture was laid in a hydraulic press VP 400-100 at a temperature of 160°C and vulcanized for an hour. In the case of using sevilen as a polymer matrix, the samples were molded in a press at 120°C for 5 minutes. Then, the samples were tracked for a day. Then circles with diameters of 28 mm and 100 mm were cut to measure the sound absorption coefficient. To measure the sound absorption coefficient, we used an acoustic Kundt tube interferometer with a set of pipes: 100 mm for measuring low frequencies and 28 mm for measuring high frequencies. Double-sided blades were also cut to determine the physicomechanical properties on a Zwick Roell tensile testing machine at a tensile speed of 500 mm/min.

3. The discussion of the results
It is known that the sound absorption of materials substantially depends on the filler. In particular, the sound-absorbing properties effectively improve the fibrous fillers. In this case, the sound incident on the membrane propagates along the fiber, scattering [8-10]. The most accessible of fiber fillers are wood fillers, so it was of interest to evaluate the effect of wood fillers - wood flour grade A560, wood dust on the sound absorption coefficient of model composite materials. It is also known that sound absorbing characteristics have porous materials. A large number of studies are devoted to the study and improvement of the sound-absorbing properties of compositions based on polyurethane foam. The effect of porous fillers on the sound-absorbing properties of composite materials based on elastomers or thermoplastics is less studied. In this regard, the effect of conventional and expanded vermiculite, as well as Cloisite 15A organoclays, on the level of sound-absorbing characteristics of composite materials based on elastomer and thermoplastics was also studied.
Figure 1 shows the dependences of the sound absorption coefficient of polymer composite materials depending on the nature of the filler for a sound frequency of 16-500 Hz. The higher the sound absorption coefficient, the better the sound absorption properties of the material. As can be seen from the presented results in the low-frequency region, the sound absorption coefficient does not change. An increase in sound absorption coefficient is observed only at frequencies above 2500 Hz (Figure 2, a, b).

In the frequency range 2500-5000 Hz, polymer-composite materials with wood fillers have a slightly higher level of sound absorption compared to compositions with porous fillers. More significant differences appear only at 6300 Hz. Compositions with wood dust naturally have higher sound-absorbing properties than composites with wood flour grade A-560, since the length of the fibers in wood dust is longer than in wood flour –2 mm and 0.25 mm, respectively, Figure 2, a).

An analysis of the physico-mechanical characteristics of the studied compositions showed that an increase in particle size naturally leads to a decrease in tensile strength, since compositions with wood flour have higher strength than compositions with wood dust (table 1). Among porous and layered fillers, compositions with expanded vermiculite have the least strength, and the greatest with Cloisite 15A.
15A. The decrease in the tensile strength at break with increasing particle size of the filler is due to the fact that larger particles are places of localization of stresses and the formation of defects.

**Table 1.** Physico-mechanical characteristics of compositions based on butyl rubber with various fillers.

| Indicator             | Wood flour | Wood dust | Vermiculite | Vermiculitis swollen | Cloisite 15A |
|-----------------------|------------|-----------|-------------|----------------------|--------------|
| Tensile strength, MPa | 2,67       | 1,56      | 2,67        | 1,56                 | 2,95         |
| Elongation at break, %| 25,8       | 54,2      | 25,8        | 54,2                 | 49,5         |

The effect of the filler content (by the example of vermiculite) on the sound absorption level of an elastomer-based polymer composite material was studied. As can be seen in Figure 3, a twofold increase in the content leads to an increase in the sound absorption coefficient only at high frequencies.

It should be noted that the technology for producing composite materials based on elastomers implies the need for a vulcanization stage. To simplify the manufacturing technology of composite materials, it is possible to use thermoplastic polymers. Therefore, it was also of interest to evaluate the effect of the nature of the polymer matrix on the sound absorption level of composite materials. Considering the above, the properties of the polymer composite material were studied both on the basis of thermoplastics and on the basis of elastomer. A copolymer of ethylene with vinyl acetate was used as a thermoplastic. The advantage of SEVA is its low melting point of 110°C, i.e., processing can be carried out at fairly low temperatures, as well as good compatibility with polar fillers, such as the studied wood and porous fillers.

As can be seen from the data presented in Figure 4, the CEVA-based polymer composite material has lower sound absorption in the frequency range 2500-5000 Hz, compared with the butyl rubber composite material. In both cases, wood flour A560 was used as a filler.

![Figure 3](image-url) **Figure 3.** The dependence of the sound absorption coefficient of the polymer composite material depending on the content of vermiculite.

![Figure 4](image-url) **Figure 4.** Dependence of the sound absorption coefficient of the polymer composite material depending on the nature of the polymer matrix.

The lower level of sound absorption coefficient for compositions with SEVA is apparently due to an increase in the stiffness of the composite material. In this case, it is also interesting to note that it
turned out that the use of a filler did not affect the sound absorption level of the polymer composite material based on SEVA - the sound absorption curve for filled and unfilled thermoplastics is the same.

4. Conclusion

Thus, sound-absorbing materials based on various polymer matrices - butyl rubber and a copolymer of ethylene with vinyl acetate, containing fillers of various nature were obtained. It was shown that sound absorption depends on the polymer matrix used - the sound absorption coefficient in the frequency range 2500-5000 Hz for a polymer composite material based on an elastomer is greater than that for a material based on a thermoplastic. It was also found that the nature of the studied fillers (wood flour, wood dust, vermiculite, expanded vermiculite, organoclay), as well as their content, does not significantly affect the level of sound absorption of the polymer composite material. Differences appear only at a frequency of 6300 Hz. At high frequencies, expanded vermiculite has shown itself to be the most effective. In the case of using, as a polymer-based thermoplastic, the introduction of a filler does not affect the values of the sound absorption coefficient in the entire frequency range.

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