Strength and Rigidity of Modified Epoxy Composites Under Static Loading

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Abstract. The creation of building materials and products with improved properties, increased efficiency, contribution to a decrease in material consumption, cost and ease of manufacturing, is one of the most important tasks in the field of production of building materials. The use of modifying components in the manufacture of polymer composites is one of the main methods for improving their physical and mechanical properties. Plasticizers, finely dispersed fillers and other components are used as modifying additives. During the following studies, organosilicon varnish and asbestos-containing wastes from construction and chemical industries were used as modifiers. New materials have been developed on the basis of modified epoxy binders, including those made by compression and vibrocompression with the use of waste, which are distinguished by high physical, mechanical and operational properties. Such materials expand the raw material base for the manufacture of new compositions, protective polymer coatings and polymer concretes.

1. Introduction
The creation of building materials and products with improved performance properties, increased efficiency, contributing to a decrease in material consumption, cost and ease of manufacturing, is one of the most important tasks in the field of construction production. The following works are devoted to the technology of obtaining polymer composite materials [1, 2, 3, 4, 5, 6, 7, 12, 13, 14, 15, 16, 19, 21]. One of the ways to increase the durability of buildings and structures is the use of polymer composite materials (PCM) during their construction, the scope of which in construction is steadily expanding. The following works are devoted to the study of the resistance of building composites under the influence of various aggressive factors [8, 9, 10, 11, 12, 13, 20, 21, 22, 23, 24, 25].

The use of modifying components in the manufacture of polymer composites is one of the main methods for improving their physical and mechanical properties. Plasticizers, finely dispersed fillers and other components are used as modifying additives. In these studies, organosilicon varnish and asbestos-containing wastes from construction and chemical industries were used as modifiers.

Corrosion-resistant polymer composites (PC) filled with waste, in addition to reducing their cost due to the introduction of such components, additionally allow solving problems associated with the disposal of industrial waste in various industries and environmental protection. The purpose of the research is to develop the properties of composite materials based on modified epoxy binders filled with asbestos-
containing waste from industrial and construction industries. This requires solving the following main tasks:

– to substantiate and reveal the effectiveness of using epoxy composites based on an epoxy binder modified with organosilicon varnish and asbestos-containing fibrous finely dispersed fillers using the polystructural theory of the formation of building composites and mathematical methods of experiment planning;

– to optimize rheological parameters, modes of compression and vibrocompression of materials and products made of epoxy composites based on an epoxy binder modified with organosilicon varnish and asbestos-containing fibrous fine-dispersed fillers.

The samples of modified epoxy composites were tested for flexural and compressive loads. In experimental studies, the strength and deformability of the composites were determined on standard samples having the shape of a prism with dimensions of 2×2×7 cm. When establishing the influence of the quantitative content of organosilicon varnish and fillers, a matrix composition was adopted, consisting of the following components: epoxy resin ED-20 (100 parts by weight) and polyethylene polyamine (10 parts by weight). Diane epoxy resin ED-20 in accordance with GOST 10587-84 was used as an epoxy binder. Polyethylene polyamine (PEPA) (TU 6 02 594 85) was used as a curing agent. Polysiloxane – organosilicon varnish KO-922 was used as a modifying additive for epoxy binder. As fillers were used: quartz sand, crushed to a specific surface of 2000 cm²/g; fibrous waste from the chemical industry (FWCI) with a specific surface area of 4000 cm²/g; finely dispersed construction waste (ground slate, FDCW) with a specific surface area of 5100 cm²/g. FWCI are finely dispersed asbestos fibers, which contain the main minerals of cement clinker in an amount from 0% to 10%. FDCW are finely dispersed asbestos fibers (percentage about 10-12%) in combination with finely dispersed Portland cement (about 88-90%). Quartz sand was used as a filler for the reference composition. We tested samples made both by injection molding, by compression and vibrocompression.

2. Purpose of research

Corrosion-resistant polymer composites (PC) filled with waste, in addition to reducing their cost due to the introduction of such components, additionally allow solving problems associated with the disposal of industrial waste in various industries and environmental protection. The purpose of the research is to develop the properties of composite materials based on modified epoxy binders filled with asbestos-containing waste from industrial and construction industries. This requires solving the following main tasks:

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3. Methods of research

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4. Experimental results and analysis

It is known that the introduction of plasticizers increases the ability of a material to undergo large highly elastic and forced highly elastic deformations. Strength, modulus of elasticity during plasticization continuously decreases with increasing concentration of the plasticizer. At the same time, it was determined that the modulus of elasticity and strength properties in some cases can increase. Such change in the mechanical properties of polymeric materials is the opposite of the change observed during plasticization, therefore this effect is called antiplasticization. An increase in the modulus of elasticity and strength occurs only up to a certain concentration of the introduced substance, a further increase in the content of the additive leads to a decrease in the value of these characteristics. This can be seen from the results shown in Figures 1 and 2.

The results of flexural and compression tests of filled composites made by different molding methods are shown in Figures 3 and 4, respectively. It follows from the graphs that for composites made by various methods, there are optimal indicators of the quantitative content of the filler. With the injection molding method, higher strength values correspond to a degree of filling in the range from 0.4 to 0.6.

Compression (and especially vibrocompression) of ECM not only promotes the formation of a dense composite structure, but also increases their strength characteristics, primarily in tension in bending, due to the appearance of additional interphase contact interaction, which can compete with the strength of chemical bonds.

As shown by the results of testing samples obtained using compression, the filling of polymers also has its limits. With an increase in the filler content above 0.9 by volume, there is a sharp decrease in the strength characteristics due to its undercompaction, which occurs in composites of injection technology with a significantly lower filler content.

The highest compressive strength corresponds to the samples based on FDCW. Also, samples based on FWCI have rather high properties, which indicates the presence of the reinforcing effect of asbestos fibers. However, in the case of a composite based on FWCI, we can only talk about the physical modification of the matrix material with reinforcing fibers; therefore, the use of FDCW as a modifier is preferable. This thesis is also confirmed by tensile bending tests. Compositions based on FWCI also have lower strength compared to compositions based on FDCW.

When the samples were destroyed, no violation of the adhesion bonds of the binder with the filler surface was found in composites based on FDCW; at the same time, an insignificant degree of peeling of FWCI fibers from the polymerized matrix was noted. Molds and moldings based on FDCW have a fracture in the fillers at the defective places in the polymer. In this case, unbroken filler particles emerging on the fracture surface were always covered with a polymer cover. It can be argued that compositions based on FDCW, in contrast to those based on FWCI, work as a single system up to destruction without breaking the adhesive bonds between the binder and filler grains. In this case, we can talk not only about physical modification of the material with reinforcing fibers, but also about chemical hardening and increasing rigidity.
While strength is determined by the stress at which a material or structure is destroyed, the deformation resistance of a material is characterized by rigidity. In turn, rigidity is determined by the
deformation that develops under the action of a given force or stress. The main parameter characterizing the stiffness of materials under load is the modulus of elasticity.

After testing the samples of press composites and casting compositions for bending, the elastic modulus indices for the studied compositions were calculated (Figures 3 and 4).

**Figure 3.** Dependence of the ECM flexural modulus on the plasticizer content:
1 - casting composition based on FDCW, 2 - compression composite based on FDCW,
3 - vibrocompression composite based on FDCW.

**Figure 4.** Dependence of the ECM elasticity modulus on the plasticizer content:
1 - casting composition based on FWCI, 2 - compression composite based on FWCI,
3 - vibrocompression composite based on FWCI.
From the data obtained, it can be seen that the compositions based on FDCW have higher indices of the modulus of elasticity than compositions based on FWCI. This can be explained by the higher strength of the adhesive bonds between the binder and the filler surface. At the same time, it was noted that compressed compositions have a higher rigidity than their injection molded counterparts. It is obvious that the manufacturing technology has a positive effect on the rigidity of the material up to a certain limit.

5. Conclusions
New materials have been developed on the basis of modified epoxy binders, including those made by compression and vibrocompression with the use of man-made waste, characterized by high physical, mechanical and operational properties and expanding the raw material base for the manufacture of new compositions, protective polymer coatings and polymer concretes.

The peculiarities of the influence of the modifier - organosilicon varnish - and fillers based on asbestos-cement waste on the properties of epoxy composites were revealed, and the regularities of changes in shrinkage deformations, damping properties, static and impact strength of modified epoxy composites, depending on the structure-forming factors, were established.

It has been established that the developed materials have high physical and technical characteristics.

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