Shrinkage of frame polymer concretes in road construction

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Abstract. It is known that with the same raw material composition, it is possible to obtain different structures of composite materials. So, for example, polymer concretes can be made using traditional technology and the method of phase-by-phase forming. At the same time, frame technology reduces material consumption without loss of strength properties and increases durability. Polymer composite materials of phase-forming by combining properties viscoelastic binder and rigid matrix. It has highly damping performance. The article considers the possibility of using the frame structure polymer composite material in road construction. The composition is also considered, the advantages are determined and a comparison with traditional materials is made. The shrinkage stresses of polymer concrete that occur during the polycondensation reaction of furan resin are quite large and can exceed the permissible ones, which leads to a violation of the monolithic nature of the structure due to the appearance of micro- and macrocracks. In this work, the kinetics of shrinkage within 28 days was studied. The composition of the frame polymer composite material includes the following components: furfural acetone monomer (FAM resin), benzosulfonic acid, granite crushed stone, andesite flour, quartz sand. Theshrinkage of phase-formed polymer concrete was measured on samples hardening under normal temperature-humidity conditions. The generally accepted technique was used, shrinkage deformations were installed along the axis of the sample on two opposite faces with a clock-type indicator with a division price of 0.001 mm. Also in the work is a diagram of the device for determining the deformations of the shrinkage of samples and the results of the study are given. Experimentally established the intensity of shrinkage, which manifests itself in the first three days of curing, in the future its change is insignificant and by the seventh day it fades. According to the test results, it was established that the linear shrinkage of frame polymer concretes is three times less than the shrinkage of polymer concretes with a conventional structure.

Keywords. shrinkage; frame polymer concrete; damping properties; polymer composite material; polymer concrete; vibration creep deformation; furfural acetone monomer

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1 Introduction

Composite materials based on polymers are widely used in the construction industry. Recently, the use of polymer composite materials is gaining wide momentum in the field of road construction. Organic binders are used to create composite materials with various properties that allow the composite to work at certain conditions (Figure 1) [1-6].

Fig. 1. Frame polymer concrete in expansion joint constructions.

For several decades now, it has been an urgent task to study the mechanical properties of polymer composite materials of the frame structure. This is due to a significant variety of their mechanical characteristics. Polymer materials can be both elastic like rubber and brittle – like glass. Knowledge about the strength, mechanisms of deformation and destruction of polymer composites is still insufficient. If we compare it with modern ideas obtained in the field of strength of traditional polymer concretes, where significant progress has been made.

Knowledge of both the general laws of the mechanical behavior of frame polymer composites and the specific properties of a certain type of polymer material is necessary for technologists and designers. For those who work in the field of materials science, construction and other industries. The uncertainty of many properties of phase-formed polymer concretes constrains their use, despite the obvious advantages of structures using these composites. Therefore, the prediction of such properties, in particular, durability, is given a special place in scientific research [7-9].

It should be noted that with the same set of constituent components, it is possible to obtain different structures of composites. For example, polymer concretes can be manufactured using traditional and frame technologies. A high degree of filling is achieved when using the frame method of manufacturing construction products. The phase-by-phase molding of polymer concretes involves the preliminary production of a porous frame by gluing together grains of coarse aggregate with subsequent filling of voids with a matrix [10].

This method makes it possible to produce separately in optimal modes a frame adhesive, a highly porous frame, an impregnating matrix composition and, as a result, a frame polymer composite material on different types of binders by nature. Frame technology for the manufacture of composite materials has been recognized both in our country and abroad [11]. Composite materials based on polymer binders are most effective for use as various protective coatings operated under the influence of various aggressive media. In frame composites, the matrix perceives the impact of aggressive media to a greater extent.

At the same time, the method of phase-by-phase molding provides a decrease in material consumption with a simultaneous increase in strength indicators and an increase in durability [12, 13].

Polymer composite materials of the frame structure due to the combination of the properties of the viscoelastic binder and the rigid matrix have highly damping properties. Such materials, due to high vibration-absorbing characteristics, allow them to be used in structural elements of deformation joints of bridge structures [14]. Thus, when assessing the durability of the material, it is worth paying special attention to its shrinkage during operation.

Almost all concretes are subject to shrinkage, and in reinforced concrete structures it occurs in cramped conditions due to the presence of reinforcement, it should be noted that in the case of a frame structure, deformations will be relatively free [15, 16].

The shrinkage stresses of polymer concrete that occur during the polycondensation reaction of furan resin are quite large and can exceed the permissible ones, which leads to a violation of the monolithic nature of the structure due to the appearance of micro- and macrocracks.

The increase in the degree of filling of polymer concrete is due to the ordering of rigid structures with a high modulus of elasticity around the grains of the filler. It is the presence of such structures that leads to the occurrence of internal shrinkage stresses in the polymer composite material [17].

2 Methods

Shrinkage deformations of frame polymer concrete were measured on samples hardening at normal temperature and humidity conditions. The generally accepted technique was used, shrinkage deformations were installed along the axis of the sample on two opposite faces with a clock-type indicator with a division price of 0.001 mm. The diagram of the device for determining the deformations of the shrinkage of samples is shown in Figure 2.

Furfurolacetone monomer does not require additional heating before use. It has a low viscosity. When it mixed with a hardener, it is not poisonous and has a sufficiently long vitality. Benzosulfonic acid was used as a hardener – a common catalyst for curing furfurolacetone monomer. Usually the resin become to a solid state occurs by an ionic mechanism. The composition of the polymer-concrete composition, taking into account the components for the manufacture of a frame made of coarse aggregate and FAM resin, as well as furfurolacetone monomer for impregnation, is shown in Table 1 [18, 19].

Table 1. The composition of the polymer composite material of the frame structure.

№	Components	quantity, kg/m3
1	Furfurolacetone monomer (FAM)	301,3
2	Granite crushed stone	1600,0
3	Quartz sand	441,3
4	Andesite flour	406,7
5	Benzosulfonic acid	71,3

The presence of fillers in the composite is always accompanied by a simultaneous improvement of some characteristics of the filled material and a decrease in others. For example, a rigid solid filler increases the elastic modulus of the material, but reduces deformation. Therefore, the choice of filler and its contents is always an optimization task.

Previously, the authors conducted studies for furfural acetone composites of the frame structure. The dependences of changes in physical and mechanical characteristics on the granulometric composition are known. An increase in strength with an increase in the filler concentration is observed in composites up to a certain limit, after which the strength decreases, which is due to a lack of binder for complete wetting of filler particles, as a result of this, the solidity of the mixture is broken, the voids of the composite grow and its density drops.

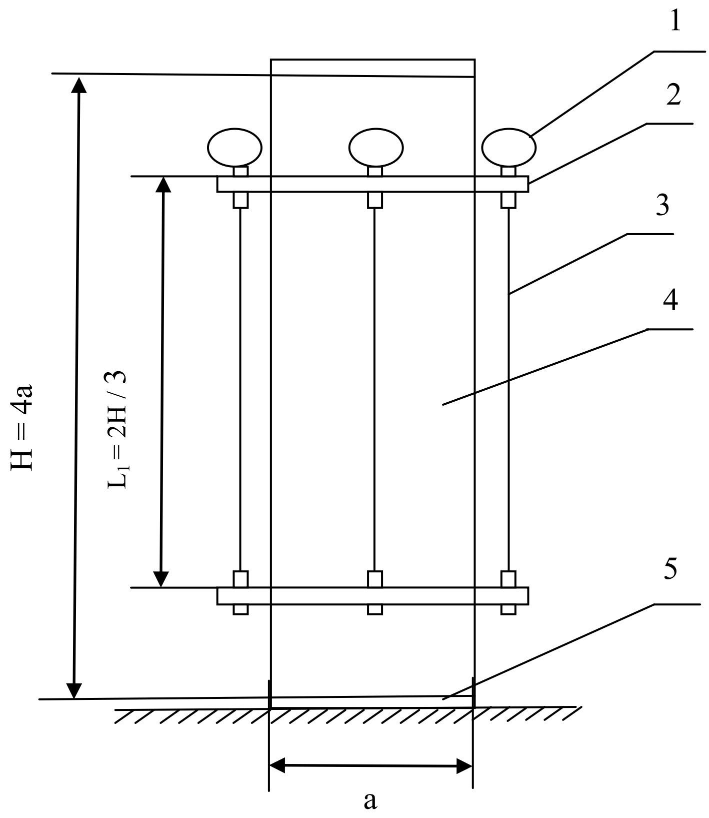

Fig. 2. Components for the production of concrete mix/ 1- a clock-type indicator; 2 - a frame for attaching indicators; 3 - swinging rod; 4 - sample; 5 - metal plates; L1 - measurement base.

Also an important point in the selection of the composition is the presence of a defect-free interface between binder - filler and binder-filler, which helps to increase water and chemical resistance. If contact is broken at the interface, the aggressive medium fills cracks, voids, accumulates in them and causes a decrease in the properties of the material. Since this boundary, due to the developed surface of the filler and, especially, the filler, is large, its condition for the composite material is crucial.

Taking into account the structural role of benzosulfonic acid, it can be assumed that in low-filled composites and composites with filler in the absence of a fine fraction, an increased hardener content is necessary to obtain a material of increased strength [13, 14, 18, 19].

According to the test results, the average values of absolute deformations Δl_1 (t), mm, for each loaded and unloaded sample are calculated as the arithmetic mean of increments (relative to the initial reading) of the instrument readings on the four faces of the corresponding sample.

According to the average absolute values of deformations, the relative values of deformations $\varepsilon_1(t)$ are calculated after the sample is fully loaded according to the formula: $\varepsilon 1(t) = \frac{\Delta l_1 (t)}{l_1}$, where l1 is the base for measuring deformations, mm. Relative deformations of unloaded samples are taken as shrinkage deformations $\varepsilon_{shr}(t)$.

3 Results

Polymer concrete made using frame technology has, at the first stage of molding, an already hardened frame made of a large filler that blocks shrinkage phenomena of the impregnation matrix. The kinetics of changes in shrinkage deformations of frame polymer concrete and polymer concrete of conventional structure on granite rubble is shown in Figure 3.

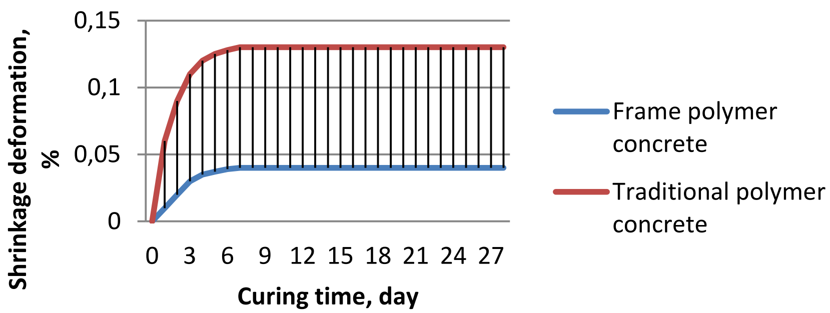

Fig. 3. Components for the production of concrete mix.

4 Conclusions

According to the data obtained, shrinkage is intensively manifested in the first three days of curing. But then shrinkage change is insignificant and by the seventh day it fades. It is important to note that shrinkage deformations of polymer concrete samples with a frame structure are significantly lower than those of polymer concrete made using traditional technology, more than three times.

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