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CONCRETE WITH A COMPLEX OF MODIFIED ADDITIVES FOR CONSTRUCTION

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ABSTRACT

The purpose of this article is to study the use of local waste based on mineral finely dispersed additives similar to substances that are formed as a result of cement hydration, which ensures high quality, increases frost resistance and forms a dense dissolved mixture. Reducing the consumption of a binder in mortar and concrete mixtures due to the introduction of modifying additives is also an important research field. The paper presents the results associated with pro-ducing a complex modifying additive consisting of waste products from marble and silicon di-oxide nanoparticles and its effect on the properties of cement systems. It is shown that the introduction of a modifying additive, while reducing cement consumption, can increase the compressive strength of cement paste up to 56 %. The X-ray phase analysis is used to determine the composition of the modified cement paste.

Improvement in quality of concrete compositions can be achieved both by using chemical additives, and using local components to create a new generation of concrete, which is a highly relevant objective for concrete technology. The industrial wastes produced by the enterprises of Volgograd region are complex mineral and organic compounds having various chemical and physical properties. Among additives of the organic nature the construction acrylic paints production waste is of scientific and practical interest.

It has been checked that it is possible to use an organic additive, a water-dispersible acrylic monomer (WDAM) – construction acrylic paints production waste as a modification, in the fine grain concrete, improving the basic properties of the construction composition. Studies have shown particular pattern of the modified concrete formation process, consisting of the water-repellent plasticizing effect of WDAM additives. The regularities of changes in the quality parameters of the concrete composition and the number of introduced additives are established. The relations of changing performance properties of effective concrete with modification WDAM have been confirmed by the results of experimental studies and developed regression model.

The study shows that the creation and use of new modifiers is one of the actual ways to further enhance the performance of building materials, as well as evidentiates the tendency to expand the list of chemical additives with complex effect with organic waste. It is evident that the utilization of waste products and more efficient use of material resources have a proven economic effect.

The industrial wastes produced by the enterprises of the Volgograd region are complex mineral and organic compounds having various chemical and physical properties. Most of them are experimentally tested at the department of building materials and special technologies of Volgograd State University of Architecture and Civil Engineering to reveal the possibility of using for construction of composite materials, as well as additives or components that improve the basic properties of building compositions. Among additives of the organic nature the paint material (PM) production waste, water-dispersible PM in particular, is of scientific and practical interest. Feature of acrylic composition is that acrylic polymer emulsion as a binder is independently used in the manufacture polymer-cement solutions. Acrylic composition in general terms is a pigment, water, and an acrylic resin serving as a binder component. Organic additive of water-dispersion of acrylic monomer (WDAM) is a paint material production waste that is physically in the first stage of skinning, in which the particles are drawn together to reversible contact. Thus, this fact enables authors to investigate the dispersed aqueous phase solution as the modifying additives of concretes.

A significant decrease in water absorption of modified concrete, porosity decrease and density and the compressive strength increase in comparison with the effects of the plasticizer-3 and waterproofing additive NGL94, confirms the possibility of using WDAM as an additive with the plasticizing and water-repellent effect. In the analysis of three-dimensional image of fine grain concrete test samples, which was obtained by using a universal double-beam system Versa 3D ™ DualBeam ™, many interfaces in the concrete structure (28 days), affecting the physical and mechanical characteristics of the original fine composition, are clearly visible

A prerequisite for the improvement of concrete structure formation was a factor related to the boundaries of the section "Cement joist - filler", where there are dimensional structural defects and their matching with characteristic dimensions for a variety of physical phenomena in interfacial contact area, and it became one of the main indicators for a significant change in the properties of concrete by modifications WDAM. Modifier targets the processes of forming the cement composition grained structures , which are characterized by structural changes in the modified cement system caused by receipt of a denser composition structure, the pore space reduction in the viewing area, increasing the capacity of cement binder, together with the development of plasticizing effect in cement matrix modified by WDAM. It provides a greater degree of use of building crystalline strength potential, improves the quality of co-operation of all the components of the concrete composition. The complex modifying effect of WDAM additives manifested as a result of various physical processes occurring in the hardening system, and also due to chemical processes at the interface between the phases "cement stone - grain aggregate", "cement stone - pore structure" .

WDAM plasticizing effect depends on the presence of hydrocarbon radical and a double bond in the molecule of the acrylic monomer, which are capable of reacting with the binder minerals or products of hydration, which has a favorable effect on the improvement of the technological and operational properties. Hydrophobic properties of WDAM additives exhibited in the formation of a dense and homogeneous structure of the modified concrete composition. There is a decrease in amount and sizes of macrospore , which have the correct circumferential shape with smooth oval edges and sizes from 0.5 to 0.05 mm with a predominant pore size of 0.1 mm. The system of uniformly distributed pores with a water-repellent surface in the hardened modified concrete decreases capillary leak, and reduces the permeability of concrete. Repellent effect of WDAM gives hydrophobic (water-repellent) properties to the walls of the pores and capillaries in the concrete. Thus, a water dispersion of acrylic monomer provides meaningful impact on the formation of a fine grain structure of the composition. Management of structural changes in the modified cement system enables to produce concrete compositions with improved properties due to the hydrophobic plasticizing effect of WDAM. Maximum increases of the capability to take into account the technological factors, and design requirements for the concrete are due to the methodology of the design of its composition. The relationship "property - structure – concrete structure" is the basis for an approach to the design of concrete formulations based on a quantitative analysis results and the joint solution of mathematical equations relating the performance properties of concrete with parameters of its structure. Selection of the optimization factors of concrete modified by hydrophobic plasticizer WDAM, is on the basis of technological and economic feasibility and obtaining of a material with improved performance characteristics. After statistical processing of the experimental data the regression equation, quantitatively characterizing the dependence of the strength, density, porosity, water absorption by the modified concrete on studied factors, was obtained. The mathematical model of the process is a function that links the parameters of optimization: compressive strength (Rcom), bending strength (Rben), density (p), water absorption (W) with variable factors - content additives WDAM (x1,% of cement weight) and water-cement ratio W / C (x2).

The widespread usage of concrete around the world is mainly due to its excellent formability in the fresh state and its good mechanical parameters and durability in its hardened state. However, the resulting mechanical parameters and durability of the concrete composite are affected by its microstructure without signs of micro-defects. One of the most common micro-defects of cement composite is the formation of micro-cracks due to excessive volume changes and the production of hydrating heat. Thus, it can be said that the good mechanical resistance and the resulting durability of the concrete composite depends on its hydration processes and the volume changes that have taken place during this hydration.The resulting micro-cracks due to excessive volume changes become a place for the penetration of aggressive media from the surrounding environment into the micro-structure of concrete, which has a negative impact on the durability of the composite. In addition, micro-cracks occurring on the surface of the composite adversely affect its applicability for architectural purposes. A significant negative impact of micro-cracks is the reduction of the resistance of concrete to mechanical abrasion and to abrasion caused by flowing liquids, while in micro-cracks, the further development of discontinuities occurs due to contact with abrasive particles and flowing media. Therefore, one of the important requirements for concretes for the construction of dams, drainage tunnels, sewers, canals and Barbour constructions, etc., is to achieve a low-shrinkage value to prevent cracking in these massive and highly stressed structures.

The volume changes of the concrete composite can be divided into several stages, which follow each other or overlap . In general, these volume changes can be divided into practically uncontrollable and controllable. The first mentioned include chemical and autogenous volume changes, which are the basic processes accompanying the hydration processes of Portland cement . This type of shrinkage is, therefore, directly dependent on the type of cement and its parameters, such as its chemical and mineralogical composition and its fineness of grinding. Expert publications based on worldwide research attribute to this type of shrinkage up to 20% of the total volume changes of the concrete composite, although its size can hardly be influenced by the composition of the concrete mixture alone, if we omit the possible partial replacement of Portland cement with an active additive .

The highest part of the total volume changes of the concrete composite, according to the performed studies, falls on shrinkage due to drying. This type of shrinkage is already directly dependent on the treatment of the composite after its production, the shape of the structure and exposure to ambient conditions . However, the composition of the concrete mixture itself can also have a direct impact on this process of volume changes. Published results often look for connections between the consistency of a fresh concrete mixture, more precisely the water–cement ratio and volume changes due to drying. In general, the conclusion is often published that with an increasing water–cement ratio, the volume changes of the composite increase mainly by drying. However, other studies point to the danger of excessive reduction of the water–cement ratio due to strong superplasticizers, which may mean danger in terms of long-term volume changes of the composite .

Although a number of studies have dealt with the impact of the type of used aggregate and its grading curve on the volume changes of the composite, it is not possible to clearly determine the intersection of the obtained results. Some research provides a picture of the suitability of crushed aggregates, which can have a positive effect on volume changes in the composite. Others have favored the use of quality mined aggregates, which can achieve a comparable degree of consistency through a lower dose of water and a lower amount of fine fractions. This theory generally applies, especially to the higher degrees of the consistency of fresh concrete, which is a trend in ready-mixed concrete today, and it relies on the theory of a lower specific surface of mined aggregate grains with a spherical grain shape compared to crushed aggregates. This fact results in a lower required dose of water for wetting the surface of aggregate grains. This statement is supported by the research of Polat et al., where 4 specific grain shapes of aggregates, spherical, flat, elongated and mix type aggregates, in concrete mixture with uniform water–cement ratio (w/c) = 0.3 were investigated. The research showed that the best workability of the fresh concrete by the slump test was for aggregates with a spherical grain shape (same as mined aggregate) of 150 mm and, conversely, the worst workability with elongated aggregates (crushed), namely 110 mm . As a result, lower water–cement ratio values can generally be applied, which has a direct impact on the volume changes of the composite .

Concretes with different mineral aggregate type—psammite, quartz, amphibole and granodiorite—were compared. Concrete formulas with a maximum aggregate grain size of 16 and 22 mm were assessed. When crushed and mined, aggregates were used, and the concretes were monitored, which showed the same grading curve of the aggregate mixture. The second part of the study is directly related to the first part, and it is devoted to the influence of binders on the shrinkage of concrete. The effect of the binder component on the shrinkage of the concrete was monitored on the concrete mixtures produced using the same aggregate and maintaining the same strength class of concrete, C 45/55. The effect of the addition of finely ground limestone, finely ground granulated blast furnace slag and coal high-temperature fly ash was monitored.

The innovativeness and usefulness of this study is seen in the complexity of the solution of this experiment, which in the second part deals with the influence of aggregates and subsequently the influence of mineral admixtures on the shrinkage of concrete. Another significant benefit or novelty is focused on the possibility of measuring volume changes immediately from the fresh state. The results presented in this experiment demonstrate that most of the volume changes take place in the fresh state, which is in conflict with some standardization methods, which consider the beginning of measurement to measurement after gaining handling strength from 1 day of age. If the initial shrinkage is not captured, the results of volume changes may differ significantly, which may affect the final similarity of concrete structures.

The Properties of the Aggregate. Aggregate forms a filler component in concrete and occupies the largest part of its volume, namely 70% to 80% . Although aggregate can be classified as an inert material from the point of view of ongoing hydration and chemical processes, it can have a fundamental effect on the course of volume changes due to its largest share in the concrete composite. From the point of view of the effect of the aggregate on the volume changes of concrete, the effect of the maximum grain size and the type of grading curve of the aggregate mixture is discussed in worldwide research. The majority of produced concrete mixtures are composed of at least two fractions of aggregate, where one fraction is fine aggregate, i.e., up to a maximum grain size of 4 mm, and the other fraction is coarse aggregate, with a larger aggregate grain size. The most commonly used fractions of coarse aggregates in Central Europe include fractions of 4–8, 8–16, 11–22 or 16–22 mm. These fractions can be mixed as needed with each other, or some of them can be omitted when creating the resulting grading curve; thus, continuous, or discontinuous grain curves are formed .

In the performed experiment, the effect of the type of grading curve (continuous versus discontinuous) and the effect of the maximum aggregate grain, specifically Dmax 16 mm and Dmax 22 mm, were assessed . Furthermore, the effect of the used type of aggregate was evaluated in terms of its production (mined versus crushed) in relation to its mineralogy and physical-mechanical parameters.

For the evidence and practical application of this experiment, a total of four formulas with different mined aggregates and four formulas with different crushed aggregates were produced. All aggregates meet the requirements of the standards for aggregates for concrete production according to EN 12620 + A1 and EN 13242 for aggregates for civil engineering and infrastructure.

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