Durability of Fine-Grained High-Strength Concrete in Corrosive Environment

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Abstract. The use of fine-grained high-strength concrete of man-made materials as components entails the risk of corrosion processes in concrete. A peculiarity of possible corrosion processes is iron-containing sulfosilicating compounds in rubble, which greatly complicates the prediction of structure durability made of such concrete. High-strength construction composites, which differ from ordinary concrete with a higher content of cement stone, fine particles of binder and fillers, as well as a multi-component composition, necessitate the development and modification of ways to increase and predict structure durability made of such materials. The paper deals with design and technology of product manufacturing from fine-grained high-strength concrete of increased durability in close connection with the assessment of their reliability and durability.

1. Introduction

Technogenic raw materials as the source material of fine-grained high-strength composites are currently attracting the attention of scientists and engineers from different countries. At the same time, the use of fine-grained high-strength concrete of man-made materials as components entails the risk of structural destruction processes in concrete (corrosion processes). A peculiarity of possible corrosion processes is iron-containing sulfosilicating compounds in rubble, which greatly complicates the prediction of structure durability made of such concrete. In terms of the environment, the most dangerous for critical structures are sulphonic liquid and gaseous systems that cause cracking of concrete, and significantly reduce its carrying capacity. High-strength construction composites, which differ from ordinary concrete with a higher content of cement stone, fine particles of binder and fillers, as well as a multi-component composition, necessitate the development and modification of ways to increase and predict structure durability made of such materials, which to a large extent depends on the properties of the components [1–4].

The theoretical basis to make durable high-strength materials is a new scientific direction geonics, which uses the study results of geological processes to create materials of a new generation [2].

2. Materials and methods

Questions on theory and practice of the behavior of cement concretes in aggressive environment are reflected in the studies of Soviet and foreign scientists [5,6]. The reduction of bearing capacity of concrete is a complex physical and chemical process, which depends on the composition and structure of concrete, and the parameters of corrosive environment that surrounds concrete. During the
interaction of cement aluminates and active elements of the environment, concrete breaks down, and the products of this destruction are deposited in pores and cracks, among which calcium trisulfohydroaluminate and gypsum are found. In this regard, such aspects as a preliminary study of conditions for structure formation of high-strength concrete, the role of technological methods in this process and the influence of the structure on the quality of concrete are important.

An important source to increase the economic efficiency of concrete production of a new generation is the development of methods to optimize the structure, which contributes to obtaining a high degree of orderliness of its constituent elements, and the manufacture of binders obtained with the use of man-made products.

There are more than 50 methods to determine corrosion resistance of cement and concrete. They all take long periods of time. The most objective assessment of corrosion resistance of cement is made according to NIIZBB method [7].

The studies used mineral additives containing aluminate and carbonate components, and polymer types - Mellflux 2651, Melment, as well as fine ground quartzitic sandstone, shale from by-product rocks of the Kursk Magnetic Anomaly (KMA). The use of complex organic-mineral additives in concrete, binders of a wide range, where raw materials of technogenic origin are used as a silica component in combination with hyperplasticizers is promising for modern materials science.

It seems important when creating high-strength materials of the subject and methodological apparatus of transdisciplinary sciences, in particular, the laws of similarity of affinity, etc. [8]

The processes of structure formation of composites with technogenic components require their study and intensification of work to optimize the composition and structure of high-strength materials due to the selection of the correct ratio of new initial man-made products and management of structure formation processes. This will help to obtain highly functional concrete with low material and energy production costs [9,10].

3. Main part

Durable high-strength composite was obtained by developing the main component - composite binder. Its composition was a completely homogeneous powder mass, obtained by mixing separately ground raw materials with hyper plasticizer. The basis of this mixture was ordinary Portland cement PC 42.5 D0, to which powdered mineral modifier (PMM) was added. The composition of PMM was introduced. Currently, silica fume, aluminum-containing additive, carbonate-containing additive, etc. are used. As well as composite binder without plasticizer, in a hardening system with PMM, artificial stones have a tight contact zone with a minimum content of pores and microcracks. This is due to the specific structure of the components, actively formed matrix of binders, and the use of water stored in pores, as well as the microstructure of the contact zones of aggregate and cements stone.

Thus, the introduction of PMM in the cement system made it possible to increase the activity of binder to 100 MPa. The stone structure based on it is characterized by the absence of a large number of pores and the density of contacts between the individual phases of neoplasms (Fig. 1).

Figure 1 shows that the solid frame formed is composed of individual hydrated HR grains and PMM components of technogenic origin of varying degrees of dispersion with pronounced contacts with neoplasms. It is noticeable with a larger increase that these particles are almost completely covered with hydration products, since the particles of technogenic raw materials are good substrates with active surfaces, which contributes to rapid nucleation. In addition, the smallest particles of filler, as well as non-hydrated cement grains, are the centers of crystallization.

Based on the developed composite binder, a high-strength fine-grained composite was obtained (Table 1).

By the 28-day period of hardening, it is characterized by a high degree of orderliness of granular component with high density (Figure 2).
Table 1. Indicators of construction and technical properties of high-strength fine-grained composite.

| Indicator                                      | Value                              |
|------------------------------------------------|------------------------------------|
| Average density, kg/m³                         | 2100-2200                          |
| Compressive strength, MPa                     | 80,0-97,5                          |
| Water holding capacity, %                     | 80-90                              |
| Coefficient of constructive quality (c.c.q.)  | 0,36                               |
| Brand on water resistance, W                  | 4                                  |
| Brand on frost resistance, F                  | 300                                |
| Abrasion, g/cm²                                | 0,4                                |
| Shrinkage                                      | no cracks                          |
| Heat conductivity coefficient, W / (m · K)    | 1,29                               |

Figure 1. Structure micrograph of cement stone based on composite binder with PMM.

Figure 2. Structure micrograph of fine-grained high-strength composite.

The figure shows the degree of structure compaction and almost the complete absence of pores in
concrete. This is achieved due to the corrected composition of hardening matrix, the introduction of optimal amounts of fine technogenic products, their densest packaging and the co-sealing effect of hardening.

Durability was evaluated with a new accelerated test method using a persulfate-containing solution. The presence of persulfate ion ($\text{S}_2\text{O}_8^{2-}$) in the course of oxidation leads to the formation of two ions $\text{SO}_4^{2-}$, which causes a chain reaction of ettringite-like phase’s formation at a much higher rate than in the sulfate solution. The main criteria and controlled process parameters were relative linear elongation and resistance coefficient (Table 2).

**Table 2.** Characteristics of high-strength samples in ammonium persulphate solution and water.

| Age of tests, days | Type of solution | Linear elongation, mm/m | Flexural strength, MPa | Compressive strength, MPa | Flexural Coefficient |
|-------------------|------------------|-------------------------|------------------------|---------------------------|----------------------|
| 21                | (MH$_4$)$_2$S$_2$O$_8$ H$_2$O | 1.92/ -0.28 | 9.69/ 11.40 | 57.2/ 66.3 | 0.85 |
| 28                | (MH$_4$)$_2$S$_2$O$_8$ H$_2$O | 2.09/ -0.36 | 10.73/ 13.41 | 58.9/ 67.4 | 0.80 |
| 35                | (MH$_4$)$_2$S$_2$O$_8$ H$_2$O | 2.11/ -0.43 | 10.49/ 15.20 | 59.4/ 72.7 | 0.69 |

From the data of Table 2 it can be seen that the ultimate elongation is reached by the samples after 28 days of stay in aggressive solution (0.3), as well as the limiting coefficient of persistence (0.8). At the same time, limiting characteristics of conventional cement-sand mortar were achieved much earlier - at the age of 21 days.

As a result of testing the durability and corrosion resistance of high-strength fine-grained concrete, it was confirmed, firstly, a significant acceleration of concrete destruction, and secondly, the increased resistance of the developed high-strength composite was established compared to conventional concrete.

**4. Conclusion**

The increase in structure density was observed with an increasing effect during the entire time of hardening. During this period, there are many changes in the formed structure of concrete due to contraction, and reducing porosity. At the end of the hardening period, when artificial stone reached its maximum density and, consequently, its dynamic characteristics, we had the increase in the destructive process. It leads to volume increase and flexural strength decrease.

Thus, a model to create fine-grained high-strength hardening compositions of increased durability in corrosive environment has been proposed. The results obtained enable to conduct further improvement of high-quality composites production, and the use of methods to create model systems to predict the durability of dense materials and obtain new durable composites, expand the possibilities to improve and manage structure formation processes.

**References**

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Acknowledgments
The reported study was funded by RFBR according to the research project № 18-03-00352, using equipment of High Technology Center at BSTU named after V.G. Shukhov.