Comparative analysis of the compression strength characteristics of polymer concrete modified by ultra-fine by-products silicon and aluminum industries

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Abstract. Presently, one of the actual problems of concrete science is the improvement of concrete formulations by using industrial waste, ultra-fine by-products from the production of aluminum and silicon industry, as well as modification by means of additives. The aim of scientific research is development of new technologies for obtaining concrete with enhanced performance characteristics. The article provides an overview of the causes of concrete destruction and methods for increased physical-mechanical characteristics and of concrete. The results of a literature search on the experience of using silica fume and polymers in concrete are presented. The advantages and disadvantages of using silica fume and polymers in the composition of concrete are identified. A study was carried out to determine the effect of various modifying additives on the physical-mechanical characteristics of concrete. Experimental studies have been conducted on the joint use of silica fume and polymers in concrete mixture. The results of the study are: the optimal amount of silica fume is 10-20\%, the optimal amount of polymer is 1.0-3.5\%. On the basis of tests to determine the strength revealed that the class of concrete increased from B15 to B30 compared with the composition of the control sample.

1. Introduction
Concrete is the only and most widely used building material in the world. According to analytical companies and the assessment of the Ministry of Economic Development of Russia, the construction industry made a key contribution to improving the dynamics of GDP in 2018. In January-December 2018, Russian plants produced a total of 53.8 million tons of cement. Despite the fact, that cement production decreased by 1.6-1.9\% (compared with the previous year), demand for it does not decrease [1].

Large volumes of production and consumption of cement are determined by the number of buildings and structures is being built, both in road construction and in civil and industrial.

One of the main reasons for the destruction of concrete is a group of factors integrated on the basis of chemical effects on concrete. These include carbonization, leaching, sulfatization, destruction by chlorides, chemical reaction between cement alkalis and aggregates.

An equally important reason is the physical cause of the destruction of concrete. This means the destruction of concrete resulting from shrinkage, overstretched, mechanical factors (abrasion or impact). This group also includes fire damage and seismic impact.
To prevent most of the factors leading to the loss of technical and operational characteristics, it is possible through the use of a complex of additives. Having analyzed GOST 24211-2008, we can group all concrete additives in the following groups:

- plasticizers,
- mobility regulating additives,
- boosters,
- increase in corrosion resistance,
- additives for frost resistance of concrete,
- mineral additives,
- complex additives [2].

All used concrete additives have both disadvantages and advantages. Most disadvantages can be avoided with proper use of supplements. But, despite this, it should be remembered that the use of additives is inextricably linked with the rise in price of final construction products. In this regard, a problem is the cost of production without loss of technical and operational characteristics. This is possible by replacing any component of the concrete formulation with a material similar in properties. Such materials are waste and by-products of industrial - by-products from the production of aluminum and silicon industry (silica fume), thermal power station waste (fly ash), etc. Silica fume was selected for our scientific research [3-5].

Silica fume is a by-product of ferroalloy and aluminum production. Silica fume (hereinafter SF) easily reacts with calcium hydroxide, which is formed during the hydration of Portland cement. Due to the inherent physical and chemical properties of SF, it is a highly active pozzolan. SF is a dispersed material with a specific surface area in the range of 13,000 - 30,000 m²/kg [6-9].

Silica fume is available in several basic forms: suspension, compacted, unconsolidated and granular SF.

The main advantages of using SF are to improve the structure of concrete and increase strength. The main disadvantage is that SF is a dispersed material that increases water consumption. By calculating the water-cement ratio, the specific amount of water required for the desired consistency is determined. It should remain liquid, but have a high viscosity [10-14]. Excessive addition of water to the mixture will lead to the following consequences:

- loss of the required consistency,
- increase in setting time,
- loss of volume of the mixture,
- formation of pores and voids,
- decrease in strength and durability.

To regulate the water-cement ratio and give the mixture additional positive characteristics, it is proposed to use a polymer. The use of polymers allows to achieve such properties as:

- high strength and abrasion resistance,
- water holding capacity,
- increase in the duration of setting time,
- high rates of water resistance and waterproofness,
- increased indicators of frost resistance [15-17].

Based on the data obtained as a result of a review of the causes of concrete destruction and methods for improving the physical-mechanical characteristics of concrete, as well as a review of the experience of using silica fume and polymers in concrete, a plan of experimental studies on the joint use of SF and polymer was compiled.

2. Materials and methods
The aim of the research was:

1. Determine the optimal amount of SF in the concrete mixture,
2. Determine the optimal amount of polymer in the concrete mixture,
3. To identify the optimal combination of SF and polymer,
4. Determine the strength of the resulting concrete.

A series of samples was made with different contents of SF and latex. These samples gained strength in wet conditions. All samples were tested for strength. Samples of compositions that showed the best strength indicators were selected. The data are presented in figures 1-3.

![Figure 1-2. Graph comparing the dynamics of the strength set of the composition of Control sample + latex (left). Graph comparing the dynamics of the strength set of the composition of Control sample + SF (right).](image)

![Figure 3. Graph comparing the dynamics of the strength set of the composition of CS + SF + latex (wet conditions of hardening).](image)

After analyzing the graph of the dynamics of the set of concrete strength, we can conclude that the optimal amount of SF is 10-20%, and polymer - 1.0-3.5%.

3. Results
Based on the results of the studies, the following results were achieved:
1. The optimal amount of SF - 10-20%,
2. The optimal amount of polymer is 1.0-3.5%,
3. According to the density analysis, the developed concrete is a heavy type of concrete,
4. Based on tests to determine the strength, it was revealed that the class of the developed formulation increased from B15 to B30 compared to the composition of the control sample.

4. Conclusion
The combined use of silica fume and polymer allows us to achieve a number of positive technical and operational characteristics of concrete. In addition, the use of silica fume allows you to solve a number of current problems:
- import substitution (use of resources of the local raw material base, namely SF of Bratsk),
- environmental friendliness of the final product through the use of silica fume.
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