TECHNICAL SCIENCES

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MODIFICATION OF CONCRETE DESIGNED FOR STRENGTHENING UNDERGROUND STRUCTURES OF MINES

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Abstract
The conducted studies of the influence of the Sika Plast-520 hyperplasticizer and blast furnace slowly cooled slag on the speed of formation of the strength of fine-grained concrete based on slag Portland cement established the factors that affect the value of the compressive strength of this concrete. It is proven that they consist of the used amount of slowly cooled blast furnace slag and hyperplasticizer. Sika Plast-520.

Keywords: fine-grained concrete, Portland cement, hydration, concrete modifier, strength, surfactants

INTRODUCTION

Concrete is one of the most popular materials in the construction of houses, residential and non-residential structures. It has a sufficiently high strength, is easy to work with and has a relatively low cost. The disadvantage of all concrete mixtures based on Portland cement is the occurrence of shrinkage after pouring into the formwork, the risk of cracks and delamination. Thanks to concrete that has minimal shrinkage, or does not have it at all, it is possible to reduce the time of manufacturing building structures and reduce the probability of defects. Such concretes are used for road restoration, restoration of load-bearing surfaces, staircases and floors, sealing of joints between reinforced concrete structures.

Unlike traditional types of concrete, non-shrink concrete has a minimal risk of cracks and increased strength. This property is currently ensured by adding a large amount of superplasticizers to the composition of concrete. They increase the strength of cement during compression, demonstrate a quick reaction with water at the beginning of solidification.

Additives with pozzolanic properties show the ability to hydraulic hardening when mixed with lime, gypsum or cement. These additives include granulated blast furnace slag, fuel slag, natural pozzolans, glazes, low-calcium fly ash, etc..

It is believed that filler additives, in particular carbonates, also participate in the chemical processes that occur during the hydration and hardening of cements, but their interaction with cement hydration products occurs very slowly [1], so their influence on the properties of cements is limited [2]. Such additives include natural silicates of calcium and magnesium, as well as carbonates of calcium, magnesium and iron, chalk.

Of all types of cement, slag portland cement has the lowest consumption of natural materials with the lowest energy consumption, which contains up to 50% slag, is usually used under the same conditions as ordinary portland cement. Slag portland cements, containing the maximum amount (up to 80%) of slag, are low-temperature and are used in massive hydraulic structures, for the manufacture of structures exposed to the action of aggressive waters.

But in slag portland cement, the strength gain at the moment of the start of solidification of materials, this process is significantly slower than in portland cement. Slag portland cement acquires a strength close to that of cement after 6–12 months, depending on the temperature and humidity conditions of solidification. After some time, slag portland cement shows significantly greater strength than portland cement.

Taking into account the multifunctional effect of surface-active substances used in ultra-low concentrations [3], research aimed at further improvement and development of concrete technology based on slag portland cements [4], which contain carbonates, with a high operational resource, should be considered relevant, is a directed regulation of phase processes - and structuring of cement stone by using effective surface-active substances in extremely small doses.

ANALYSIS OF RECENT PUBLICATIONS ON THE ISSUE.

As is known, the amount of water added to cement during the preparation of concrete is much greater than that required for its chemical binding in products of hardening of the binder. Excess water evaporates, leaving pores, which increases the porosity of the cement stone and increases its permeability to aggressive environments, thus reducing stability and durability. Therefore, by increasing the density of cement stone, a method of reducing the amount of water that evaporates in cement stone and concrete can be recognized.

One of the ways to reduce the amount of water that evaporates from concrete is the use of so-called new generation concretes, in particular on binders of low water consumption [5], or with the use of nano additives [6,7]. The indicated concretes have high strength at an early age, but the hydration of Portland cement does not occur to the full extent, which will obviously affect their durability.

It is obvious that the more water during cement hardening will be bound into stable, strong minerals, the less will be the shrinkage of the cement stone and the higher will be its density and, therefore, its strength. This is consistent with the conclusion made in [8] that it is better to use those binders for concrete whose hardening is accompanied by a strong stable binding of the maximum amount of water with moderate contraction and, therefore, a significant increase in the volume of solid of the phase formed in comparison with the volume of the initial solid phase. This position is confirmed by the data given in [9], that when aluminates are converted into more complex forms, for example, sulfoaluminates, a significant decrease in the concentration of defects in the structure of cement stone is observed due to the effect of microreinforcement of the structure of cement stone.

One of the most well-known minerals formed during the hardening of Portland cement compositions, which contain a significant amount of chemically bound water, are calcium hydrosulfoaluminates, of which two calcium hydrosulfoaluminates are best known [8]. Therefore, ensuring the presence of a significant amount of calcium hydrosulfoaluminate-type minerals in the hydration products of the dispersed system that hardens will ensure an increase in its density and, as a result, strength and corrosion resistance, as well as a decrease in its deformability. However, the amount of these minerals in known dispersion systems based on Portland cement is limited. In addition, the highly sulfated form of calcium hydrosulfoaluminate is thermodynamically unstable.

Under certain conditions (introduction of calcium carbonates or calcium chlorides into the hardening system of Portland cement compositions), in the process of hydration of calcium aluminates, according to [8], calcium carbo- and chloroaluminates such as calcium monocarboaluminates and calcium monochloroaluminates can occur. to be formed However, these minerals are not very stable and decompose at temperatures above 70°C. According to [8], calcium sulfate in monohydrosulfoaluminate can be replaced by metal silicates. These minerals gradually, in the process of hardening of the composition, turn into a high-silicate form.

The nature of the influence of the aggregate on the process of hydration and hardening of cement depends on its nature and mineralogical composition. A large number of studies are devoted to the effect of aggregates on the process of cement hydration and structuring of cement stone in concrete. Chemical interaction can take place between aggregate and binder in concrete compositions [9]. The authors [10] showed that the use of limestone aggregate significantly increases the degree of hydration of cement.

But not only aggregates consisting only of carbonates have an effect on the properties of concrete. Thus, the iron ore rocks of the Kryvyi Rih deposit contain iron carbonate, which leads to an increase in the strength of concrete when these rocks are used as a fine aggregate [8, 11-14].

Studies of the system "portland cement cement - mineral additive - water - surface-active substance" established [15] that the rate of formation of certain neoplasms is determined by the mineralogical composition of cement and additives, as well as the ratio of components in the system.

The availability of these studies makes it possible to adjust the content of the complex modifier "carbonate mineral additive - surface-active substance" of the system to ensure the physical and mechanical characteristics of concrete. Despite the practical significance of such results, the kinetic regularities of the processes of forming the strength of concrete with the simultaneous use of carbonate mineral admixture, fine aggregate and surface-active substance applied in ultrasmall doses have not been sufficiently considered.

The feasibility of using complex modifiers containing calcium and iron carbonates is confirmed by the improvement of the physical and mechanical properties of concrete and a significant increase in its mechanical strength [15-17]. According to the authors [15], this is due to the formation of a significant number of nanostructures during the hydration of Portland cements in concrete. However, no relevant physical and mechanical studies are given to confirm this hypothesis. Therefore, there are reasons to believe that the insufficient determination of the effect of complex carbonate modifiers "carbonate mineral additive - surface-active substance" on the speed of formation of the strength of fine-grained concrete formed with their participation during the hydration of portland cements determines the need to conduct research in this direction.

EXPERIMENTAL PART

The purpose of the conducted research was to determine the rate of formation of the strength of fine-grained concrete with an individual and complex modifier based on iron carbonates. To achieve the goal, the following tasks were solved:

– to determine the effect of superplasticizer and iron-based carbonate modifier on the change in the speed of formation of the strength of fine-grained concrete at different values of the water-cement ratio;

- to determine the effect of iron-based carbonate filler on the change in the speed of formation of the strength of fine-grained concrete.

Materials and research methods

The research was carried out using cement SEM II/B-S 400 PrJSC "Kryviy Rig Cement", which contains 75% blast furnace granulated slag, and modifiers - hyperplasticizer of organic origin Sika Plast-520 and iron ore beneficiation waste with a content of iron carbonates of 26-39%. Dnipro polyfraction river sand was used as fine aggregate.

The components of the concrete mixture were moistened to the humidity determined by the experiment plan and the mass was mixed for 4 min. Additives were introduced with an aqueous solution at the rate of Sika Plast-520 - per mass of cement. Experimental samples with side dimensions of 40x40x160 mm were made by the method of vibration molding, part of which, after hardening in air for 3 days, continued to harden in air, and the other part - in water.

Determination of the effect of modifiers on the hardening of cement stone in the early stages was carried out on cement samples with W/C of 0.5, 0.55 and 0.60. The main indicators of the properties of concrete samples determined in the experiment were: compressive and bending strength limits. The determination of the specified indicators was carried out according to the methodology of the relevant State Standards of Ukraine. For simplification and clarity of processing results, strength indicators were converted into relative units (%).

The results of our own research and their discussion

The results of determining the mechanical strength of cement concrete samples in the early stages of hardening with W/C= 0.5-0.6 are presented in Fig. 1.

It should be noted that the carbonate modifier has different application efficiency depending on the water content (W/C) in the system. The greatest effectiveness of the carbonate modifier is manifested at average (relative to the experimental plan) values of water consumption.

According to the experimental data shown in fig. 2, the effectiveness of the carbonate modifier changes over time. It practically does not depend on the water content and is a 110-120% increase in the strength of concrete with a carbonate modifier content of 10-20% of the system mass.

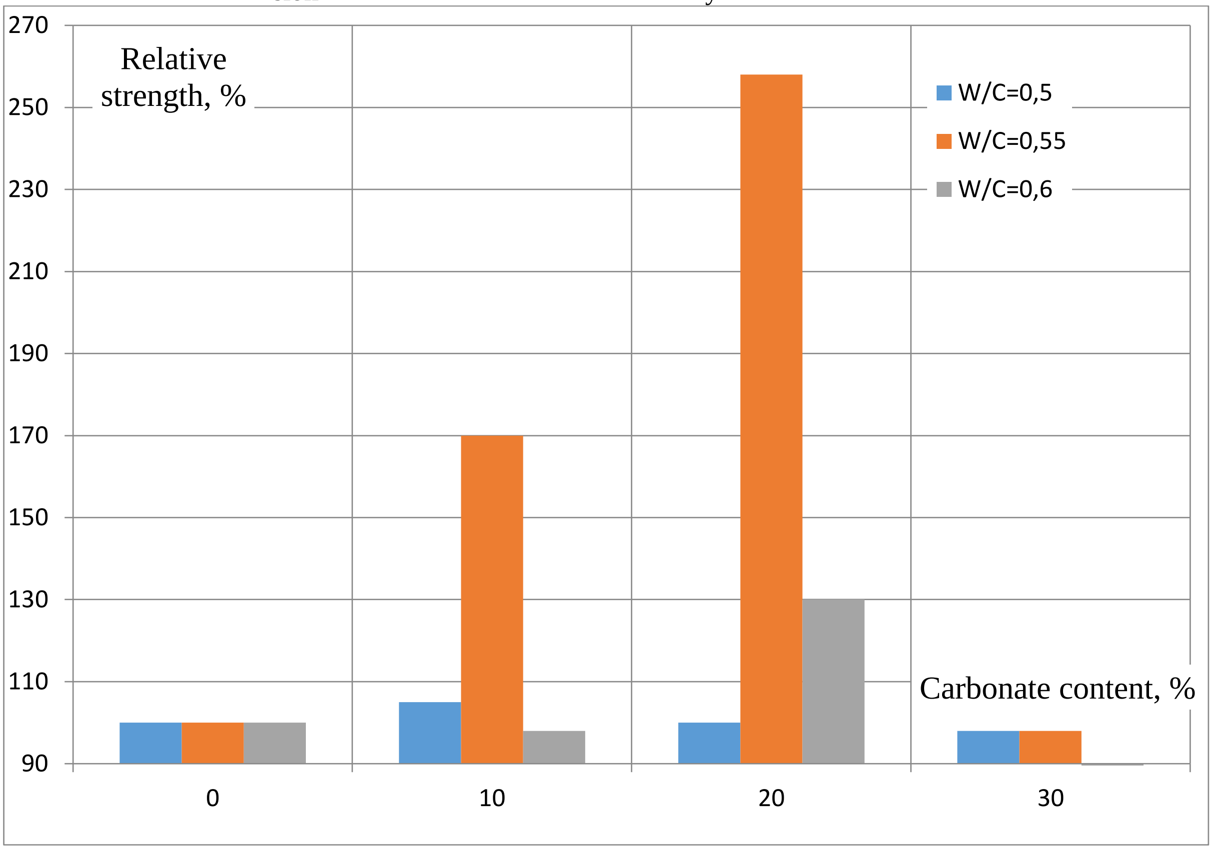

Figure 1. *The influence of carbonate cement on the relative strength of concrete at the age of 7 days*

At the same time, the simultaneous use of carbonate modifier and hyperplasticizer in extremely small doses leads to an increase in the effect of increasing the strength of concrete (Fig. 3).

In this case, the efficiency of using the complex "carbonate modifier - hyperplasticizer" provides an increase in the strength of concrete by at least 150% and reaches 400%.

As can be seen from fig. 4 and fig. 5, when using the "carbonate modifier - hyperplasticizer" complex, its effectiveness at the age of 28 days of concrete does not exceed ensuring an increase of concrete strength by more than 40%.

Thus, the optimal content of the complex "carbonate modifier - hyperplasticizer" in fine-grained concrete is:

Carbonate modifier based on iron - 20% of the mass of the mixture of carbonate modifier and Portland cement;

Hyperplasticizer - 0.0002...0.0004% of the mass of the mixture of carbonate modifier and slag Portland cement.

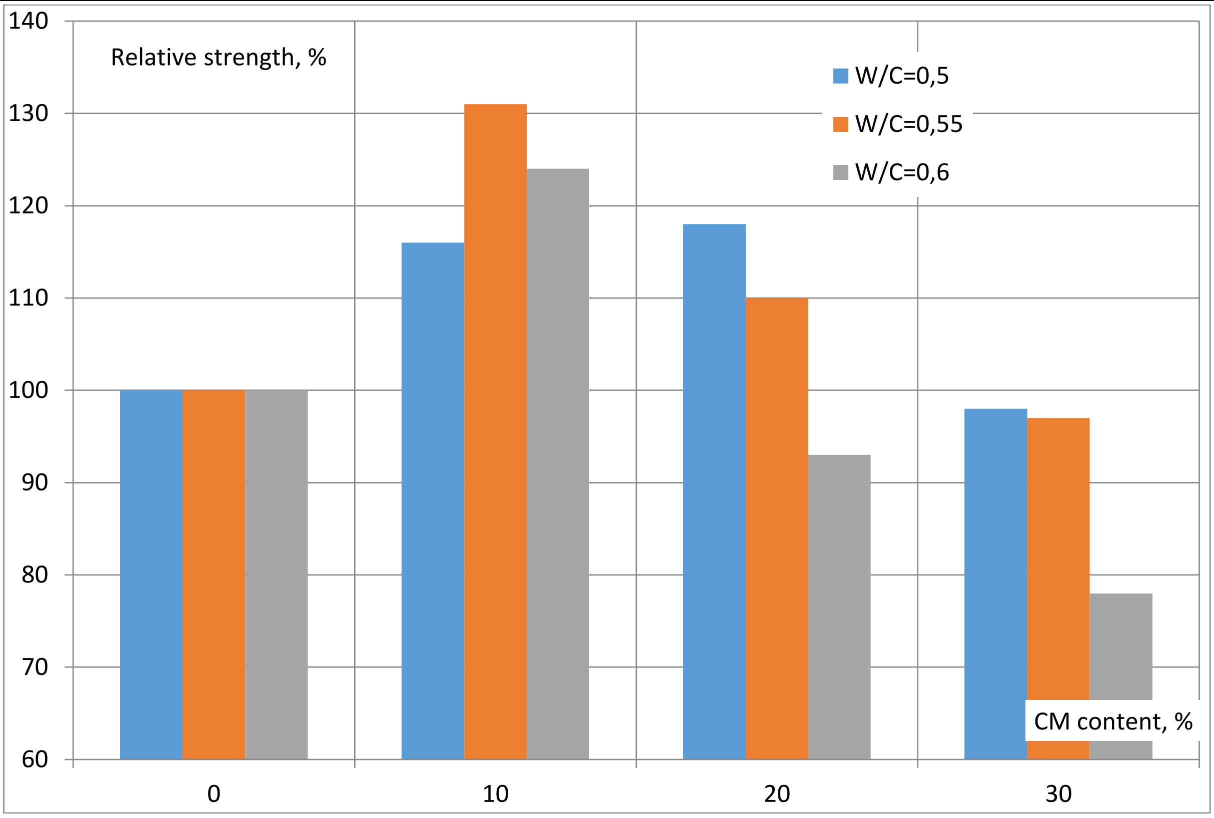

***Figure** 2.*
The influence of the carbonate modifier (CM) of cement on the relative strength of concrete at the age of 28 days

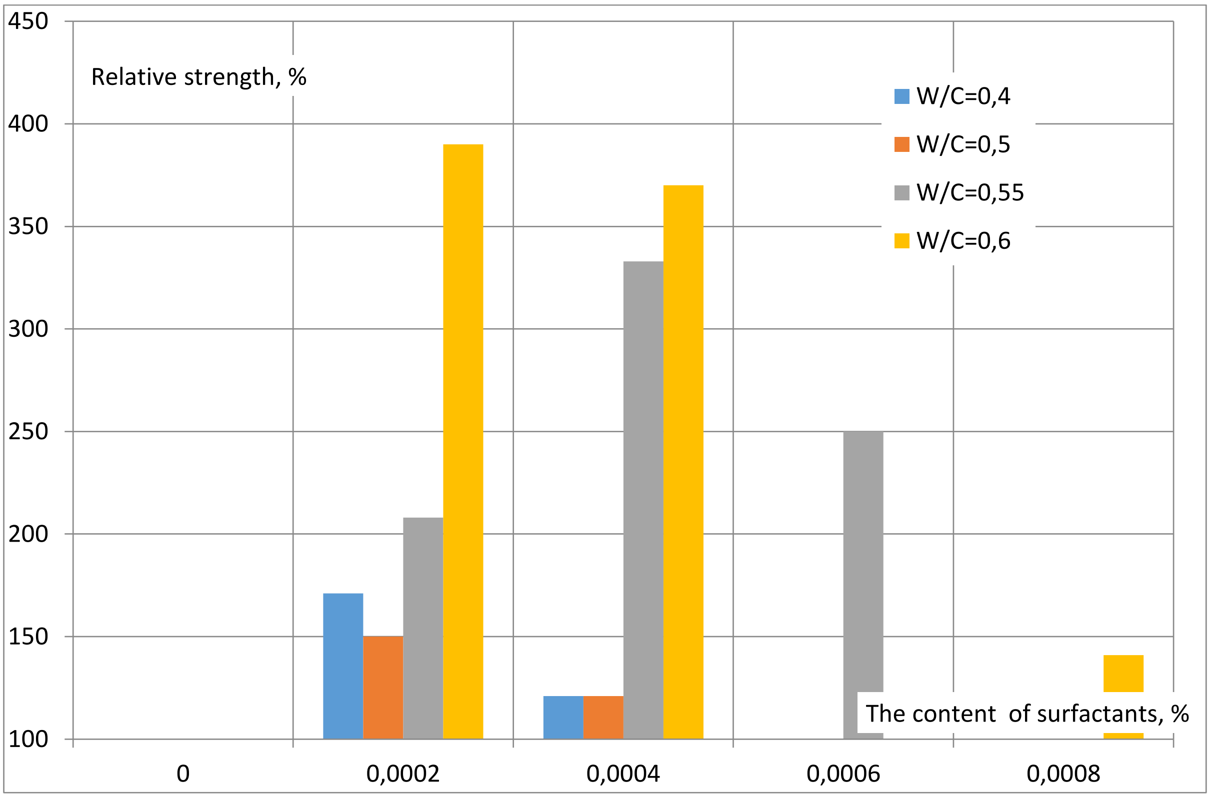

***Figure** 3. The effect of hyperplasticizer on the relative strength of concrete at the age of 7 days (carbonate modifier 20% by weight of cement)*

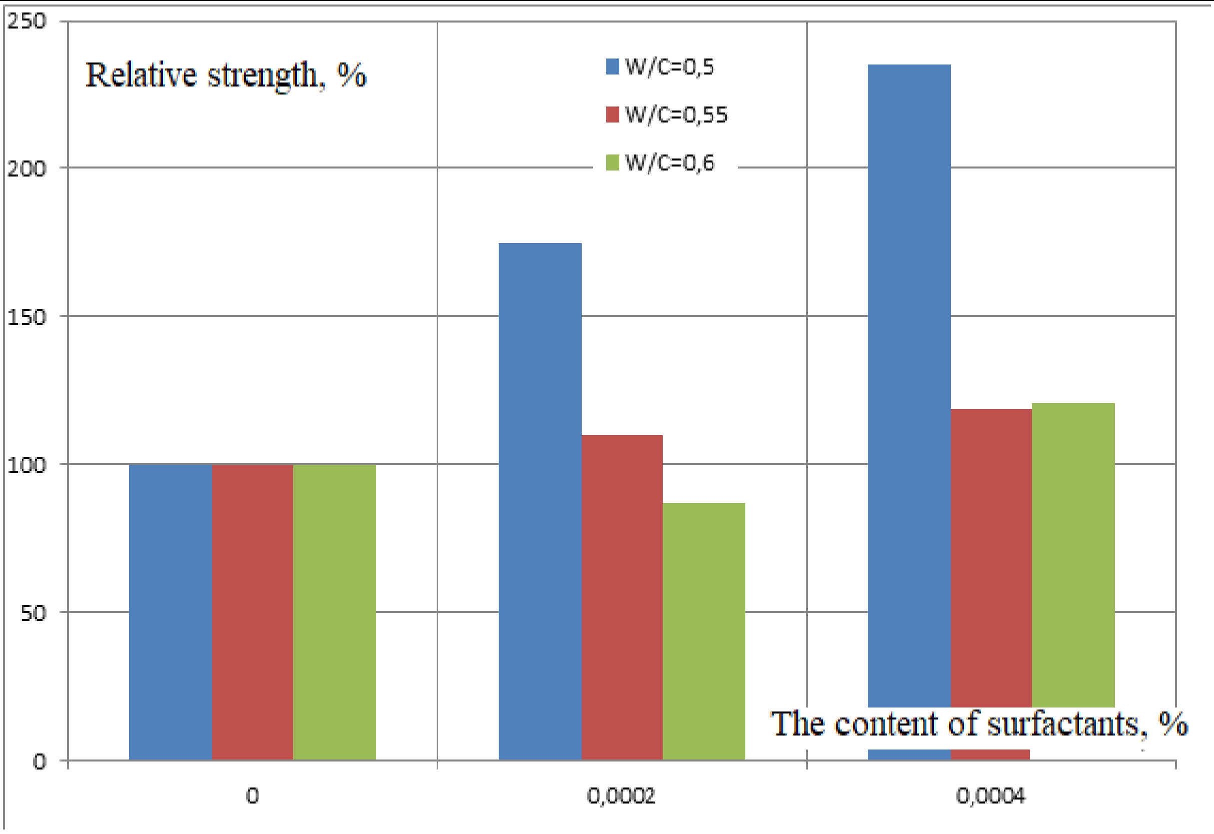

***Figure** 4. The influence of the complex "carbonate modifier - hyperplasticizer" on the relative strength of concrete at the age of 28 days*
(carbonate modifier 10% by weight of cement)

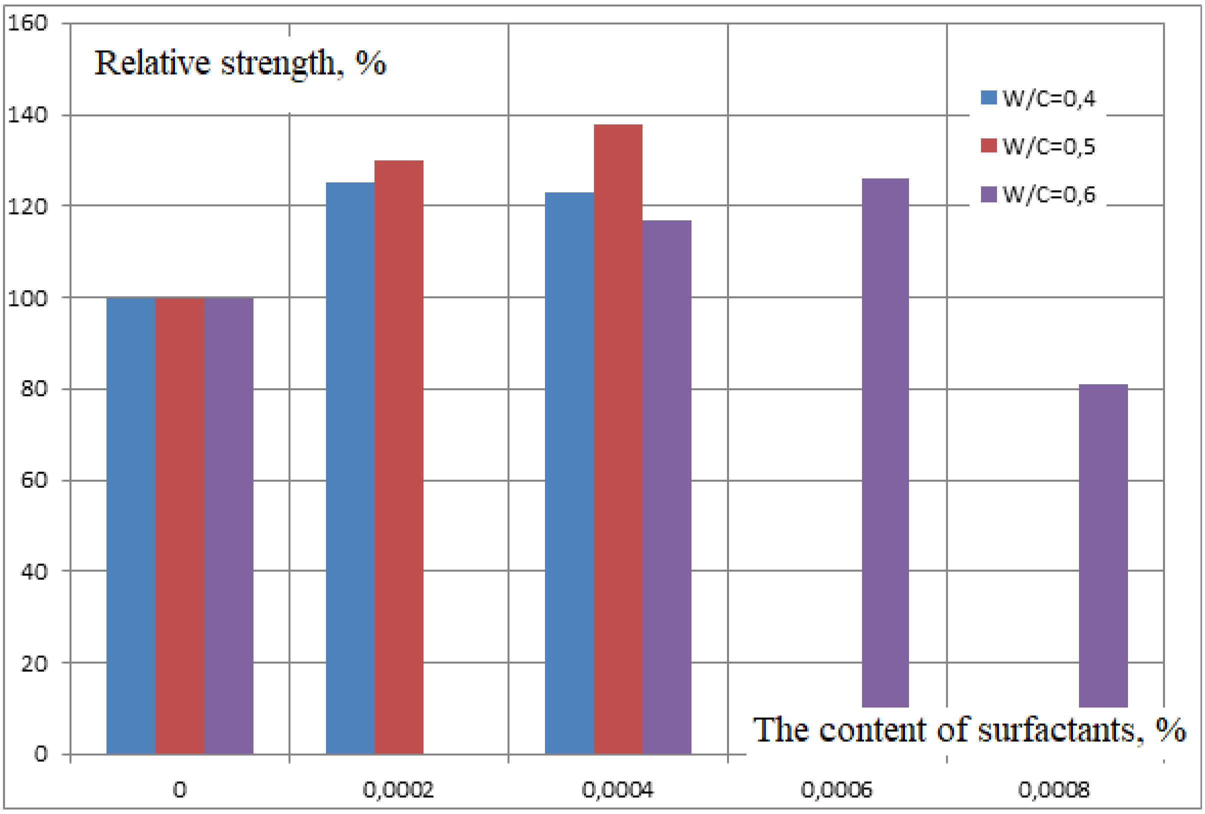

***Figure** 5. The influence of the complex "carbonate modifier - hyperplasticizer" on the relative strength of concrete at the age of 28 days*
(carbonate modifier 20% by weight of cement)

When determining the effectiveness of the complex modifier on the hardening process of slag Portland cement, as follows from the obtained results (Fig. 1), it is natural to increase the speed of formation of strength by cement stone. This is obviously due to the dispersing action of the hyperplasticizer (surfactant) of organic origin Sika Plast-520 and the formation of adsorption layers on the surface of clinker minerals, which slow down the diffusion of hydroxyl ions and the formation of crystal hydrates. It should be noted that the presence of surfactant additives leads to an increase in the effect of accelerating the formation of strength by fine-grained concrete. Obviously, such a mechanism of surfactant influence is the process regulation factor, thanks to which the complex modifier helps to increase the strength of concrete in the late stages of hardening. The effect of accelerating the speed of structure formation, and therefore the strength of concrete over a certain time, depends on the water content in concrete. An increase in the water-cement ratio leads to an increase in the effect of increasing the strength of concrete. This can be explained as a tangential effect, which confirms the formation of polyhydric minerals. In this sense, the interpretation of the results shown in fig. 2,3,5.

A comparison of the hardening terms and the duration of the hardening periods of modified cement with different W/C indicates the acceleration of the hardening processes of the cement dough. This does not differ from the practical data, well known from the works, the authors of which, by the way, also associate the change in the duration of the process with the formation of less stable compounds in the composition of concrete precisely in the third time interval of hardening. But, in contrast to published research results, the data obtained on the effect of Sika Plast-520 and a complex modifier containing iron carbonate on the hardening process of Portland cement allow us to state the following: - the main regulator of the process is not so much the formation of a significant number of nanostructures, but the deflocculating effect of modifiers and dilution of cement dough; – the correct arrangement of additives in the Sika Plast-520 → complex modifier series has a significant impact on the process. Such conclusions are expedient from a practical point of view, because they allow a reasoned approach to determining the required amount of modifier and hyperplasticizer. From a theoretical point of view, they are able to assert the determination of a certain mechanism of the hydration processes of Portland slag cement in the presence of the complex "modifier containing iron carbonates - hyperplasticizer", namely the formation of an increased amount of minerals that contain a significant amount of chemically bound water, which are certain advantages of this study.

Conclusions:

1. The conducted research established that the hyperplasticizer and the modifier containing iron carbonates have a significant effect on changing the nature of hardening processes, phase and structure formation of fine-grained concrete based on Portland slag cement in the early stages of hardening.

2. Features of the formation of the structure of fine-grained concrete, containing a hyperplasticizer in ultra-small doses and a carbonate modifier containing iron carbonates, are to further increase the strength of concrete. Due to this, the mechanical strength of concrete increases and is 300% of the strength of concrete without additives. This indicates the possibility of directed regulation of the processes of forming a strong structure of fine-grained concrete by using the complex "carbonate-containing modifier based on iron carbonates - hyperplasticizer" as a complex modifier.

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