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APPLICATION OF GYPSUM IN MICELLAR CATALYSIS OF PORTLAND CEMENT HYDRATION REACTIONS

To obtain modern high-quality concrete, a sufficient number of special additives are used. The most common additives are surfactants. The use of surfactants leads to a decrease in the ratio of water to cement, which, in turn, leads to an increase in the strength of concrete. At the same time, the degree of hydration of cement decreases, which reduces the durability of concrete. In addition, as a result of the interaction reactions between cement minerals and the surfactant, substances are formed that are not inherent in the cement cameo, which hardens without additives. It is established that the active components of modern concrete are micelles filled with active mineral fillers, such as gypsum, as well as superplasticizers. The optimal combination of these additives-modifiers allows you to control the rheological properties of concrete mixtures and modify the structure of cement stone so as to ensure the properties of concrete, ensuring high operational reliability of structures. However, they have certain shortcomings that prevent their widespread use. The aim of the study is to determine the effect of gypsum, which is used as a reaction powder filled with micelles of colloidal surfactants, on the strength of powdered concrete and catalysis of hydration reactions of Portland cement components. Studies and their results have shown that the use of micelles of colloidal surfactants filled with gypsum leads to increased efficiency of both components. This enhances the catalytic effect of the hydration reactions of the components of Portland cement and gypsum itself. Increasing the rate of hydration of Portland cement components provides increased productivity of concrete and reinforced concrete structures. Analysis of the results of the research showed the presence in the system under study of the optimal content of reactive powder capable of entering into a hydration reaction.

Key words: *cement, gypsum, micelles, strength, surfactants, plasticizers.*

Formulation of the problem

In recent years, interest in multicomponent reactions (MCR) has sharply increased. New MCRs and variants of already known reactions provide access to a huge variety of structures, including those of natural origin, capable of exhibiting a wide range of chemical activity, and the range of available compounds is constantly increasing.

Intensive construction methods require the introduction of modern technologies that would ensure the manufacture of structures in a short time, increase the turnover of molding equipment, and shorten the production cycle. For high-speed technologies, it is mandatory to use quick-setting binders to obtain high-strength concrete in one or two days. Therefore, there is a need to develop high-performance fast-hardening building composites that ensure the commissioning of facilities in a short time and their reliable operation throughout the entire life cycle. Repair, restoration and reconstruction of existing construction sites, the restoration of operational functions of which is possible only for certain short periods of time (underpasses, sidewalks, buildings at airports and railways, hydraulic structures), requires the use of effective fast-hardening materials. The hardening process of Portland cement, which is the basis for the production of most building structures, is based on hydration reactions, which are referred to as MCR. At present, the application of various types of catalysis to almost all reactions used in chemistry, including MCR, has become a stable trend. Even those transformations that were previously carried out without the use of any catalysts are now involved in the range of catalytic processes, which reflects the general general trend towards increasing the efficiency of chemical synthesis.

Analysis of recent research and publications

The multicomponent synthesis of chemical compounds became a separate area of research. The authors of these works note a higher efficiency of multicomponent transformations, as compared to multistage syntheses, and the possibility of automating syntheses based on them. In addition, new MCRs and variants of already well-known reactions open up access to a huge variety of structures, including those of natural origin, which can exhibit a wide range of chemical activity, and the range of available compounds is constantly increasing. It should be noted that the use of catalytic methods to increase the efficiency of MCR has a special specificity. Such transformations are complex systems consisting of a network of subreactions; therefore, traditional methods for accelerating chemical processes (using high temperatures, acids or bases) often do not give the desired result. They usually act non-selectively, accelerating side two-component reactions, leading to the appearance of undesirable products in the system. Methods that increase the efficiency of chemical synthesis include the use of nanomodified water [1–5], micellar solutions [6–8], and inorganic compounds (clays, zeolites, silica gel, metal oxides, carbon nanotubes, and nanofibers) [5; 9–16]. The use of these methods made it possible to significantly expand the scope of old, well-known reactions and discover a number of new ones. In recent years, this approach has found application in the field of MCR. The effect of the use of all known inorganic compounds used as nanocatalysts for hydration reactions of Portland cement components is significantly increased with the additional introduction of surfactants of organic origin. In this case, micelles of surfactants are artificially created, which are filled with inorganic compounds. At the same time, it is known that in water all its molecules are interconnected by hydrogen bonds, but at the points of contact with the organic phase, a layer of water molecules with free OH groups is formed, which can catalyze a wide range of reactions. The phenomenon of changing the properties of water upon the introduction of surfactant micelles into it was noted only in a small number of studies [1]. At the same time, it should be noted that all inorganic compounds currently used to catalyze hydration reactions are inactive or inactive with respect to water. Guidance on the development of the "sol-gel" technology to be filled with inorganic speech micelles for adjusting the density of concrete [5; 9–17].

Setting objectives

The purpose of the research is to determine, using the example of gypsum, the effect of an inorganic substance, as a reactive powder, which is used simultaneously with a colloidal surfactant, on the strength of fine-grained concrete and the rate of its formation. In accordance with the goal, the objectives of the study are to determine the dependence of the strength of concrete on the amount of gypsum, both in the presence of a colloidal surfactant and without it; to determine the effect of a colloidal surfactant on the effectiveness of gypsum as a component of a filled micelle – a catalyst for hydration reactions of Portland cement components, while monitoring the increase in concrete strength.

Presentation of the main material of the study

For the production of concrete, Portland cement grade M400 was used by "Kryvyi Rih Cement" OJSC (Ukraine). Building gypsum ground to a specific

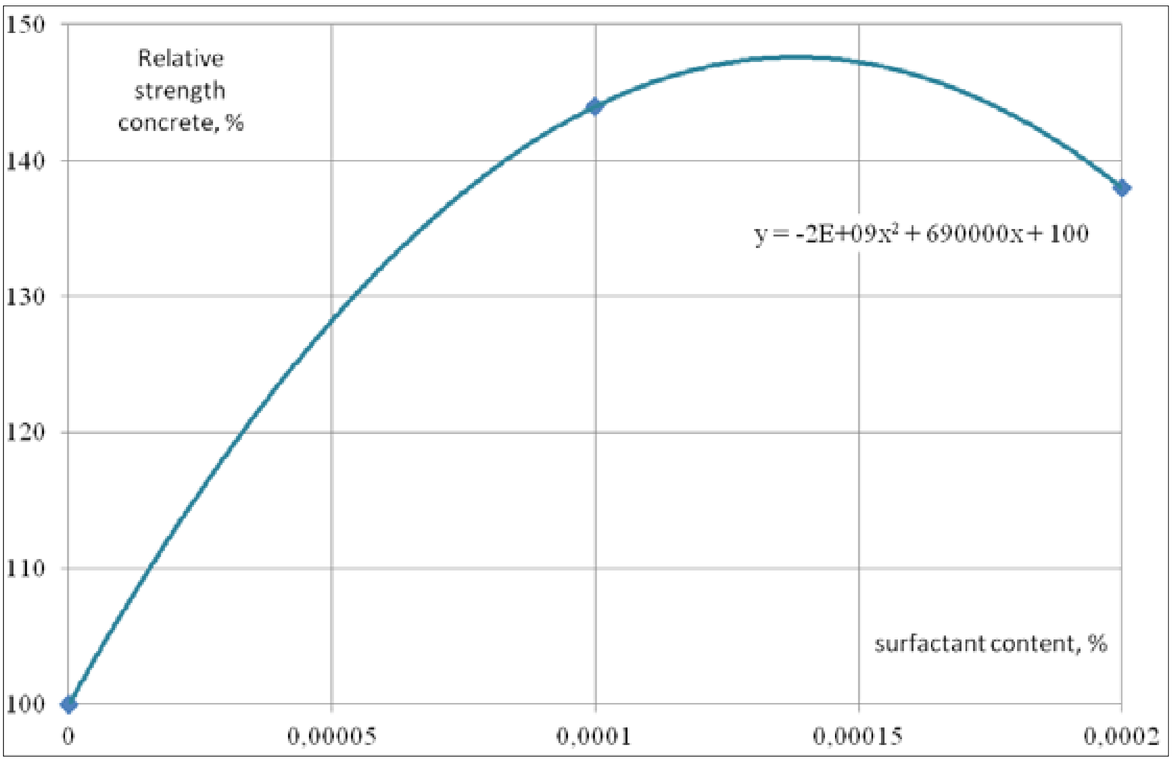

Fig. 1. Influence of surfactants on the strength of gypsum stone at the age of 7 days

surface area of 300 m²/kg was used as the reaction powder. Sodium oleate (Simagchem Corp., China) was used as a micellar surfactant (MPAR).

The components of the concrete mixture were dosed in the quantities required, according to the experimental design, in quantities, mixed with a laboratory mixer for 2 minutes. The resulting mixture was contained with a vibration seal in a metallic form having a side size of 16 × 4 × 4 cm. Formed in this way, concrete samples were hardened for 28 days at an ambient humidity of 70 ± 10 % and an ambient temperature of 293 ± 2 K.

The compressive strength of the stone obtained as a result of hydration of the dispersed system "gypsum – hydrophobic surfactant – water" (Fig. 1).

The compressive strength of the stone obtained as a result of hydration of the dispersed system "Portland cement – hydrophobic surfactant – reactive powder" when used as a reactive gypsum powder is higher than the strength of concrete obtained on the basis of Portland cement without additives (Fig. 2). The same phenomenon is also observed at the age of 28 days (Fig. 3).

When the system under consideration contains gypsum in the amount of 5 % and a surfactant in the amount of 0.02 %, a sharp increase in the rate of hydration reactions occurs, which ensures an increase in the rate of formation of concrete strength (Fig. 4).

Thus, concrete containing micelles filled with 5 % gypsum at the age of 2 days has the strength of concrete without additives at the age of 7 days. At the same time, the strength of concrete obtained as a result of catalysis of hydration reactions at the age of 28 days is 120 % of the strength of concrete without additives.

When the system under consideration contains gypsum in the amount of 10 % and a surfactant in the amount of 0.02 %, a sharp increase in the rate of hydration reactions occurs, which ensures an increase in the rate of formation of concrete strength (Fig. 5). So, concrete containing micelles filled with gypsum in an amount of 10 % with a surfactant content in an amount of 0.01 %, at the age of 2 days, has the strength of concrete without additives at the age of 7 days. At the same time, the strength of concrete obtained as a result of catalysis of hydration reactions at the age of 28 days is 138 % of the strength of concrete without additives.

Thus, the presence of a complex surfactant in the dispersed system provides increased compressive strength of the resulting concrete.

The rate of strength gain in compression of concrete obtained as a result of hydration reactions in the dispersed system "Portland cement – surfactant – reaction powder" depends on the amount of reaction powder (gypsum under experimental conditions) and surfactant used.

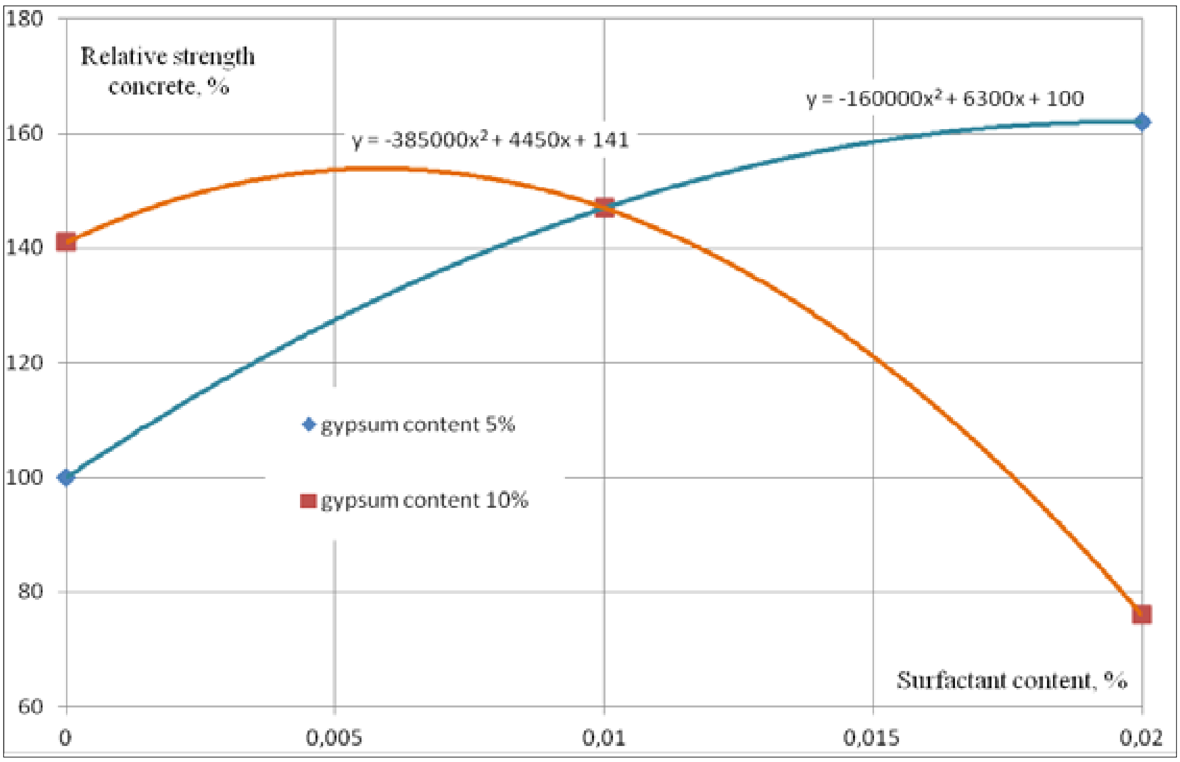

Fig. 2. Relative strength of concrete at the age of 7 days

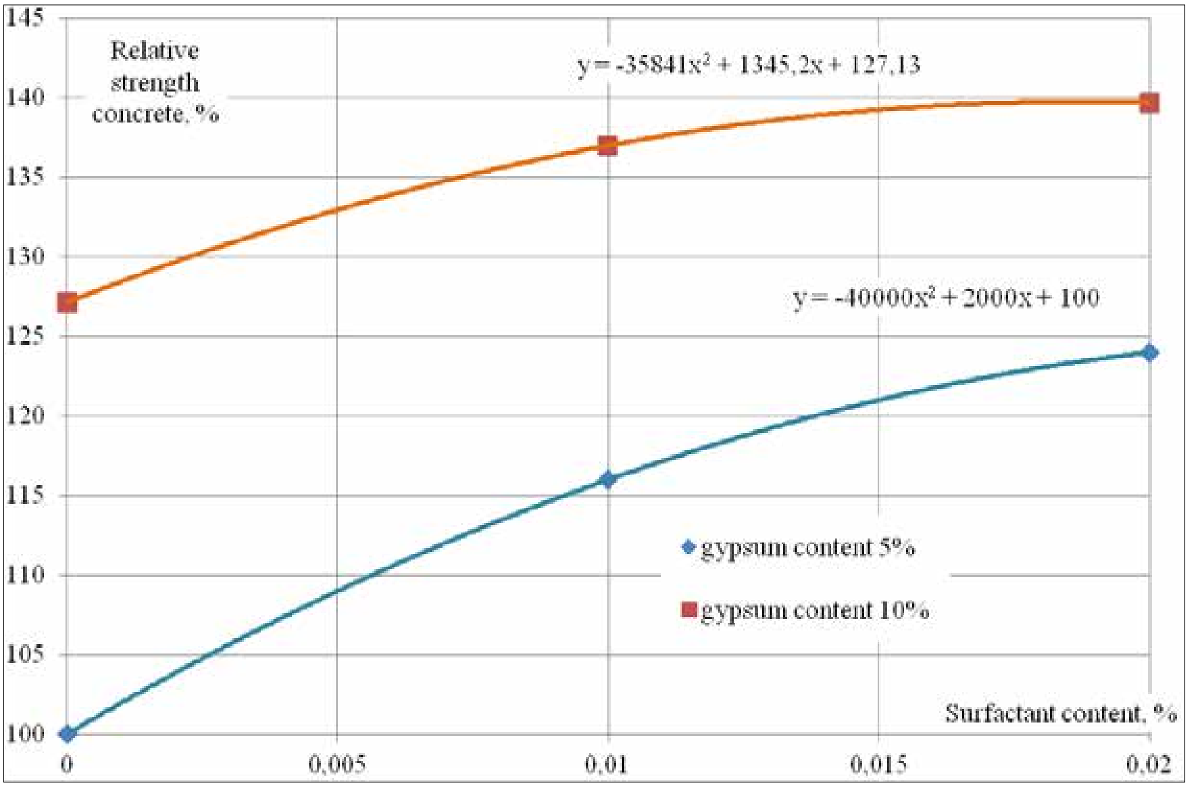

Fig. 3. Relative strength of concrete at the age of 28 days

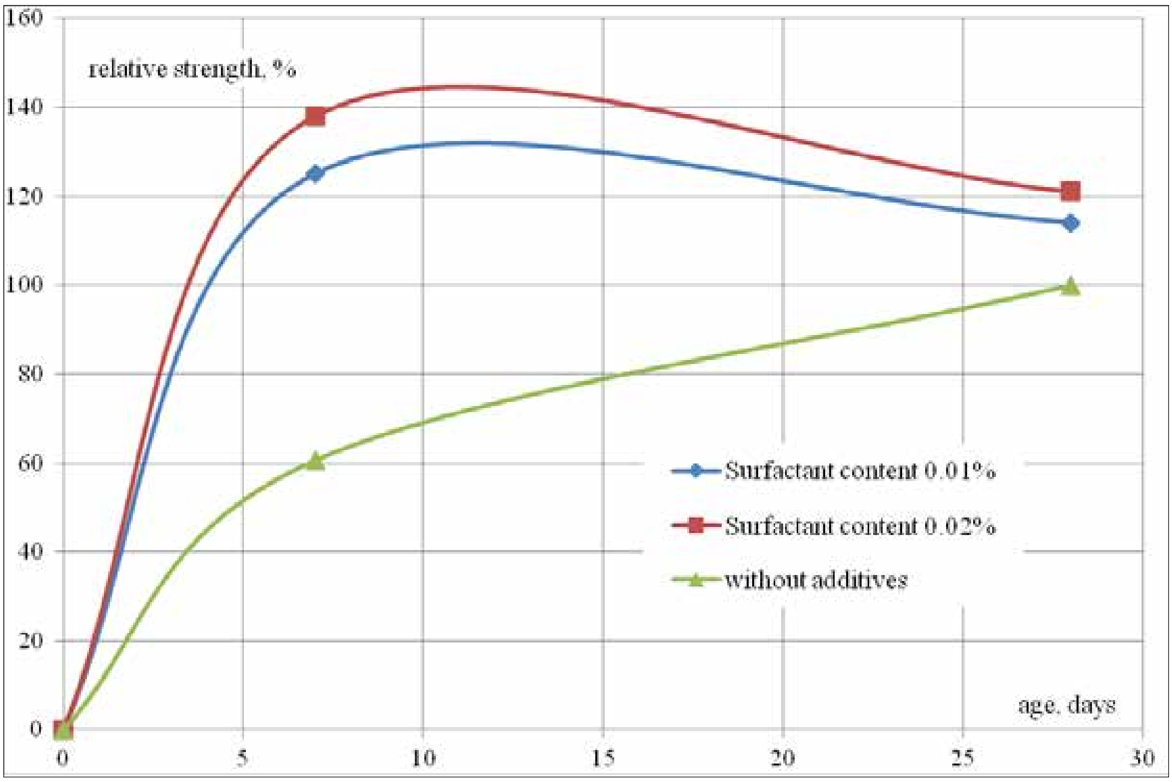

Fig. 4 Change in concrete strength over time (5 % gypsum)

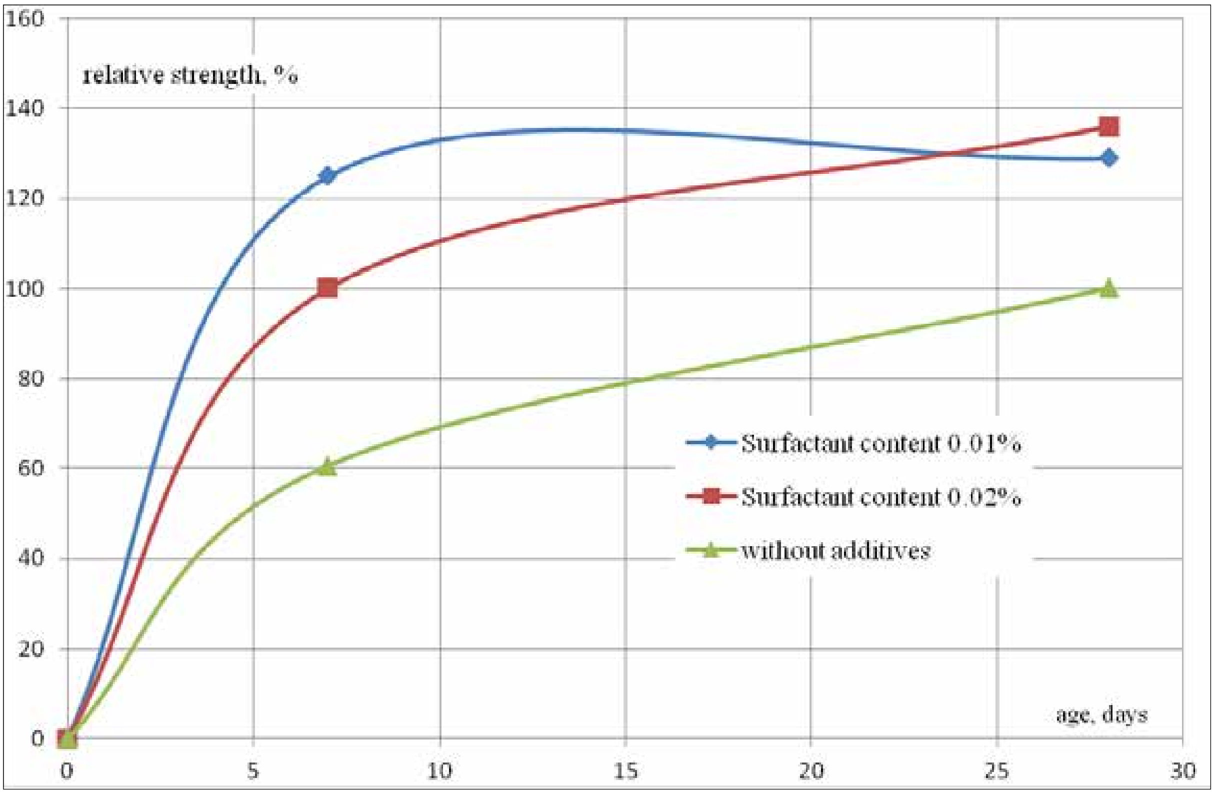

Fig. 5 Change in concrete strength over time (10 % gypsum)

Under the experimental conditions, the highest rate of curing of concrete is provided by the content of gypsum in the amount of 5 % and surfactant in the amount of 0.02 %. Concretes containing gypsum in the amount of 10 % and surfactant in the amount of 0.02 % have the maximum increase in the strength of concrete.

Thus, surfactant micelles filled with gypsum provide an increase in the rate of hydration reactions of Portland cement components, which ensures an increase in the rate of concrete strength formation.

An analysis of the results of the studies performed showed the presence in the system under study of the optimal content of the reactive powder capable of entering into hydration reactions.

Conclusions

The conducted studies and their results showed that the use of micelles of colloidal surfactants filled with gypsum leads to an increase in the efficiency of the use of both components. This increases the effect of catalysis of the hydration reactions of the components of Portland cement and the gypsum itself. An increase in the rate of hydration of the components of Portland cement provides an increase in the productivity of the production of concrete and reinforced concrete structures.

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Шишкіна О.О. ЗАСТОСУВАННЯ ГІПСУ У МІЦЕЛЯРНОМ КАТАЛІЗІ РЕАКЦІЙ ГІДРАТАЦІЇ ПОРТЛАНДЦЕМЕНТУ

Для отримання сучасних бетонів високої якості застосовують достатню кількість спеціальних добавок. Найбільш розповсюдженими добавками є поверхнево-активні речовини. Застосування поверхнево-активних речовин призводить до зменшенні відношення води до цементу, що, в свою чергу, призводить до збільшення міцності бетону. В той же час зменшується ступінь гідратації цементу, що призводить до зменшення довговічності бетону. Крім того в наслідок реакцій взаємодії між мінералами цементу та поверхнево-активною речовиною утворюються речовини, які не притаманні цементному камею, який твердів без добавок.

Встановлено, що активними компонентами сучасних бетонів є міцели, наповнені активними мінеральними наповнювачами, такими як гіпс, а також суперпластифікаторами. Оптимальне поєднання цих добавок-модифікаторів дозволяє контролювати реологічні властивості бетонних сумішей і модифікувати структуру цементного каменю таким чином, щоб забезпечити властивості бетону, що забезпечують високу експлуатаційну надійність конструкцій. Однак вони мають певні недоліки, які перешкоджають їх широкому застосуванню. Метою дослідження є визначення впливу гіпсу, який використовується як реакційний порошок, наповнений міцелами колоїдних поверхнево-активних речовин, на міцність порошкоподібного бетону та каталіз гідратаційних реакцій компонентів портландцементу.

Проведені дослідження та їх результати показали, що використання міцел колоїдних поверхнево-активних речовин, наповнених гіпсом, призводить до підвищення ефективності використання обох компонентів. Це посилює ефект каталізу реакцій гідратації компонентів портландцементу і самого гіпсу. Збільшення швидкості гідратації компонентів портландцементу забезпечує підвищення продуктивності виробництва бетону та залізобетонних конструкцій. Аналіз результатів проведених досліджень показав наявність у досліджуваній системі оптимального вмісту реакційно-здатного порошку, здатного вступати в реакції гідратації.

Ключові слова: *цемент, гіпс, міцели, міцність, поверхнево-активні речовини, пластифікатори.*