Досліджено вплив наномодифікаторів на швидкість формування міцності при стиску та початкового модуля пружності дрібнозернистих бетонів. Встановлено вплив кількості поверхнево-активних речовин, які утворюють міцели, на швидкість формування міцності і деформативних властивостей дрібнозернистих бетонів. Визначено особливості впливу міцел на формування міцнісних та деформативних властивостей дрібнозернистого бетону

Ключові слова: дрібнозернистий бетон, наномодифікатор, модуль пружності, міцелярний каталіз, поверхнево-активні речовини

Исследовано влияние наномодификаторов на скорость формирования прочности при сжатии и начального модуля упругости мелкозернистых бетонов. Установлено влияние количества мицеллообразующих поверхностно-активных веществ на скорость формирования прочности и деформативных свойств мелкозернистых бетонов. Определены особенности влияния мицелл на формирование прочностных и деформативных свойств мелкозернистого бетона

Ключевые слова: мелкозернистый бетон, наномодификатор, модуль упругости, мицеллярный катализ, поверхностно-активные вещества

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STUDY OF CHANGE IN THE DEFORMATION-STRENGTH PROPERTIES OF NANOMODIFIED FINE-GRAINED CONCRETES OVER TIME

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1. Introduction

Sandy (fine-grained) concrete of the new generation, in addition to dispersed cement, additionally includes the combination of dispersed and fine-grained additives. Such additives include the ground natural sands or microsilica, reactive pozzolanic additives and fine sands at strictly optimum ratio [1–4]. Creation of effective concretes of such type is possible through the activation of powders that are included in the composition of these concretes, the use of super-plasticizer (SP) and hyper-plasticizers (HP).

Such concretes typically consist of 7 or 8 components, which, in the majority of the cases, are applied in the form of powders. This is required to not only improve the strength of concrete, but also for a considerable reduction in the consumption of cement, which makes it possible to call such concretes powder-activated or reaction-powder (RPC). The composition and technology of such concretes substantially increase their cost, even in comparison with the high-functional and ultra high-functional concretes.

This is why the fine-grained concretes, including the reaction-powder ones, are practically not utilized at present in the technology of manufacturing the bearing structures both in the prefabricated and in the monolithic construction. This is linked to the fact that the given concretes are characterized by increased consumption of cement. In turn, the increased consumption of cement is the reason for significant deformativeness of the indicated concretes, especially those obtained from the high-plastic concrete mixtures, which also limits the use of fine-grained concretes in the manufacturing of bearing structures.

The most expanded area of contemporary application of fine-grained concretes, including the powder-reaction ones, is the fabrication of small-piece articles by the methods of power extrusion or vibrocompression. It is possible to produce the following out of such concretes:

– the upper layers of bridge structures, industrial flooring;
– structures of complex shape;
– containers for nuclear waste and toxic substances;
– building structures for banks and computer centers;
– pressure and non-pressure pipes [5–8].

The established phenomenon of increased speed of the formation and the magnitude of strength at compression of fine-grained concretes through the application of the micellar catalysis [9, 10] makes it possible to decrease the cement consumption and to reduce the period of constructing the monolithic structures. Reduction in the consumption of cement will in turn lead to a decrease in the deformativeness and cost of these concretes.

However, given that a change in the strength of fine-grained concretes over time already has been to a certain extent studied, the change in deformation properties of the given concretes over time has not been actually addressed. However, the deformation properties of concretes are employed in the calculation of ferroconcrete structures and, without determining their magnitude, the application of fine-grained concretes to fabricate the ferroconcrete structures is impossible. This is particularly so for the monolithic constructions. Examining a change in the deformation properties of fine-grained concretes nano-modified by the micellar catalysis will make it possible to determine the time when it is possible to load the monolithic structures with operating loads. This indicates the determination of the period when a building is fully constructed, which is a relevant task in the monolithic construction.

2. Literature review and problem statement

The theoretical prerequisites of the synthesis of strength and durability of high-quality construction composites is the more complete utilization of energy of portland cement or other hydraulic binding by:

– using the nanocatalysis in order to create optimum microstructure of concrete stone of both the dense [9] and the porous concretes [10];

– applying a directed complex of effective chemical modifiers [11];

– decreasing the macroporosity and improving the crack-resistance [12];

– using the highly dispersed silicate materials with anomalous hydraulic activity both for the concretes on portland cement [13] and for the concretes on alkaline binder [14];

– strengthening the contact zones between a concrete stone and a filler 15;

– applying the super-plasticizers [16].

Article [9] shows the possibility to increase the rate of strength formation of dense reaction powder concrete, paper [10] – of porous reaction powder concrete. The given studies prove that the introduction into the composition of fine-grained concretes of the colloidal surface-active substances, capable of forming micelles, leads to a sharp increase in the rate of strength formation of these concretes at compression and in its magnitude. These phenomena are explained from the point of view of the theory of micellar catalysis. According to this theory, colloidal surface-active substances are capable of forming the micelles, which exert catalytic effect on the reaction of cement hydration.

However, in the given articles, similar to many others [11–16], the subject of research is the strength of the obtained material rather that its deformation.

An insignificant number of papers are devoted to the problem of control over the deformation properties of fine-grained concretes [17]. The main direction of studies, given in the work indicated, is the application of the micro-reinforcement of concrete using the fibers. This method of control over the properties of fine-grained concretes is effective enough; however, it has limitations in application because of the complexity of technology for introducing the fibers into a concrete mixture.

The use of surface-active substances, which form micelles (MSAS), due to the emergence of the effect of micellar catalysis, makes it possible to avoid the specified complexity in the technology of preparing the concrete [18]. However, up to now, we have not found the answer in the scientific literature to a question about the rate of the formation of deformation properties of the given concretes and its comparison to the rate of strength formation. This predetermined the need to address the problem in present work.

3. The aim and tasks of research

The aim of present study is to determine the influence of the micelle forming surface-active substances (MSAS) on the rate of formation of the deformation properties of fine-grained concretes and to compare it to the speed of strength formation.

To accomplish the set aim, the following tasks were to be solved:

– to establish experimentally a dependence of the rate of formation of the deformation properties of fine-grained concretes on the content of micellar-type catalysts;

– to establish an interrelation between the rates of formation of the deformation properties and strength at compression of the specified concretes.

4. Materials and methods of research

4. 1. Materials used in the research

In order to prepare the samples we used the standard portland cement PC II/B-Sh-400 produced by PAO “Heidelberg cement” (Krivoy Rog, Ukraine). The waste of the enrichment of iron ores and the finely dispersed part of these wastes was used as the mineral powder. As a micelle forming surface-active substance, we employed sodium oleate, whose content in the concrete made up from 0 to 0.00030 %.

4. 2. Methods of research

In order to determine the magnitude of strength of concrete at compression, we fabricated cube samples the size of the sides of 150×150×150 mm. The preparation of the concrete mixture was conducted by mixing its preliminary-measured components in a laboratory concrete mixer. Upon preparation of the concrete mixture, we put it into metal molds of the cube samples and compacted by vibration on a laboratory vibrating table. Upon the fabrication, the molds of the cube samples, filled with the compacted concrete mixture, were stored in a climate-controlled chamber at temperature 293 K and relative humidity 60 % prior to testing at the age of 7 and 28 days. The strength test of the samples was carried out by applying an external load from the universal testing machine UMM-100.

The samples of concrete for determining its deformativeness were prepared analogously. However, in this case, we fabricated prism samples the size of sides of 100×100×400 mm.

The deformations of concrete under the load, created by the universal testing machine UMM-100 (Russian Federation), were registered by dial indicators with the scale value of 0.01 mm. When determining the deformations of concrete, we applied load to the samples by steps holding at each step of the loading for 3 minutes. In the analysis of results of the research, we used relative magnitude of the deformations of concrete, defined as a quotient of dividing the absolute deformations of concrete by the magnitude of measurement base of the deformations (distance between the supports of a dial indicator). The strength of concretes at compression was regulated by changing the water-cement ratio and the consumption of cement.

5. Results of examining a change in the strength at compression and the deformativeness of fine-grained concrete

In the process of research we established a change in the strength of the examined concrete over time both when testing the cube samples (Fig. 1) and while testing the prism samples (Fig. 2, 3) depending on the content in the concrete of the surface-active substance, which forms micelles in the aqueous solution.

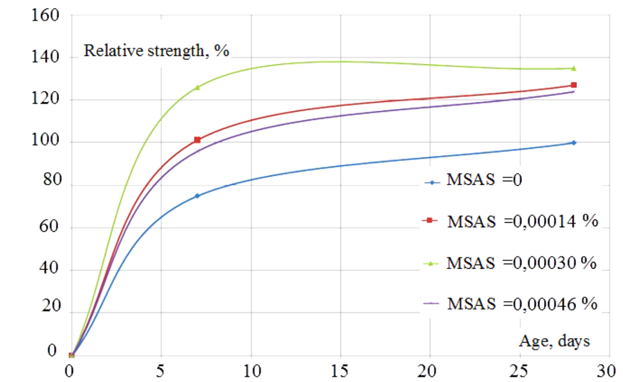

Fig. 1. Change in strength at compression of reaction-powder concrete over time (obtained when testing the cube samples)

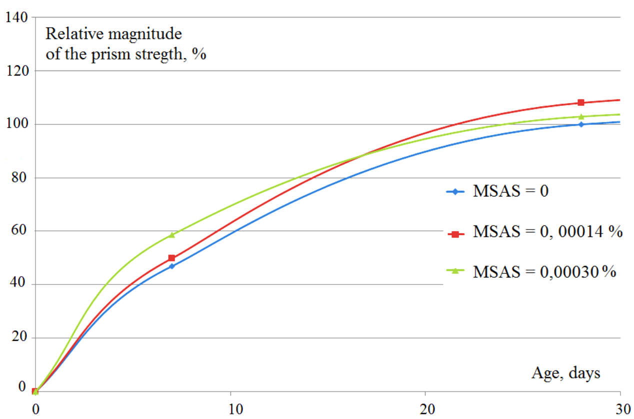

Fig. 2. Change in strength at compression of reaction-powder concrete over time (obtained when testing the prism samples)

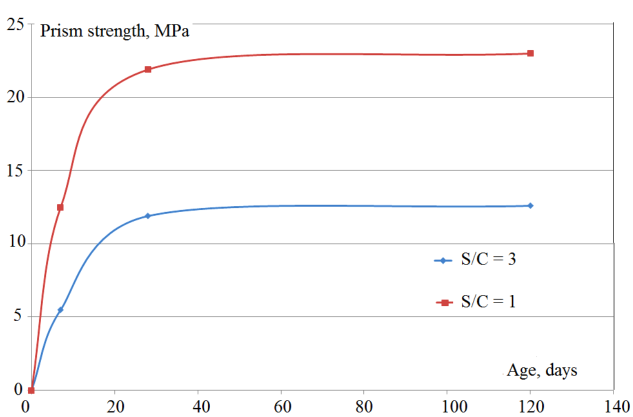

Fig. 3. Change in strength at compression of reaction-powder concrete over time depending on the ratio between the cement and the filler at the content of MSAS in the concrete in the amount of 0.0003 % by weight of the cement (obtained when testing the prism samples)

In addition to the strength properties, we studied the deformation properties of the examined concretes. In the course of experiments, we obtained the dependences "stress – deformation" at different age (7 and 28 days) of concrete (Fig. 4, 5). In addition, we studied influence of the content of MSAS in concrete on its strength at compression and deformation under a load.

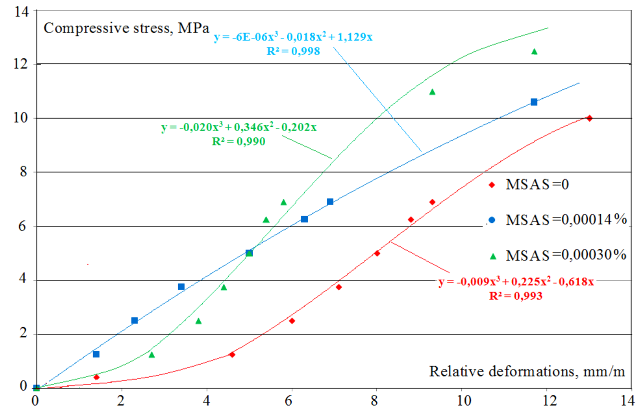

Fig. 4. Interrelation "stress – deformation" in concrete at the age of 7 days

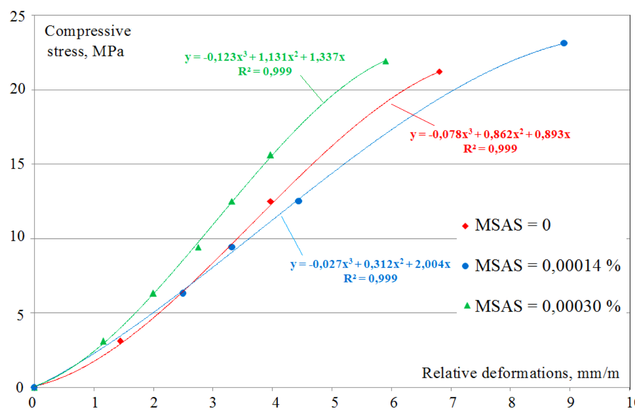

Fig. 5. Interrelation "stress – deformation" in concrete at the age of 28 days

Furthermore, we carried out studies into the influence of ratio between a filler and cement in concrete on its prism strength (Fig. 3).

6. Discussion of results of examining a change in the strength at compression and the deformativeness of fine-grained concrete over time

Results of experiments revealed that the introduction into the composition of reaction-powder concretes of the surface-active substances, which form micelles (MSAS), due to the emergence of effect of the micellar catalysis when forming the properties of concrete stone, leads to an increase in the strength of the given concretes at compression. This phenomenon is observed both when testing the cube samples (Fig. 1) and the prism samples (Fig. 2, 3).

When studying the influence of the micelle-forming surface-active substances (MSAS) on the properties of reaction powder concretes, we should note an ambiguous influence of MSAS on the properties of these concretes.

Thus, the introduction of MSAS to concrete leads to a sharp increase in the strength of concrete, which was determined by testing the cube samples (Fig. 1). At the same time, the strength of the given concrete, established by testing the prism samples, depends considerably less on the content of MSAS in concrete (Fig. 2).

Results of determining the strength at compression of the examined concrete demonstrate that an increase in the content of MSAS in concrete to a certain limit leads to an increase in the strength at compression. When MSAS reach a specific concentration, the system displays maximum strength, which, depending on the composition of concrete, makes up 120–250 % of the strength of concrete without additives.

It should be noted that the strength of concrete at compression when testing the cube samples has a tendency toward the stabilization over time up to 28 days (Fig. 1). This effect does not depend on the ratio between the filler and the cement (Fig. 3). However, the strength of concrete at compression, obtained as a result of testing the prism samples, demonstrates stabilization of the magnitude only in 28 days (Fig. 6).

At the same time, the character of change in the deformation properties of the examined concretes over time is considerably different from the character of a strength change at compression.

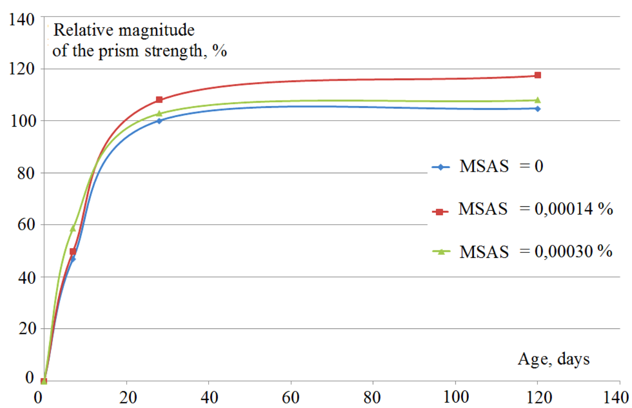

Fig. 6. Change in the prism strength of concrete over time

As the strength at compression, the deformation properties of reaction-powder concretes (initial modulus of elasticity and maximum compressive strains) depend on the presence and the amount of MSAS in concrete.

Results of experiments (Fig. 4, 5, 7) reveal that an increase in the content of MSAS in the examined concrete leads to a decrease in its deformativeness (an increase in the initial modulus of elasticity and a decrease in the maximum compressive strains). These phenomena are observed both at the early age (7 days) and at the later age (28 days).

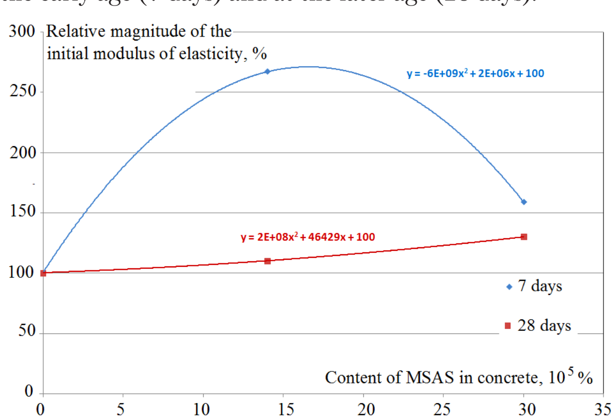

Fig. 7. Influence of MSAS on the magnitude of the initial modulus of elasticity in concrete

In the course of time, a character of the interrelation "stress – deformation" of the examined concretes changes, passing from the curvilinear to the linear dependence (Fig. 8). The angle of slope of this dependence increases (a magnitude of the initial modulus of elasticity), as well as the magnitude of stresses that destroy concrete and its maximum compressive strains.

In addition, during the controlled period (up to 28 days) of changing the deformation properties of reaction-powder concretes, we could not establish the stabilization period of the indicated properties (Fig. 9). The same relates also to the prismatic strength of concrete. Consequently, the stabilization of deformation properties of powder-reaction concretes takes place after 28 days of its hardening.

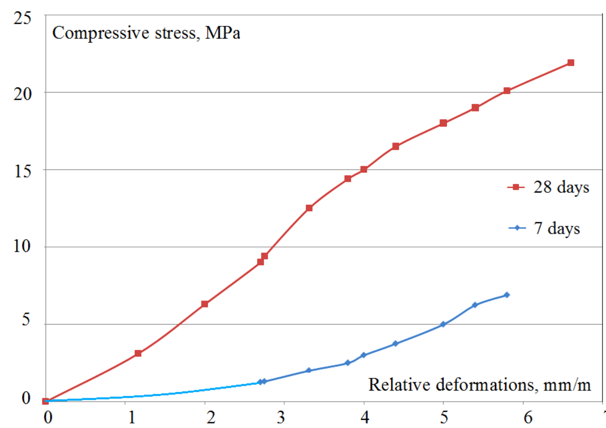

Fig. 8. Change in the diagram "stress – deformation" of concrete over time

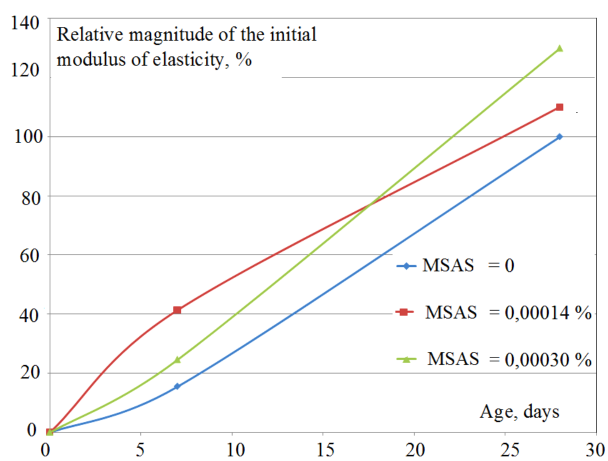

Fig. 9. Change in the magnitude of the initial modulus of elasticity in concrete over time

The conducted research allows us to regulate the rate of formation of both the strength and the deformation of reaction-powder concretes. This is possible due to the application of surface-active substances that form micelles, which are the nanocatalyst of the processes of cement hydration. The application of the micellar catalysis (nanocatalysis), when compared to other methods of improving the strength of fine-grained concretes, is characterized by the simplicity of application and the insignificant quantity of nano-material. At the same time, still remain unexplored is the influence of water-cement ratio and the kind of cement on the deformation properties of fine-grained concretes, activated by the surface-active substances that form micelles. This would help extend the scope of application of such concretes in the production of ferroconcrete structures.

Based on the results of conducted research, it is possible to regulate the rate of formation of both the strength and the deformativeness of reaction-powder concretes. This contributes to shortening the time for manufacturing the ferroconcrete structures, both prefabricated and monolithic.

The studies that we carried out and results of which are given in the present work are a part of the large-scale research into the influence of the micellar catalysis on the properties of fine-grained concretes.

7. Conclusions

1. We experimentally established a dependence of the rate of formation of the deformation properties of fine-grained concretes on the content of micellar-type catalysts. It is proven that the presence in fine-grained concrete of the surface-active substances that form micelles leads to the acceleration of formation of both the strength and the deformation properties of reaction-powder concretes. It is shown that an increase in the content of the given surface-active substances to a certain magnitude, which depends on the kind of the used cement and the composition of concrete, leads to an increase in the strength of concretes and the rate of its formation. The magnitudes of strength of the obtained concrete and the rate of its formation also depend on the type of the used cement and the composition of concrete. At the same time, the optimum content of the indicated surface-active substances, which ensures maximum magnitude of the initial modulus of elasticity of concrete prior to the age of concrete of 28 days, has not been established. The magnitude of initial modulus of elasticity of concrete at this age is proportional to its content of the micelle-forming surface-active substances.

2. The interrelation between the rates of formation of the deformation properties and the strength of fine-grained concretes is established. The strength and deformation properties of reaction-powder concretes change over time. These changes are particularly important at the early age of concrete (up to 7 days). In 28 days, the stabilization is observed, both of the strength and deformation properties of the examined concretes.

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