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ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ И ПОТЕНЦИАЛЬНЫХ ВОЗМОЖНОСТЕЙ ЗАЩИТЫ БУМАГИ СИЛОКСАНАМИ ВО ВЛАЖНОЙ СРЕДЕ

Дана оценка эффективности применения кремнийорганических покрытий различного состава для защиты бумаги на основе небеленой целлюлозы во влажных средах различной степени агрессивности. Определены потенциальные возможности их применения. Достоверность полученных данных подтверждена результатами испытаний покрытий на основе метилсиликоната калия и полиэтилгидридсилоксанами на поверхности алюмосиликатного стекла в гидротермальных условиях и установлены границы их эффективного применения.

Ключевые слова: укрепление бумаги, метилсиликонат калия, степень экранирования, краевой угол смачивания, коэффициент эффективности защитного действия.

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USE OF HIGH-PERFORMANCE PLASTICIZERS TO PROVIDE DESIGN AND OPERATIONAL REQUIREMENTS FOR THE CONCRETE COMPOSITION FOR THE CONSTRUCTION OF FLOATING COMPOSITE DOCKS

Розглянуті особливі вимоги, які пред'являються до суднобудівного бетону і бетонної суміші у зв'язку із екстремальними умовами роботи морських залізобетонних споруд. Наведена класифікація пластифікуючих добавок за ефективністю пластифікуючої дії. Розглянуто допустимий вміст шкідливих домішок у заповнювачах для важких бетонів. Наведені умови забезпечення тріщиностійкості бетону. Проведені дослідження дозволяють визначити рекомендований гранулометричний склад піску і щебеню, які використовуються для суднобудівного бетону.

Ключові слова: *плавучий композитний док, суднобудівний бетон, пластифікуючі добавки, суперпластифікатори, міцність бетону.*

1. Introduction

The working conditions of marine reinforced concrete structures (especially floating docks) are largely extreme. Reinforced concrete structures of floating docks are exposed to all known environmental influences due to the fact that they are operated in all climatic zones of the globe. At the same time, the structures of the floating dock experience the following loads:

– permanent (cargo on the deck, water pressure, etc.);
– static variables (forces of water ejection during deflection and bending of the shell);
– dynamic variables (impacts, invasions), as a result of which stresses of different magnitude and variable direction arise in the concrete.

The advantage of reinforced concrete is that concrete itself works well for compression, and tensile work is provided by reinforcing steel, which is protected from aggressive seawater by concrete. In this case, much less steel is consumed than the steel hull, as the thickness of the structures is ruled out for corrosion. Rebar is cheaper than profile and sheet. Since reinforced concrete does not corrode in water, the pontoon body does not require painting and docking. Metal towers can be painted and repaired without docking and the conclusion of the operation dock, in parallel with the repair of the ship in it [1].

Concrete blocks of ferroconcrete floating docks in all climatic zones alternately moisturized and dried, exposed to salts of sea water – chemical corrosion as a result of the reaction between cement stone and salts dissolved in sea water. In addition, in the southern, subtropical and tropical seas, the effect of chemical corrosion is enhanced by high temperature, humidity with repeated and alternating moistening and drying. In the northern and eastern seas, shipbuilding concrete in winter is repeatedly frozen and thawed alternately.

According to climatic conditions and degree of aggressiveness of the sea water, where floating docks are operated, can be divided into seas:

- with particularly strict (the Barents Sea, the White Sea, the seas of the Pacific basin);
- with severe (the Black Sea, the Caspian Sea);
- with moderate climatic conditions (the Baltic Sea).

In connection with such multifactor operating conditions of reinforced concrete vessels, as well as the development of directions for the use of reinforced concrete floating facilities, development of new types of plasticizers in order to improve the quality properties of concrete is relevant.

2. The object of research and its technological audit

The object of this research is plasticizers, which are the most popular additives to improve the quality properties of concrete, is used to build high-strength reinforced concrete products for hydraulic engineering purposes.

The production of high-strength reinforced concrete products of hydraulic engineering purpose is connected, first of all, with the maximum use of cement binding capacity, which determines the modification degree of the cement system, which provides for the absence of excess mixing water, as well as for the entrained air [2].

The thickness of the hull of the reinforced concrete vessel is sufficiently small (in places up to 4...8 cm). In order to ensure the overall and local strength of the hull, the percentage of saturation with steel reinforcement is quite large (250...600 kg/m^3). Fat compounds of concrete are used (cement consumption of 450...800 kg/m^3), mobility of 2...18 cm with a small filler and small values of water-cement ratio of 0.32...0.45. Taking into account the above data, it can be concluded that shipbuilding concretes differ from concretes used in other industries and have their own specific features.

Shipbuilding concrete should also have sufficient corrosion resistance and density. It must reliably protect the reinforcement from corrosion with a protective layer thickness of 0.5 cm for internal dry and surfaces, periodically moisturized, and 1.0...1.15 cm for the outer surfaces of the reinforced concrete vessels.

One of the most problematic places is the strength of concrete. This is due to extreme operating conditions and loads that survive the construction of the floating dock.

3. The aim and objectives of research

The aim of research is the selection of highly effective plasticizers in order to provide design and operational requirements for the concrete composition for the construction of floating composite docks. This will increase the strength of pontoons of floating composite docks.

To achieve this aim it is necessary to:

1. Consider the special requirements for shipbuilding concrete and concrete mix in connection with the extreme working conditions of marine reinforced concrete structures.
2. Classify plasticizing additives on the effectiveness of plasticizing action.
3. Consider the permissible content of harmful impurities in aggregates for heavy concrete.

4. Research of existing solutions of the problem

The complex of design requirements for hydraulic concrete is provided by the choice of source materials and additives, the design of warehouses of concrete mixtures in accordance with the operating conditions, taking into account the recommended restrictions (Table 1). The experience of the construction of hydrotechnical structures and the research of scientists [4, 5] indicate that in dense concrete, the permeability of concrete is determined, mainly, by water-cement ratio (W/C). At high W/C values the structure of concrete is characterized by large capillary pores and sedimentation voids below the surface of a massive filler, which is the reason for the high permeability of such concrete. Modified concrete of semi-dry formation is characterized by low W/C values, lack of large capillaries and sedimentation voids, which ensures their high impenetrability.

Table 1

Recommended maximum permissible values of water-cement ratio for hydraulic concrete*

Zone and operating conditions	Non-massive reinforced concrete structures in water		The outer zone of structures of massive structures in the water	
	marine	fresh	marine	fresh
Zone of variable level in climatic conditions: particularly severe severe moderate	 0.42 0.45 0.50	 0.47 0.50 0.55	 0.45 0.47 0.55	 0.48 0.52 0.58
Underwater area: pressure non-pressure	 0.55 0.60	 0.58 0.62	 0.56 0.62	 0.58 0.62
The above-water zone, in part water-washed	0.55	0.60	0.65	0.65

Note: * is built on the basis of data [3].

As for other types of heavy concrete for hydraulic concrete, the strength at the design age is normalized in accordance with GOST BV.2.7-43-96 for classes of compressive strength, axial tension and bending tensile.

For the concrete of structures subjected to alternating freezing and thawing during operation, the following frost resistance grades (*F*) are assigned: 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, 1000 With permeability restriction, increased density and corrosion resistance designate brands for water tightness (*W*): 2; 4, 6; 8; 10, 12; 14; 16; 18; 20.

In the freshly prepared concrete mixture, chemical and physical processes occur simultaneously, related to the hydration of cement grains, water separation, compaction and delamination of the mixture [6]. The increase in the strength of concrete with the additive as a whole is decreased with the increase in the duration of heat treatment, especially the isothermal warm-up stage. However, based on the increase in strength of concrete with additive, it seems possible to reduce the time of heat treatment of concrete consumption of cement [7]. The consistency of the concrete mix must ensure the reliability of transportation and the possibility of its enclosure in the formwork of the underwater structure. Therefore, the consistency should be assigned taking into account the conditions of concreting and the shape of the construction [8–12]. To solve the problem of increasing the operational characteristics of efficient hydraulic fine-grained concrete, it is necessary to optimize the compositions of such concretes and the technologies for their preparation, as well as the use of various organic and mineral modifying additives.

One of the main types that reduce the strength of concrete defects is increased porosity. The porosity arises from the concrete destruction during operation and is expressed in the loosening of its structure, weakening the bond between the crystalline new formations in the cement stone, as well as the cement stone and the aggregate particles. This leads to a decrease in the strength of concrete, and also facilitates the filtration of water and aggressive liquids into the volume of concrete, frost and abrasive destruction [13]. The solution to this problem can be a significant compaction of the concrete structure. According to the research results in the scientific and technical literature [14–19], it is known that metakaolin is introduced as a fine mineral admixture into a concrete mixture in order to reduce cement consumption and also compact the structure of concrete. Moreover, its quantity should not exceed 15 % of the mass of cement, since it contains active silica and alumina in approximately equal proportions. And for this reason, stronger than microsilica, binds free calcium hydroxide, which leads to a decrease in the alkalinity of the medium in concrete and can cause corrosion of steel reinforcement. In connection with the need to ensure the strength of concrete is a promising improvement in the composition of concretes [20–25].

Plasticizers are the most popular additives to improve the quality properties of concrete [26]. At present, plasticizer is an indispensable element of any concrete solution in construction, which is explained by a number of advantages: increasing the plasticity of the finished solution, saving the cost of cement mortar, improving the crack resistance of concrete [27]. Plasticizers are divided into 4 classifications: strong, weak, medium and superplasticizers [28]. Plasticizers began to be used in the 1940s, and due to the rapid pace of development of construction technologies they reached a qualitatively high level and are able to increase the composition of the concrete mixture [29]. According to the principle of action, plasticizers are divided into 2 types: hydrophilic and hydrophobic [30]. The main function of additives of the first kind is increasing the plastic and flowing properties of concrete [31]. Plasticizers of the second kind saturate the concrete mixture with oxygen, which in turn reduces the tension of water in the solution [32]. The hydrophobic solution is applied to the surface of the building structure. The depth of penetration is greater, the lower its surface tension and viscosity and the higher the porosity of the building material. The walls of the pores and all the particles of the material that come in contact with the solution are covered with a water repellent film of the hydrophobic agent. In this case, neither the pore size nor the texture of the solid surface changes. When hydrophobizing the solution, all times are kept open, the ability to wet with water loses their walls, while the material loses the ability to capillary absorb water [33–37]. The paper [38] also deals with the use of various activated and plasticizing additives in a concrete mix. The main drawback of plasticizers is the increa se in the time of hardening of the concrete mixture [39], which affects the timing, and later the cost of construction. In modern construction, the implementation of complex projects requires the development of efficient and high-quality concretes that can't be solved without the use of plasticizing additives in concrete technology [40].

Plasticizing additives are characterized by high efficiency and no negative impact on concrete and reinforcement. Of greatest interest are plasticizing additives from the family of super- and hyperplasticizers [41]. It is known [42, 43] that plasticizer additives, which allow to reduce the water requirement of the concrete mixture at the working concentrations corresponding to the maximum functional action (plasticization and water reduction). Additives-plasticizers give a sufficiently long blocking effect on the kinetics of hardening of most cements and the strength of concrete.

5. Methods of research

Methods of analysis and generalization of scientific literature on design and operational requirements for concrete of hydraulic structures were used during the research.

The choice of the type and brand (or class) of cement, its mineralogical and material composition is due to the necessary strength properties of concrete and the kinetics of the increase in strength in time. For hydrotechnical concrete of massive structures, the use of moderately and low-thermal cements with normalized chemical-mineralogical composition and an increased content of active mineral additives is common. For concrete, which operates under conditions of alternating freezing and thawing under the action of a mineralized aqueous medium, sulfate-resistant low-aluminate cements are used.

In addition to the design requirements for strength, frost resistance and waterproofness for hydraulic concrete in accordance with working conditions and design standards, a number of additional requirements may be presented. The design age in which technical requirements are to be provided is indicated in the design documentation. It is assigned in accordance with the design standards, depending on the conditions, requirements for concrete, methods of erection and the timing of the actual loading of structures. If the project age is not specified, the technical requirements for concrete should be provided in 28 days.

If fast reinforcement of sufficient strength of concrete is required, especially in the manufacture of prefabricated reinforced concrete elements, quick-setting cements are also used. To the fillers for hydraulic concrete as well as for cements, the requirements are determined differentially, depending on the operating conditions of structures. The most stringent requirements are imposed on concrete, working under conditions of variable water level.

6. Research results

General requirements for fillers for hydraulic concrete are similar to the requirements for fillers for other types of heavy concrete (DSTU B V.2.7-43-96). Large aggregate – crushed stone or gravel is chosen, taking into account its grain composition, the largest size, the content of clay and dust particles, other harmful impurities, grain size, strength and content of grains of weak rocks, petrographic composition and radiation-hygienic characteristics. When selecting the composition of concrete, also take into account the density, porosity, water absorption and emptiness of the aggregate grains.

For concrete in the zone of variable water level, rubble or gravel with an average grain density of at least 2.5 g/cm^3 and water absorption of no more than 0.5 % for aggregates of igneous and metamorphic rocks and 1 % for sedimentary rocks are used. For concrete inside, underwater and above-water zones, the density of grains of coarse aggregate should not be lower than 2.3 g/cm^3, and water absorption is not more than 0.8 % for aggregate from igneous and metamorphic rocks, and 2 % for sedimentary rocks.

The quality of aggregates is significantly affected by the content of pulverized, clayey and silty impurities, which is usually determined by the soaking method. Dust particles include particles ranging in size from 0.005 to 0.05 mm, in clay and silty up to 0.005 mm. Restriction of the content of silty admixtures in the aggregates is caused by the negative influence of the films formed by them on the bonding of cement stone with aggregate, and as a result, on strength, frost resistance and other properties of concrete, water demand of concrete mixes. For concrete of hydraulic structures, the content of clay and dust particles in a large aggregate (regardless of the type of rock) should not exceed 1 % for concrete of the zone of variable water level and 2 % for the underwater and inner zones. In this case, the presence of clay in the form of individual lumps is not allowed for concrete used in a variable-level zone.

Frost resistance of large aggregates for all types of heavy concrete can't be lower than the normalized concrete grade for frost resistance. For hydraulic concrete, which is demanded for frost resistance and cavitation resistance, crushed stone is used from igneous rocks of the brand for strength not lowers than 1000. The frost resistance of crushed stone and gravel is normalized taking into account the average monthly temperature of the coldest month of the year. If the latter ranges from 0 to minus 10 °C, the mark for frost resistance of crushed stone and gravel should not be lower than F100, below minus 10 °C – F200.

In the manufacture of wear-resistant hydrotechnical concrete for crushed stone and gravel, a mark on wear in the shelf drum is defined, which should be not lower than Ст-I for aggregates from igneous and metamorphic rocks and Ст-II – sedimentary rocks.

For hydrotechnical concrete, rubble of natural stone with a grade of not less than 600 is used for classes of strength to C15 inclusive, not lower than 800 for classes from C20 to C30 and 1200 for classes above C30. In crushed stone and gravel for concrete in the zone of variable level, the content of grains of weak rocks is not allowed more than 5 %.

For concrete hydraulic structures it is allowed to use sand with a size modulus from 1.5 to 3.5. The total residue on the sieve with the hole size:

– 2.5 mm from 0 to 30 %;
– 1.25 mm – from 0 to 55 %;
– 0.63 mm – from 20 to 75 %;
– 0.315 mm – from 40 to 90 %;
– 0.16 mm – from 85 to 100 %.

In this case, fine sand with a size module equal to or smaller than 2.0 is used with the obligatory application of plasticizing surface-active additives.

The content of clay and dust particles, as well as mica particles, which are often encountered when sand is used for concrete of hydraulic structures, is established taking into account its location with respect to water. For the concrete of the zone of variable water level, the content of clay and dust particles in the sand, as well as mica, must be respectively not more than 2 and 1 %, the surface zone – 3 and 2 %, the submarine and internal – 5 and 3 %. The admissible content of harmful impurities in aggregates is given in Table 2 [3].

Table 2

Admissible content of harmful impurities in aggregates for heavy concretes

Type of impurities	Limit
Amorphous varieties of silicon dioxide soluble in meadows, sulfur, sulphides (except pyrite) in terms of SO_3 for coarse aggregate for fine aggregate	not more than 50 mol/l not more than 1.5 % by weight not more than 1.0 % by weight
Layered silicates (micas, hydromica, chlorites, etc.) for coarse aggregate for fine aggregate	not more than 15 % by volume not more than 2 % by weight
Magnetite, hydromicas of iron, apatite, nepheline, phosphorites	not more than 15 % by volume (each not more than 10 %)
Halides in terms of chloride ion for coarse aggregate for fine aggregate	not more than 0.1 % by weight not more than 0.15 % by weight
Free asbestos fiber	not more than 0.25 % by weight
Coal	not more than 1 % by weight

With additives regulating the properties of concrete mixtures, plasticizing additives have been used most in the technology of hydraulic concrete.

In accordance with the effective plasticizing effect, that is, an increase in the mobility of the concrete mixture without reducing the strength of concrete, the plasticizers are divided into 4 categories (Table 3) [3].

Table 3

Classification of plasticizers of concrete mixes

Category	Name	Effective plasticizing effect (increase of cone draft with 2...4 cm), cm	Reducing the amount of water, %
I	superplasticizers	up to 20 or more	not less than 20
II	plasticizers	14...19	not less than 10
III	plasticizers	9...13	not less than 5
IV	plasticizers	8 and less	less than 5

Air-entraining additives, depending on the chemical nature, are divided into six groups:

1) salts derived from wood tar;
2) synthetic detergents;
3) salts of lignosulfonic acids;
4) salts of petroleum acids;
5) salts derived from proteins;
6) salts of organic sulfonic acids.

The considerable experience of application in the hydraulic technical concrete of the additives of the first group, obtained during neutralization by caustic soda of wood tar after extraction of turpentine from it, is accumulated. This additive, which is predominantly sodium acetate, known as neutralized vinsol or neutralized air-entraining resin.

The main purpose of air-entraining additives is a radical increase in frost resistance of concrete as a result of the creation of a rational system of air bubbles to squeeze out part of the water during freezing.

Along with plasticizing and air-entraining or gas-releasing additives in modern technology of hydraulic concrete, other additives-modifiers are increasingly being used. The desire to universalize the effect of additives and enhance their technical effect is due to the use of complex (composite) additives-modifiers.

To ensure the fracture toughness of concrete, it is necessary to fulfill the condition [3]:

$$\sigma_t = \frac{\varepsilon_u E_e}{K_s},$$

where σ_t – the tensile stress; E_e – modulus of concrete elasticity; K_s – safety factor ($K_s \approx 1{,}2...2$); ε_u – the ultimate extensibility of concrete.

The ultimate extensibility of concrete improves with increasing strength of concrete when using cement without mineral additives, introducing surfactants and polymer additives into the concrete mixture.

To ensure the necessary crack resistance of massive concrete, its shrinkage deformations are also limited. For hydraulic concrete with a relative humidity of 60 % and a temperature of 18 °C at the age of 28 days, linear shrinkage is usually not more than 0.3 mm/m ($0.3 \cdot 10^{-3}$), and at 180 days – 0.7 mm/m ($0.7 \cdot 10^{-3}$).

Depending on the operating conditions for concrete, hydraulic structures are assigned appropriate brands for frost resistance and water tightness. According to DSTU BV.2.7-43-96, the volume of entrained air in the case of frost resistance of concrete F 200 and above must meet the requirements given in Table 4 [3].

The waterproof concrete grade is assigned depending on the magnitude of the pressure gradient, that is, the ratio of the maximum head of water to the thickness of the corresponding zone of the structure. With a pressure gradient of up to 5 and the temperature of the water in contact with the construction of up to 10 °C, a concrete grade of water resistance W2 is assigned; 5...10 °C – W4; 10...15 °C – W<6; 15...20 °C – W8 and 20...30 °C – W10. At a water temperature of more than 10 to 30 °C, concrete grades for water tightness are intended to be increased by one step with corresponding values of pressure gradients. One more step (from W6 to W12) marks concrete waterproofness at a water temperature above 3 °C. In non-pressure structures of marine structures, the design brand of waterproof concrete must be at least W4. For designs with a pressure gradient of more than 30, concrete grades are assigned for water resistance W16 and above.

Table 4

The volume of entrained air is recommended for hydraulic concrete with increased frost resistance ($F > 200$)*

Maximum size of filler, mm	The volume of entrained air in the concrete mix, % at W/C		
	< 0.41	0.41…0.50	> 0.50
10	2...4	3...5	5...7
20	1...3	2...4	4...6
40	1...3	1...3	3...5
60	1...3	1...3	2...4

Note: * is built on the basis of data [3].

The composition is determined by sifting samples of sand and crushed stone through a standard set of sieves. As a result, the limiting curves of the granulometric composition [44] are determined, which are enclosed in the shaded area: for sand – Fig. 1, for crushed stone – Fig. 2.

For parts and elements of the dam, which are periodically washed by water, the concrete grade for water tightness is adopted not less than W4. When exposed to concrete flow of water with mobile sediments, as well as in the case of cavitation action of water, the concrete grade for water tightness should not be lower than W8.

Additives improve the quality of concrete and add to it special properties, which allows to accelerate the pace of production, as well as significantly cheaper it. Special properties of concrete are necessary both for the construction of pontoons, piers, basins and special structures, and for monolithic industrial construction.

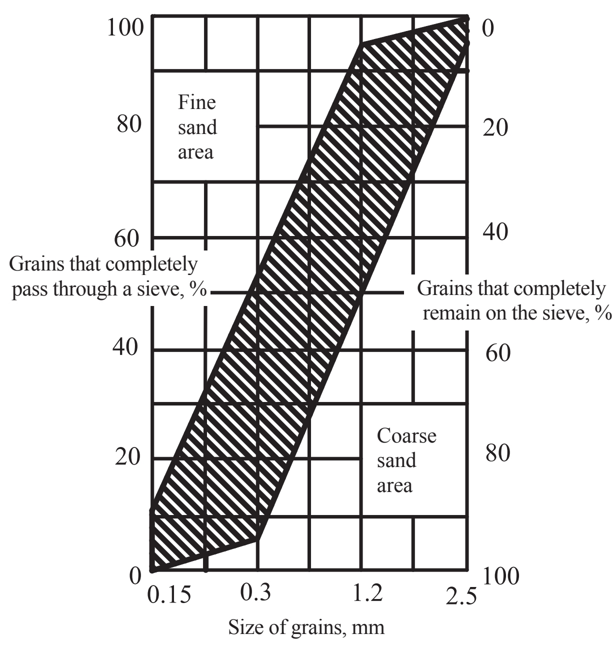

Fig. 1. Recommended granulometric composition of fine filler – sand (shaded area)

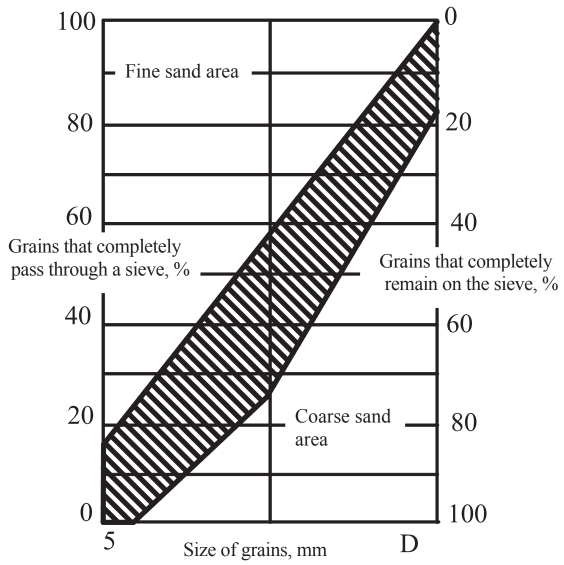

Fig. 2. Recommended granulometric composition of a coarse filler – crushed stone (shaded area)

To improve the convenience of laying concrete, plasticizers and superplasticizers are used. For the construction of pools and reservoirs of various kinds, additives are used that increase the water resistance of concrete several times. Superplasticizers in most cases are synthetic polymers: melamine resin or naphthalenesulfonic acid derivatives (C-3), other additives (СПД, ОП-7, etc.) are obtained on the basis of secondary products of chemical synthesis. Superplasticizers, introduced into the concrete mixture in an amount of 0.15...1.2 % of the weight of cement, dilute the concrete mixture to a greater extent than conventional plasticizers. The plasticizing effect persists for 1.0...1.5 hours after the addition, and after 2...3 hours it almost disappears. In an alkaline environment, these additives pass into other substances, are not harmful to concrete and do not reduce its strength.

Superplasticizers allow to use spray method of manufacturing reinforced concrete products and concreting of structures using concrete pumps and pipe transportation of concrete mixture. On the other hand, these additives make it possible to significantly reduce the W/C, while maintaining the mobility of the mixture, and to produce high-strength concretes.

State standards «Additives for concrete. Classification» define the class of additives – plasticizers. In practice this class is divided into four categories. The most significant feature in the distribution of plasticizers into individual categories is the magnitude of the plasticizing effect, that is, the change in the mobility of the concrete mixture when an additive is added to it.

A number of plasticizers significantly increases the mobility of the concrete mix, but slows down at an early age, the increase in strength of concrete causes increased air entrainment. To maintain the strength of concrete of this composition with an additive at a level not lower than the strength of the initial concrete without the additive, it is necessary to reduce the water-cement ratio in the concrete mixture and, therefore, to a certain extent reduce its mobility. The real technical effect of using such additives can be small. To evaluate it, it is proposed to introduce the concept of an effective plasticizing action, which also means the amount of plasticizing effect achieved from the use of the additive without reducing the strength of concrete.

So, for example, to the first category of plasticizers – superplasticizers – it is possible to attribute additives, the use of which in optimal dosages allows one to obtain from highly inactive concrete mixtures with a cone slump of 2...3 cm high-mobility concrete mixes. In these mixtures, the cone sediments are 20 cm or more without reducing the strength of concrete at the age of 28 days of normal hardening compared to the strength of concrete of the same composition, but without additives.

Classification of additives by effective plasticizing effect is given in Table 5 [3].

Table 5

Classification of plasticizing additives

Category	Name	Effective plasticizing effect (increase of cone draft with 2...4 cm), cm	Reducing the amount of water, %
I	superplasticizers	from 2…3 to 20 and more	not less than 20
II	plasticizers	from 2…3 to 14…20	not less than 10
III	plasticizers	from 2…3 to 8…14	not less than 5
IV	plasticizers	from 2…3 to 6…8	not less than 5

It should be borne in mind that for concretes manufactured using a specific technology, including those subjected to thermal treatment processing, the effective plasticizing action of the additive may be slightly different. The choice of plasticizer of a certain category is carried out by calculating the technical and economic efficiency of its application in a specific technological process.

Superplasticizer C-3. Organic synthetic substance based on the condensation product of naphthalenesulfonic acid and formaldehyde with a specific ratio of fractions with different average molecular weight. According to the classification C-3 refers to the plasticizing-water-reducing type – superplasticizers. Superplasticizer C-3 is intended for:

– a sharp increase in the convenience of laying and the formation of concrete mixtures without reducing the strength and of concrete durability indices (with a constant water-cement ratio);
– a significant increase in physical and mechanical properties and construction and technical properties of concrete (with a reduction in water consumption and unchanged ease of installation);
– improvement of the convenience of laying concrete mixes and increase of physical and mechanical properties and construction and technical properties of concretes;
– reduction of the cement consumption without reducing the convenience of laying a concrete mixture, physical and mechanical properties and the construction and technical properties of concrete.

Superplasticizer C-3 is also the basis for the production of complex additives of various types. Superplasticizer C-3 is recommended for use:

– for the production of all types of structures from monolithic heavy concrete classes (by compressive strength) B15 and above;
– in the manufacture of all types of prefabricated reinforced concrete structures and concrete products from heavy concrete classes (by compressive strength) B15 and above;
– for the production of all types of structures from monolithic fine-grained concrete classes (by compressive strength) B10 and higher;
– in the manufacture of all types of prefabricated reinforced concrete structures and concrete products on porous aggregates of classes (by compressive strength) of B7.5 and higher.

Plasticized concrete mixes with high convenience of laying are recommended to be used in thick-reinforced structures, thin-walled structures, complex configuration constructions, etc.

Concrete mixtures with a lower water-cement ratio (water reduction) are recommended for the production of monolithic and prefabricated reinforced concrete structures, to which high demands are placed on strength, waterproofness, frost resistance, corrosion resistance,

Superplasticizer C-3 is produced in the form of a powder (microgranules) or in the form of an aqueous solution.

7. SWOT analysis of research results

Strengths. All superplasticizers significantly increase frost resistance and waterproofness of concrete. In addition to superplasticizers, there are plasticizers of different categories, they do not exclude vibratory compaction of solutions, but allow to some extent to compact the concrete mixture, reduce cement consumption, increase frost resistance and water resistance. They all have one very important feature – they greatly facilitate the mixing of the concrete mix.

Weaknesses. Plasticizers slow down the setting and hardening of the concrete mix.

Opportunities. Use of plasticizers will give the following opportunities:
– plants producing reinforced concrete products benefit from the use of plasticizers by reducing the time of steaming or reducing the temperature in the chambers. There will be a significant saving in energy resources, accelerating the turnover of form equipment and as a consequence – an increase in production volumes;
– for obtaining equal strength concrete with the same mobility using plasticizer C-3 and without it, one cubic meter of concrete mix consumes 15 % less cement. Using this additive can reduce the amount of mixing water;
– mobility of the concrete mix increases without the effect of reducing the strength of reinforced concrete products and structures;
– strength characteristics are increased by up to 25 %;
– preparation of high-density concretes (high impermeability), which positively affects the waterproofness of reinforced concrete products and reinforced concrete structures;
– frost resistance increases to F350, crack resistance also increases;
– production of high-strength reinforced concrete products of high strength (compressive strength over 100 MPa). For example, a concrete sample of brand *m* 350 (B25) at the age of 28 days has a compressive strength of 25 MPa;
– coupling of reinforcement with concrete is increased by 1.5 times.

Threats. When choosing plasticizing additives, it is necessary to pay great attention to the choice of plasticizer manufacturers, since the quality of plasticizers can differ significantly.

When using modifiers, the concrete structure hardens more slowly. In order to compensate for the slowing effect of the use of plasticizers, a hardening accelerator can be introduced into the concrete solution, which compensates for this disadvantage. As a result, the construction hardening schedule will be aligned.

There are other types of additives for concrete and mortars, which include the following.

Hardening accelerators, which are introduced to compensate the action of the plasticizer, inhibiting the hardening process. Also, accelerators are used for concreting in cold weather. Since, the lower the ambient temperature, the slower the process of hydration of cement, the strength set occurs at a slowed pace.

Hardening retardants, which are used to increase the lifetime of the concrete mixture. In the group of retarders can be attributed douche, which also provide a slowing effect.

Air-entraining additives are used mainly to increase the frost resistance of concretes and solutions. These additives reduce the strength of concrete (1 % of the entrained air reduces the compressive strength of concrete by 3 %), therefore, it is not necessary to introduce a large amount of air-entraining additive into the concrete mix for its plasticization. The content of the entrained air is 4...5 %. In this case, the strength of the concrete is practically not reduced, since the negative influence of the entrained air is neutralized by an increase in the strength of the cement stone due to a reduction in the water-cement ratio due to the plasticizing effect of the additive. The air-entraining additive hydrophobizes the pores and capillaries of concrete, and air bubbles serve as a reserve volume for freezing water without the occurrence of large internal stresses. As a result, water resistance and frost resistance of concrete significantly increase.

Antifreeze additives for concrete provide the possibility of winter concreting at negative temperatures and the absence of additional heating of the filled structure. Some types of additives allow concreting at a temperature of –25 °C.

In modern production complex two-component additives are used. For example, the plasticizer C-3 and the hardening accelerator, microsilica, and air-entraining additives are immediately mixed. The use of such additives allows plants to produce mixtures of high strength with unique properties.

8. Conclusions

1. The specific requirements imposed on shipbuilding concrete and concrete mix in connection with the extreme operating conditions of marine reinforced concrete structures. Shipbuilding concrete should have sufficient corrosion resistance and density. It must reliably protect the reinforcement from corrosion with a protective layer

thickness of 0.5 cm for internal dry and surfaces, periodically moisturized, and 1.0...1.15 cm for the outer surfaces of the reinforced concrete vessel. For the concrete of structures subjected to alternating freezing and thawing during operation, the following frost resistance grades (*F*) are assigned: 50, 75, 100, 150, 200, 300, 400, 500, 600, 800, 1000. With permeability restriction, increased density and corrosion resistance designate brands for water tightness (*W*): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20.

2. The resulted classification of plasticizing additives on efficiency of plasticizing action.

Increase in the draft of the cone:

– Superplasticizer of the I category – from 2...3 to 20 cm.
– Plasticizer of the II category – from 2...3 to 14...20 cm.
– Plasticizer of the III category – from 2...3 to 8...14 cm.
– Plasticizer of the IV category – from 2...3 to 6...8 cm.

3. Permissible content of harmful impurities in aggregates for heavy concrete:

– amorphous varieties of silicon dioxide, soluble in meadows, sulfur, sulfides (except pyrite) in terms of SO_3 – not more than 50 mol/l;
– for a coarse aggregate – not more than 1.5 % by weight;
– for a fine aggregate – not more than 1.0 % by weight;
– layered silicates (micas, hydromica, chlorites);
– for a coarse aggregate – not more than 15 % by volume;
– for a fine aggregate – not more than 2 % by weight;
– magnetite, hydromicas of iron, apatite, nepheline, phosphorites – no more than 15 % by volume (each not more than 10 %);
– halides in terms of chlorine ion;
– for a coarse aggregate – not more than 0.1 % by mass;
– for a fine aggregate – not more than 0.15 % by weight;
– free fiber of asbestos – not more than 0,25 % by weight;
– coal – not more than 1 % by weight.

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ИСПОЛЬЗОВАНИЕ ВЫСОКОЭФФЕКТИВНЫХ ПЛАСТИФИКАТОРОВ С ЦЕЛЬЮ ОБЕСПЕЧЕНИЯ ПРОЕКТНЫХ И ЭКСПЛУАТАЦИОННЫХ ТРЕБОВАНИЙ К СОСТАВУ БЕТОНА ДЛЯ ПОСТРОЙКИ ПЛАВУЧИХ КОМПОЗИТНЫХ ДОКОВ

Рассмотрены особые требования, которые предъявляются к судостроительному бетону и бетонной смеси в связи с экстремальными условиями работы морских железобетонных сооружений. Приведена классификация пластифицирующих добавок по эффективности пластифицирующего действия. Рассмотрено допустимое содержание вредных примесей в заполнителях для тяжелых бетонов. Приведены условия обеспечения трещиностойкости бетона. Проведенные исследования позволяют определить рекомендуемый гранулометрический состав песка и щебня, которые используются для судостроительного бетона.

Ключевые слова: плавучий композитный док, судостроительный бетон, пластифицирующие добавки, суперпластификаторы, прочность бетона.

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RESEARCH OF THE PECULIARITIES OF PLASMA-ELECTROLYTIC TREATMENT OF AK12M2MGN PISTON ALLOY WITH FORMATION OF CERAMIC-LIKE COATINGS

Досліджено особливості плазмово-електролітичної обробки (ПЕО) поршневого силуміну АК12М2МгН у лужних електролітах з формуванням допованих манганом та кобальтом керамікоподібних покривів. Показано, що морфологія та склад оксидних покривів залежать від типу використовуваного електроліту. Визначено технологічні параметри ПЕО-обробки поршневого силуміну для формування рівномірних покривів із високим вмістом допантів. Запропоновані системи можуть знайти застосування в технологіях внутрішньоцилiндрового каталізу з метою зниження токсичності газових викидів двигунів та підвищення їх паливної економічності.

Ключові слова: *поршневий сплав АК12М2МгН, плазмово-електролітичне оксидування, поршневий силумін, керамікоподібний покрив.*

1. Introduction

The internal combustion engine (ICE) piston is one of the most important details of a modern car that operates under severe conditions with significant thermal and mechanical loads. Therefore, the following requirements are put forward to piston alloys' properties: lightness, strength, low friction coefficient, high thermal conductivity, wear and corrosion resistance, economic accessibility and simplicity of technological treatment [1].

Alloys of aluminum with silicon (silumines) fully meet these requirements. The high content of silicon gives