IOP Conf. Series: Materials Science and Engineering **262** (2017) 012005 doi:10.1088/1757-899X/262/1/012005

Study of Influence of Composite Materials Components on Properties of Concrete Mixtures and Concrete in Time Dynamics

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Abstract. It is accepted to call concrete a special construction mix which consists of several main components – most often, these are cement, water and various fillers. As a result of grout hardening, the artificial stone, used in many areas where durability, stability and durability are required, is formed. To improve the main characteristics of concrete, various additives are added to the mix. These substances are also capable of accelerating the speed of construction and reducing the funds expenditure. It is especially important to apply additives at the installation of coverings to airfields, at the construction of moorings, roads, at the laying of pools or during other hydraulic engineering constructions, and also at the construction of monolithic industrial facilities and houses. The article deals with the composition and quantity of complex organomineral additives, the duration and conditions for the formation of composites' structure.

1. Introduction

These Modern construction is inconceivable without the "material of the 20th century" - concrete, which firmly holds the place of the main structural material and, despite the appearance of new efficient materials and structures, will retain its leading position for many years to come.

The main prerequisites for the widespread use of concrete in the 21st century are large natural reserves of raw materials, possibility of using waste from various industries, relatively low capital and energy intensity, simplicity of technology, relatively high compressive strength and durability [1].

The main type of the used concretes is on the Portland cement. Among these concretes heavy concretes are of the most common application.

The conditionally heavy concrete can be divided into the factory-produced (in the manufacture of prefabricated elements) and commodity (transported and laid on the construction site) ones.

The annual increase in construction requires constant improvement of technological processes at all stages of producing, transporting, and laying concrete mixtures. These tasks are successfully solved with the help of chemical additives in accordance with GOST 24211. Such additives allow improving the technological, physical-chemical and operational properties of concrete, obtaining structures more durable in exploitation under different conditions [2].

Using additives is the most effective way, which increases the quality of concrete without requiring large capital expenditures. Competent application of target complex additives allows to solve any problems connected with obtaining concrete mixtures and concretes with the given properties. High

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strength, low permeability, increased durability and frost resistance can be achieved even with the use of highly mobile concrete mixtures - self-compacting concrete mixtures containing modern highly effective additive complexes [3].

The purpose of this report is to investigate the influence of components of composite materials on the properties of concrete mixtures and concrete used in the manufacture of prefabricated reinforced concrete structures, mainly housing construction, including the construction of dynamic mathematical models capable of adequately predicting the main technical indicators of quality, in time dynamics.

The objects of the study were concrete mixtures and concretes based on a cement binder.

The methods of influence on objects were composition and quantity of complex organomineral additives, duration and conditions to form the structure of composites.

As a plasticizing component in the complex additive, the chemical additive Glenium ACE 430 was used, which is an aqueous solution of a polycarboxylate ester of a certain composition and molecular configuration. The action of polycarboxylates is based on the mechanism of steric repulsion of side chains of adsorbed macromolecules in the absence of a pronounced influence of the potential on the plasticizing ability [3].

Polycarboxylates provide a very high retention of the concrete mixture, which makes them very attractive for monolithic construction and for long-term transportation of concrete mixtures. At the same time, the absence of a noticeable effect of special types of polycarboxylates on the hardening kinetics in the process of heat and moisture treatment opens up the prospect of their application in the precast concrete industry [4].

Introduction of fine-grained additives into the composition of complex additives can improve the properties of the composite in several directions. They can either improve the granulometric composition of the concrete mixture by replenishing the viscous component to the required amount of very fine particles, or improve the workability of mixtures; to increase the hydraulic properties of the binder used, to promote the production of denser concrete as a result of partial filling of air pores of concrete with additional portions of hydration products of cement clinker minerals [5].

To date, when the price of cement is constantly growing and construction in the country is increasing, saving cement binder again becomes relevant, as before.

One of the most effective materials in terms of saving cement is finely ground blast-furnace granulated slag.

2. Experimental data.

As a binder the work used Portland cement TsEM I 42,5N, corresponding to GOST 31108-2016 "Cements for general construction. Technical conditions" produced by the Novotroitsk Cement Plant [6]. The normal density of cement paste is 27.5%.

As an active mineral additive, the blast-furnace granulated slag was used in accordance with GOST 3476 produced by Mechel OAO, which was supplied in the ground form. The economic efficiency of the use of granulated slag as an active mineral additive in cement is several times higher than as a raw material component. The specific surface area of the powder was in the range 4400-4700 cm2/g. The chemical composition of the slag is given in Table 1. The mineral additive complies with the requirements of the standard [7].

Table 1. Chemical composition of blast-furnace granulated slag

Oxides content in the blast-furnace slag composition,% by weight						
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	$CaO_{св}$
38,6 – 39,1	11,7 – 12,0	2,2 – 2,5	34,7 – 35,0	9,8 - 10,3	0,6 – 0,8	0,1 - 0,3

The chemical additive Glenium Ace 430 is an aqueous solution of polycarboxylate ester. The ACE additive series - Admixture Controlled Energy - is BASF's products, the main purpose of which is to reduce energy costs at the construction industry enterprises. Glenium ACE 430 is advisable to use in

the energy-intensive construction industries that produce reinforced concrete products in order to shorten the duration of heat and moisture treatment [8-15].

The additive was put to the concrete mixture, together with the mixing water (with the last third of water).

The quartz sand of Khleborob Quarry was used as small aggregate in the experiments to determine the physical and mechanical properties of concrete. The sand has the following characteristics:

- content of pulverized, clayey and silty particles – 1,5 %;
- bulk density - 1325 kg/m3,
- voidness of sand – 49,3 %;
- MS = 2,8.

The small filler meets the requirements of GOST 8736-93 [16].

The crushed stone of Kazantsevsky Quarry of the Chelyabinsk region was used as large aggregate. Its characteristics are:

- MS – 20 mm;
- crushability of stone – 11,8 %;
- bulk density – 1370 kg/m3,
- voidness of crushed stone 43,5 %,
- fraction 1200.

The large aggregate meets the requirements of GOST 8267-93 [17].

The work used the mathematical design of the experiment to determine the dependency of the properties of concrete on the modifiers, as well as to obtain mathematical models of the studied processes and their statistical analysis, which makes it possible to obtain regression dependencies in the form of segments of power series of the second order. [18,19].

The varied factors in the experiments were:

– X1 – dosage of Glenium Ace 430 additive in% of the binder mass from 0 to 0,4%;

– X2 – amount of ground granulated blast-furnace slag in % of the binder mass, introduced instead of a part of the cement: from 40 to 70%;

The responses of the conducted experiments were assigned:

– physical and mechanical properties of the concrete samples: W/C of equal-mobility (P3) concrete mixtures, density of concrete mixture, compressive strength 4 hours after the heat and moisture treatment (mode 4+3+5+6 (65 °C) and 28, 720 days of subsequent normal hardening MPa; frost resistance of concrete F1 according to GOST 10060 in 28, 720 days, cycles [20]; water absorption by weight Wm, % (Figure 1).

3. Conclusions

The conducted experimental work proves the validity of the use of mixed binders in the concretes containing active mineral additives that work together with plasticizers.

It was found out that even with application of the slag dosage up to 70% of the binder mass and mobility of the concrete mixture P3, it is possible to obtain the strength values in the vintage age that satisfy the requirements for the manufacture of prefabricated structures of a wide range. Over time, the strength of concrete increases, and the growth rate is higher the lower the strength at the initial stage of hardening.

The staged experiments prove that in the case of Portland cement application TsEM I 42.5N, the additional introduction of up to 70% slag in the binder allows to recommend the proposed technical solution for concrete classes B40-B45.

It should also be noted that the low temperature of isothermal heating provided a guaranteed set of branded concrete strength, which after 2 years of additional hardening increased by 15 - 25%.

The obtained data on the characteristics of the structure of concrete (the values of water absorption by mass are in the range of 4.5-6.5%) suggests the potentially increased durability of concrete, which is confirmed by the estimate of its frost resistance both at the initial and later dates of hardening

The excellent surface quality of the prepared samples of concrete cubes was noted, despite the short (20-30 seconds) vibrating time. Improving the quality of the concrete surface will allow, for the production of precast reinforced concrete, especially for interior panels, to abandon the finishing post, which will lead to reduction in labor costs.

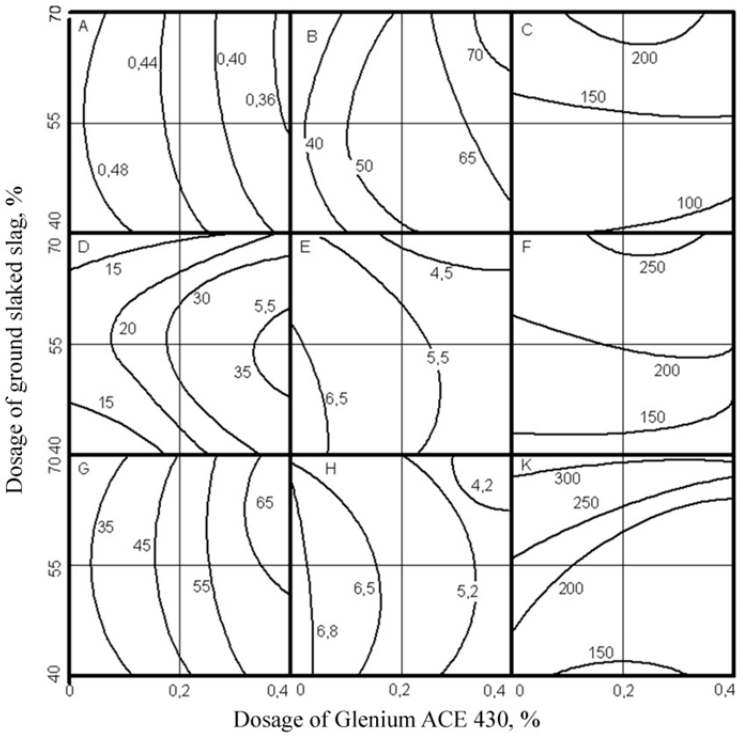

Figure 1. Influence of dosages of young blast-furnace slag and Glenium Ace 430 on the properties of concrete mixture and concrete: A − isolines of the water-binding ratio of equidistant concrete mixtures; D, G, B − isolines of concrete strength, MPa; D − after TBO, G − after 28 days of normal hardening; B − after 720 days of normal hardening; E, H − water absorption isolines by weight of concrete,%; E − after 28 days of normal hardening; H − after 720 days of normal hardening; C, F, R − isolines of concrete grades for frost resistance of concrete, F1.cycles C − after TBO, F − after 28 days of normal hardening; K − after 720 days of normal hardening.

References

[1] Falikman V R 2005 New High Performance Polycarboxilate Superplasticizers based on Derivative Copolymers of Maleinic *Acid, 6™ Int. Congress "GLOBAL CONSTRUCTION" Advances in Admixture Technology* pp 41–46
[2] *GOST 24211 2010 Additives for Concrete and Mortar. General Specifications* (Moscow: Standardinform) p 12
[3] Gamaliy E A 2009 *Complex Modifiers on the Basis of Aethers of Polycarboxylates and Active Mineral Additives for Heavy Constructional Concrete* (Chelyabinsk: South Ural St. Univ. Publ) p 217
[4] Dvorkin L I 2007 *Building Materials from Industrial Wastes Educational-Reference Manual* (Moscow: Phoenix Publishing House) p 368
[5] Sheikin A E 1979 *Structure and Properties of Cement Concretes* (Moscow: Stroiizdat) p 344
[6] *GOST 31108-2016 Cements for General Construction. Technical Conditions* (Moscow: Standardinform) p 12
[7] *GOST 3476-74 Blast-Furnace and Electrothermophosphor Granulated Slags for the Production of Cements* (Moscow: Publishing House of Standards) p 12
[8] Kosukhin M M 2005 *Regulation of Properties of Concrete Mixtures and Concretes with Complex Additives with Different Hydrophilic Groups* (Belgorod: Publishing House of BSTU) p 194
[9] Izotov V S 2006 *Chemical Additives for Concrete Modification: monograph* (Moscow: Kazan State University of Architecture and Civil Engineering Paleotyp Publishing House) p 244
[10] Ramachandran V S, Feldman R F and Kollepardi M 1988 *Additives in Concrete: A Reference Book* (Moscow: Stroiizdat) p 575

[11] Butt Yu M, Sychev M M and Timashev V V 1980 *Chemical Technology of Binders* (Moscow) p 472
[12] Usherov-Marshak A V 1984 General Regularities of the Solidification of Inorganic Binders *Reports of the Academy of Sciences of the USSR* vol 256 **2** pp 417–420
[13] Plugin A N, Usherov-Marshak A V, Sibiryakova I A and Mchedlov-Petrosyan O P 1977 Efficiency of Stabilization of Technological Characteristics of Cement *Cement* **10** pp 14–15
[14] Gorshkov V S, Timashev V V and Savel'ev V G 1981 *Methods of Physico-Chemical Analysis of Binders* (Moscow: High School Publ) p 335
[15] Shuldyakov K, Kramar L, Trofimov B and Ivanov I 2016 Superplasticizer Effect on Cement Paste Structure and Concrete Freeze-thaw Resistance *Advanced Materials in Technology and Construction AMTC-2015* (AIP Publishing) pp 070011–1–6
[16] *GOST 8736-2014 Sand for Construction Works Technical Conditions* (Moscow: Standardinform) p 8
[17] *GOST 8267-93 Crushed Stone and Gravel from Dense Rocks for Construction Works Technical Conditions* (Moscow: Standardinform) p 10
[18] Zedginidze I G 1970 *Planning an Experiment for the Study of Multicomponent Systems* (Moscow: Nauka) p 390
[19] Shestakov A L, Sviridyuk G A and Butakova M D 2015 The Mathematical Modelling Of The Production Of Construction Mixtures With Prescribed Properties *Bulletin of the South Ural State University. Ser. Mathematical Modelling, Programming & Computer Software* vol 8 **1** pp 100–110
[20] *GOST 10060-2012 Concrete. Methods for Determining frost Resistance* (Moscow: Standardinform) p 19