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INCREASING THE EFFICIENCY OF FINE-GRAINED LIGHTWEIGHT CONCRETE USING COMPLEX ADDITIVES

This work aims to investigate the physical and mechanical characteristics of high-strength lightweight concrete components on the basis of local porous fillers and complex additives. It is theoretically substantiated and practically proven that with optimal amounts of the complex additives – micro silica and superplasticizer Melflux 5581F, it is possible to obtain concrete with a compressive strength of up to 62 MPa and bending strength of 10.5 MPa, profitably using the microsilica pozzolanic activity and super plasticizer, which favorably changes the nature of porosity. Depending on the water/cement ratio, micro-and macro capillary pores of different origins, as well as other shape pores appear in the cement stone, which significantly affects the physical and mechanical characteristics of the concrete: strength, water absorption, water permeability, frost resistance, durability, etc.

Keywords: *high-strength fine-grained concrete, complex additive, pozzolanic activity, super plasticizer, filler grain size, intergranular void, mobility of concrete mix, structure formation, specific strength, physical and mechanical characteristics.*

Introduction

Concrete is a widely used building material that determines the level of civilization and the construction industry of the country. The volume of concrete used worldwide exceeds 3 billion cubic meters. The interest in this material is due to the simplicity of production technology, ecological safety, reliability of operation, and the possibility of extensive use of local raw materials and anthropogenic waste. The constant interest in concrete and the increase in demand causes a tendency to constantly improve it by using different types of mineral and chemical additives, so the production of such materials is one of the dynamically developing branches of the construction industry. With this approach, it becomes natural to explore other ways to improve the concrete structure using various complex additives, to study the relationship between the properties and the concrete structure [1].

The current level of concrete science makes it possible to develop lightweight concretes of different functionality, among which the concretes based on local highly active lithoid-pumice sand and gravel are also of great interest. The high strength of concrete is directly related to the average density, as one of the most important issues in the construction industry is to provide the required bearing capacity with a possible reduction in the structure mass. The application of structural and high-strength lightweight concrete with flexible or pre-stressed reinforcement should meet higher mechanical characteristics and durability requirements at the normalized average density, which will increase the technical and economic efficiency of the field.

Materials and Methods

Concrete is a capillary porous rock material, where pores include volumes not filled with solid material, regardless of origin. Pores can be formed for a variety of reasons, the most common is the technological porosity conditioned by the processes of concrete mixture compaction (incomplete condensation) and concrete hardening. Today, by introducing various chemical and mineral additives, it is possible to reduce technological

porosity. The mechanisms of action of these materials are different and are of particular interest. The main cause of capillary porosity formation is the evaporation of excess water from the cement mortar, which can be reduced by adding plasticizing additives. The other reason is the usage of mineral additives, which can produce various new formations and fill the voids due to pozzolanic activity while increasing the conglomerate's strength. In other words, mineral additives can participate in structural development, which does not affect the physical and mechanical characteristics of the artificial conglomerates. Due to the synthesis of a high-density cement matrix and dense compaction of fine fillers, design principles for fine-grained high-strength concrete have been developed for monolithic construction which allow to obtain deformation characteristics equivalent to concretes obtained using coarse-grain fillers [2].

The use of complex organic-mineral modifiers [3,4] is the same strategy used to solve the problem of hydraulic fine-grained concrete operational properties.

Fine-grained sand concrete has been widely used recently. In the past, their usage was limited by certain features of structure and properties. In fine-grained concrete, increasing the specific surface area of fillers increases the water need and, as a result, the cement consumption. To some extent, it increases the compression deformations, creeps of concrete, and deformity. Compared to ordinary concrete, fine-grained concrete has low compressive strength, frost resistance, and poor adhesion to the reinforcement. Complex additives improve the physical-technical indicators to avoid the mentioned problems. Due to the use of modifier-based composite binders in concrete technology, the preconditions for the usage of concrete have changed in modern concrete science [5-7]. The properties of such concretes are mainly determined by the type of the binder, the properties of the filler, the particle size and strength, the surface quality, the porosity, e.t.c. [8-10]. Fine-grained concretes are characterized by the absence of a rigid stone structure, a higher specific gravity of the fillers, and sometimes an increased volume of intergranular voids. For that reason, compared to traditional coarse-grained concrete, such concretes require a 20... 40 % higher consumption of cement paste. The strength of the concrete will decrease by reducing the filler sizes and cement consumption. Therefore, clean and coarse grain sands (fineness modulus), and gravel with grain sizes of 5 -10 mm, should be used in fine-grained concrete.

High strength for such concrete is possible by providing some conditions deriving from the physical foundations of the concrete structure. The main ones, especially in the case of dense, solid fillers, are the application of a low water-to-cement ratio, the addition of plasticizers, complex additives, reaction-active micro silica, thorough mixing, the provision of more favorable conditions for setting, etc. Increasing the cement consumption and micro-reinforcing favor the increase of the concrete strength. Because of the low water-to-cement ratio and high filler concentration, despite the cement price, the shrinkage of such concrete is not more than in ordinary concrete, and in certain situations it is even less.

According to the interstate standard (GOST 31914-2012), the strength limit of high-strength concrete should not be less than 60 MPa. However, the strength limit of such concrete is very conditional as it is mainly related to the degree of development of science and technology in the production of cement, concrete, and additives. Therefore concretes are conventionally divided into high-strength, special high-strength, and super-strong concretes. LC 50/55 and high grades (according to EN 206-1) are presented for high-strength lightweight concrete.

In addition to enhancing quality, the challenges of increasing the efficiency of construction materials include lowering material and energy prices. As a result of the development of high-rise frame construction, some issues related to the production and use of high-strength lightweight concrete with high mobility were raised. They are due to various problems arising in monolithic house-building technology, such as concrete mix layering by height, disturbance of homogeneity of concrete, formation of cavities due to insufficient compaction of concrete mixture, e.t.c., which inhibit the provision of necessary physical and mechanical characteristics of the structure. Due to the use of various mineral micro dispersion fillers and modifiers, in particular micro silica, ash loss, and other highly-efficient modern modifiers, these negative phenomena were possible to compensate. One of the most universal (effective) methods for modeling the structure and adjusting

the properties of concrete is the introduction of additional components into the concrete mix [11-15]. The combination of superplasticizer with micro silica allows the production of high-strength lightweight concrete or lightweight concrete with traditional strengths, reducing the consumption of cement.

Based on the above, the task was set to study the possible methods of obtaining lightweight high-strength concrete with lithoid pumice sand of Jraber mine, using 42.5 class Portland cement and micro silica. The apparent density of 42.5 class (CEM-I, 42.5N) Portland cement from Ararat Cement Plant used in the study was 1031 kg/m^3 , and the residue on the 80-micron sieve was 9.249%. Table 1 shows the results of determining the cement activity by standard methods.

Table 1. Test results of Ararat cement Plant

Cement CEM-I, 42.5N, <i>g</i>	450
Multi-grain sand, <i>g</i>	1350
Water, <i>ml</i>	225
In the case of bending, the tense strength limit at the age of 7 days, <i>MPa</i>	4.001
Compression strength at the age of 7 days, <i>MPa</i>	43.409
In the case of bending, the tense strength limit at the age of 28 days, <i>MPa</i>	6.468
Compression strength at the age of 28 days, <i>MPa</i>	48.366

The fineness modulus of lithoid sand was $M_k = 3.02$, and the apparent density was 1148.6 kg/m^3 . The granular composition of lithoid sand is shown in Table 2. The apparent density of micro silica is 314.5 kg/m^3 .

Table 2. Granular composition of lithoid sand

Sieve hole sizes, <i>mm</i>	5	2.5	1.25	0.63	0.315	0.16	< 0.16
Total residue, %	0	38.605	11.715	10.64	10.015	10.35	18.675

Microsilica particles, having an extremely fine and amorphous structure, increase the water demand of the concrete mix. That's why superplasticizers were also used. The quantity of micro silica adjusted within 5–30 percent of the cement mass throughout processing, and 0.45 percent superplasticizer Melflux 5581F was used (Table 3, Fig.).

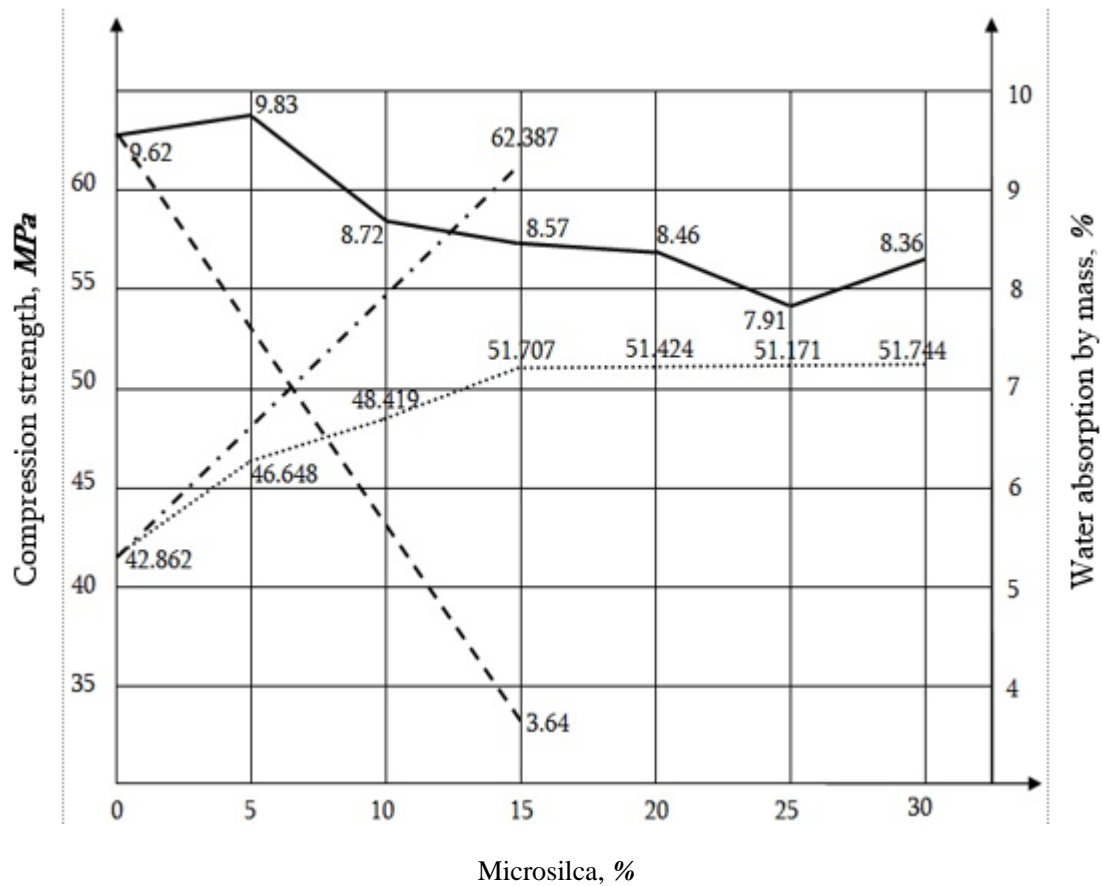
Table 3. Characteristics of lightweight concrete mix

N	Lithoid pumice sand, <i>kg</i>	Ararat cement CEM-I 42.5N, <i>kg</i>	Micro silica, <i>kg</i>	Water, <i>l</i>	Superplasticizer Melflux 5581F, <i>kg</i>	Density of freshly made concrete, kg/m^3	Slump, <i>cm</i>
1	1000	425	-	290	-	1975.3	5
2			21.25 (5 %)	295	-	1979.2	6
3			42.5 (10 %)	305	-	1971.4	6
4			63.75 (15 %)	315	-	1963.5	5
4'			63.75 (15 %)	330	-	1931	8
5			85 (20 %)	325	-	1945.3	6
6			106.25 (25 %)	335	-	1954.4	6
7			127.5 (30 %)	340	-	1932.3	4
8			63.75 (15 %)	260	1.9125 (0,45%)	1978	4
9			63.75 (15 %)	315	1.9125 (0,45%)	1897	17

In Table 4 the lightweight fine-grained concrete experiment results are shown.

Table 4. Characteristics of lightweight concrete

N	Density in a dry state, kg/m^3	When bending, tense strength limit at 7 days, MPa	Compression strength at 7 days, MPa	When bending, tense strength limit at 28 days, MPa	Compression strength at 28 days, MPa	Effect of micro silica on the increase in compressive strength, %	Water absorption by mass, %
1	1871	3.586	38.414	6.445	42.862	-	9.62
2	1905	3.919	41.940	7.445	46.648	8.83	9.83
3	1847	4.242	39.381	3.672	48.419	12.96	8.72
4	1865	5.336	40.303	3.678	51.707	20.63	8.57
4'	1852	5.982	45.882	5.466	46.990	2.41	10.4
5	1857	4.974	38.458	4.154	51.424	19.97	8.46
6	1931	6.801	38.890	6.758	51.171	19.38	7.91
7	1832	5.854	42.163	7.34	51.744	20.72	8.36
8	1862	6.752	43.665	10.567	62.387	45.55	3.641
9	1831	4.232	31.511	7.239	48.742	13.71	3.890



- the limit of the compression strength depending on the quantity of microsilica,
- . - the limit of the compression strength depending on the quantity of microsilica (15%) and superplasticizer (0.45 %),
- water absorption depending on the quantity of microsilica,
- - - water absorption depending on the quantity of microsilica (15 %) and superplasticizer (0.45%)

Fig. Variation of physical and mechanical properties of crushed concrete depending on the number of types of additives used

The pozzolanic reaction of micro silica increases the hydration process of calcium silicate and causes explicit changes in the concrete structure porosity, thus reducing capillary porosity and increasing gel content, giving the concrete two main properties: improved strength and increased permeability.

The experimental results show that within 5... 30% consumption of microsilica, the strength of concrete, depending on the mass of microsilica, is not monotonous. Furthermore, in the case of the same number of other components, an increase in water consumption from 315 to 330 liters causes a decrease in strength from 51.707 to 46.99 MPa.

The experiments were carried out using the specified 4 and 4' compositions, in which Melflux 5581F superplasticizer was added by 0.45 percent of the cement mass in both cases, taking into account the fact that the quantity of micro silica of more than 15% does not cause significant changes in the strength. If the mobility of the concrete mix was almost unchanged ($CS = 4$), a significant increase in concrete strength was observed (20.65%). In the case of an unchangeable amount of water ($CS = 17sm$), the increase in concrete strength decreased significantly (3.72 %).

Based on the selected quantities of a binder, water, and Jraber mine perlite sand, using micro silica and Melflux 5581F superplasticizer, it was possible to obtain high-strength lightweight concrete with a strength of 62.387 MPa, which is not available for ordinary lightweight concrete.

Conclusion

As a result, a constructive lightweight concrete with a higher structural quality coefficient was obtained, which at the age of 28 days was characterized by a compressive strength limit of 48.742 – 62.387 MPa at normal compaction and an average density of 1862 – 1829 kg/m³ in the dry state.

The developed concrete is a lightweight concrete of constructive significance with high operational properties that can be used in residential and public construction, high-rise buildings, bridges, reinforced concrete multi-layered items (farms, beams, cross-bars), etc. This type of concrete will significantly expand the architectural solutions available for construction. By reducing the mass of elements in the structure, the range of applications for lightweight concrete as a constructive material will be expanded.

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