International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

Improving Portland Cement Properties with Additives

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ABSTRACT*— One of the most perspective directions in the beginning of the XXI century in the field of building materials technology is creation of materials with essentially new characteristics approaching them to metal, ceramics and polymers. It is represented that this serious problem can be solved, involving complex modifiers of a special purpose with which use it will appear possible to receive and group of the special binders. These materials should be characterized also high strength by indicators at bend and a stretching, and also ultrahigh density and durability at compression.The development of construction production necessitates the creation of effective high-quality materials, the use of which is economically feasible and can reduce energy costs and the consumption of raw materials. Increasing the strength of cement stone in the manufacture of concrete for various purposes is an urgent task, the solution of which can significantly reduce the consumption of binder in concrete or increase its strength.As a result of long-term studies, it was found that it is possible to successfully solve the problem of increasing strength and improving the characteristics of Portland cement due to its mechanic and chemical processing. This technology includes the mechanic and chemical processing of Portland cement and its modification. This article presents the results of a study of the effect of mineral and chemical additives on cement strength.*

keywords*— building nanotechnology, dense cement matrix, hydration kinetics, multicomponent composite materials, mechanical and chemical activation, mechanical properties, silica fume, super plasticizer*.

I. INTRODUCTION

concrete is the most widely used artificial multiphase, nanostructured composite that wears out over time. The properties of concrete directly depend on the degradation processes taking place at all dimensional levels (from nano- to micro- and macrolevels), where the properties at each level affect each successive in order from lowest to highest. The amorphous phase and C-S-H serve as the “glue” that holds together all the concrete components. This "glue" is a nanomaterial. Studying concrete “from bottom to top”, at the nanoscale, we can say that it is a composite consisting of molecular structures, surfaces (aggregates and fibers), as well as chemical bonds that interact through local chemical reactions, intermolecular forces and interfacial diffusion. It has been established that processes occurring at the nano level have a direct effect on the final characteristics and properties of the final material. Nanotechnology has changed our view, expectations and ability to control the "world" of the material. These advances will greatly affect modern construction, as well as cement-based materials.

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However, despite the successes achieved, nanotechnology is at the very initial stage of their research; nanotechnologies are just beginning to show their fruits, going from fundamental research to the real world of production.

In the world of construction practice, the share and role of high-quality concrete (High Performance Concretes) is rapidly growing and accompanies the rapid development of architectural forms and functionally new types of structures. To obtain such concrete, it is necessary to use Portland cement of higher strength (600-700). With large-scale construction in our country, obtaining such concrete is also relevant. Portland cement, produced at thousands of enterprises for several decades, has practically stopped developing its main quality - the strength of a standard stone, at class 52.5 (grade 500). And this despite the desire of builders to have more durable, quick-hardening and long-lasting concrete [1,2,3].

It is well known that high-strength cement pastes, mortars, and concretes can be obtained by introducing optimal combinations of cement, filler, and super plasticizer. Very often silica fume is used as a filler due to the high specific surface of its particles and also because it is a very reactive pozzolanic material that reacts with free calcium hydroxide (CH) and forms hydro silicates. The dispersed interaction of colloidal particles in cement mortars and concrete mixtures determines the structure density and other characteristics of concrete after the completion of hydration processes of cement binders.

Super plasticizers are the most effective chemical additives in concrete and mortar. Over the past 30 years, their development and implementation into practice has provided major progress in the technology of concrete and other materials based on Portland cement. The use of this group of additives has significantly improved the technological and operational properties of concrete and mortar. Despite the wide experience in using plasticizers in modern concrete technology, these additives are not always used effectively. This is often due to the lack of a methodology for technologists to evaluate the effectiveness of these additives, as well as clear ideas about the influence of various factors on the effectiveness of the use of super plasticizers, taking into account the positive and negative effects of additives on the properties of concrete [4,5].

Super plasticizers are linear polymers with hydrophobic and ionisable hydrophilic polar groups. The nature of hydrophilic and hydrophobic groups should provide a minimum amount of surfactant in order to avoid foaming and air absorption by impurities. The addition of small amounts of super plasticizer improves workability, but often this leads to undesirable effects of delayed setting of cement paste. Super plasticizers are often used in concrete technologies for three different purposes or their combinations:

- increase workability without changing the composition of the mixture to improve the characteristics of concrete laying;
- reduce the required water of a standard consistency to increase the strength of concrete;
- reduce both water and cement for a given workability (workability) in order to save cement and reduce creep, shrinkage and thermal loads caused by heat of hydration of the cement [6].

In this work we studied the influence of mineral and chemical admixtures to cement properties.

II. METHODOLOGY

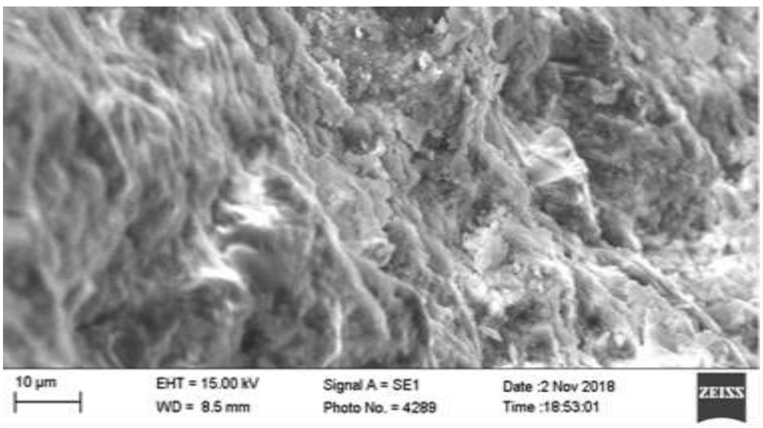
The materials used in this work are the cement clinker of Behkabad cement JSC, silica fume - a by-product of the Angren silicon plant, Megaplast JK-08 superplasticizer.

Preliminary studies have shown an increase in the strength of cement samples containing the addition of silica fume during curing.

Analysis of the test results showed that the highest strength indicator is for samples containing 7-10% silica fume. Although the strength of samples containing 15–20% silica fume is slightly lower than the strength of samples with 7–10% silica fume, these indicators are still higher than the strength of control samples. The test results are shown in Table 1.

Table 1: The effect of the amount of mineral additives of silica fume on the strength of cement. Here, the w/c ratio is 0.4

№	**The amount of silica fume relative to the mass of cement, %**	**Strength, MPa**					
		3 day		**7 day**		**28 day**	
		Bend	**Compression**	**Bend**	**Compression**	**Bend**	**Compression**
1	0	3,9	14,19	5,09	22,5	6,8	40,2
2	5	4,9	18,33	6,0	31,47	7,71	47,65
3	7	5,38	24,9	6,08	34,7	8,83	54,22
4	10	5,28	22,94	5,67	31,86	8,50	51,97
5	15	4,77	17,01	5,35	26,91	6,45	46,33
6	20	4,07	16,4	4,23	21,62	6,29	44,62



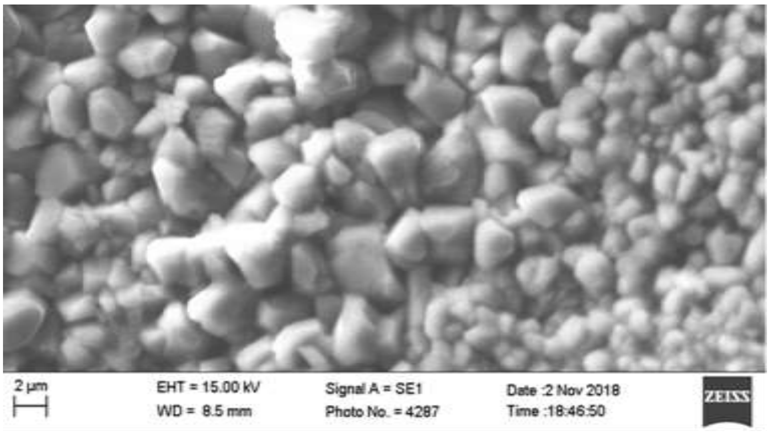


Figure 1: The microstructure of cement stone without the addition of MK

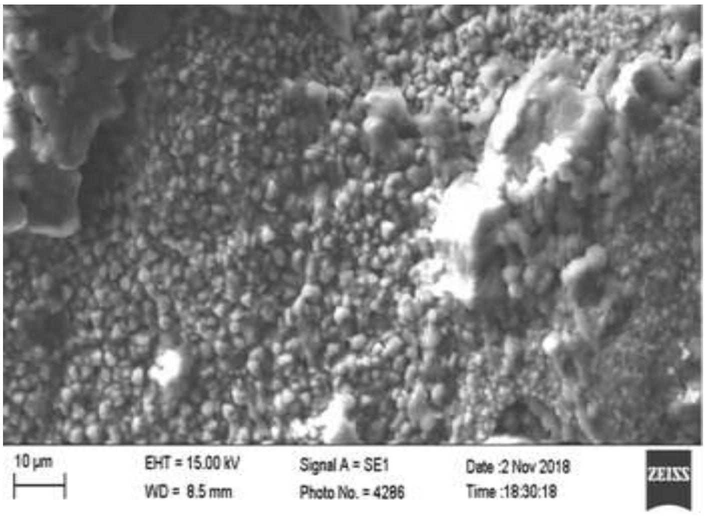


Figure 2: Muticrostructure of cement stone with the addition of MK (15%)

It can be seen from Figs. 1 and 2 that the structure of the non-added cement stone is heterogeneous, has a block character, and is represented by weakly crystallized calcium hydro silicates, including Portlandite crystals (Fig. 1). MK additive promotes the formation of a dense homogeneous structure, represented mainly by low-basic calcium hydro silicates (Fig. 3).

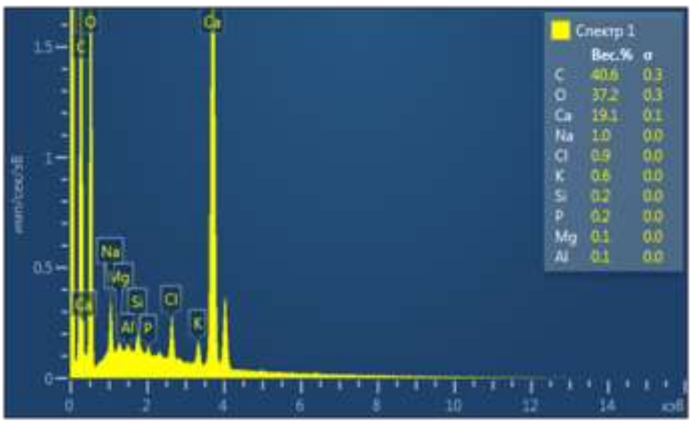


Figure 3: Elemental composition of a cement sample with the addition of MK (15%).

Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

The water demand of cement compositions with active mineral additives can be leveled using superplasticizer. Superplasticizers, while maintaining the mobility of the concrete mixture, can reduce water demand by 20-30%.

Table 2 shows the test results of cement samples obtained by introducing into Portland cement clinker the optimal amount of a highly dispersed mineral supplement of silica fume and the optimal dose of superplasticizer based on Megaplast JK-08 naphthalene sulfonates and its subsequent grinding (water/cement ratio w/c = 0.26):

Table 2. Strength indicators of Portland cement containing a chemical and mineral additive

№	The amount of mineral and chemical additives relative to the mass of cement,%	Strength, MPa					
		3 days		7 days		28 days	
		Bend	Compression	Bend	Compression	Bend	Compression
1	0	3,6	12,3	4,9	21,4	5,8	41,3

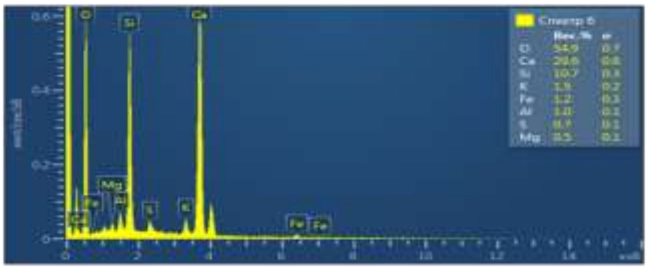


Figure 4: elemental composition of the control sample at the age of 3 days curing.

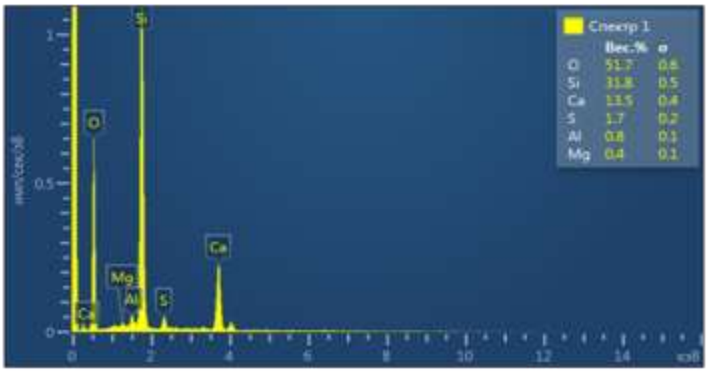


Figure 5: Elemental Composition Of The Sample With Additives Of Superplasticizer And Silica Fume At 3 Days Curing.

III. RESULTS AND DISCUSSIONS

Fig.4 shows the relative chemical composition of cement sample without additives. High concentration of calcium is due to the formation of Ca(OH)2 crystals. Fig.5 shows the relative chemical composition of cement sample with additives. A high concentration silicon and low concentration of calcium shows that silica has got into the structure but hasn't reacted with Ca(OH)2 to produce C-S-H gel of which calcium occupies a good portion. These silica particles occupy the pores in the gel and make the microstructure uniform. A good percentage of oxygen may contribute to the reaction of silica with Ca(OH)2 which produce C-S-H gel. Another explanation to the increase in strength can be due to the availability of sufficient silica to make the microstructure denser and uniform

The dependence of the strength of the samples on the content of the mineral additive may be due to the fact, that the interaction of the additive with clinker materials occurs in the contact zone of the particles of these components. The mechanism of action of hydraulically active additives is mainly due to their chemical interaction with lime formed as a result of C3S hydrolysis during cement hydration.

Obviously, the optimum amount of additive corresponds to the case when the particle of the additive is densely surrounded by particles of cement on all sides. A smaller amount of additive leads to a decrease in the efficiency of formation of a strong structure. With its larger content, direct contacts between the particles of the additive are possible, which also reduces the effectiveness of its influence on the optimal structure formation.

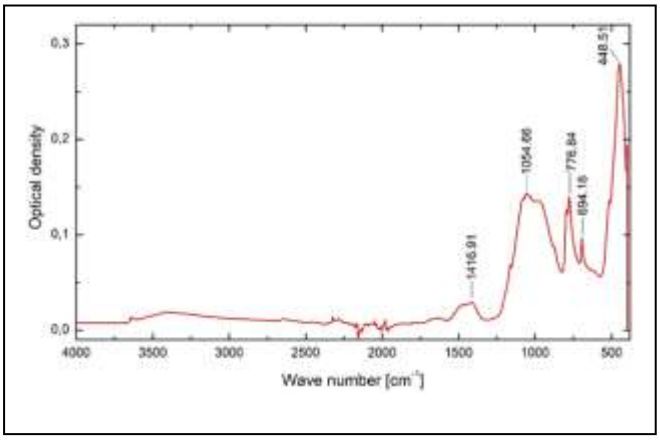


Figure 6: FTIR spectra of control cement paste curing 3 days

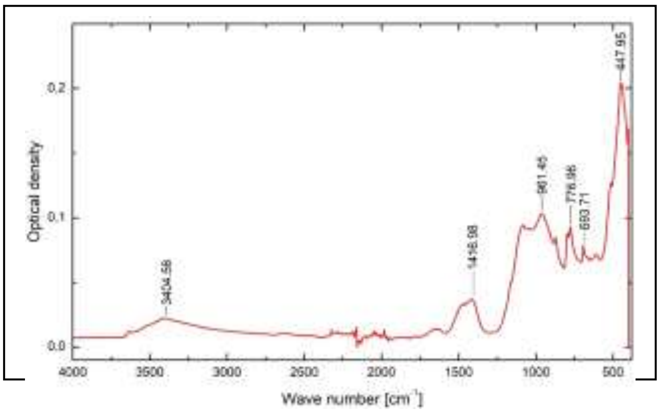


Figure 7: FTIR spectra of cement paste with silica fume and super plasticizer 3 days curing

From the Figures 6 and 7 we can see that the small band located at 3404,56 cm-1 is attributed to the –OH band from hydrated lime (CH). Its intensity increase due to presence of super plasticizer and pozzolanic activity of silica fume. The widths of those bands increase with curing time, due to the continuous hydration of cement phases in addition to the pozzolanic reaction of silica fume with liberated lime, leading to the formation of additional hydration products. The band 1416,98 cm-1 is assigned to C-O bond stretching of CO32-. Its intensity decrease with curing time due to the increase of the pozzolanic reaction between silica fume and Ca(OH)2, which is the main phase for carbonation. The detected band at 961,45 cm-1 is attributed to the formation of CSH, which its intensity increases and its position is shifted towards higher frequencies with hydration time. This is due to the increase of both hydration reaction of cement phases and the pozzolanic reaction of silica fume with free lime forming additional amounts of hydro-silicates. The band at the 447,95 cm-1 is assigned to the bending vibration of Si-O bond in SiO42- which increases with curing time due to the pozzolanic reaction and formation of additional hydrated silicates.

IV. CONCLUSION

From the obtained results, we can draw the following conclusion:

• The introduction of super plasticizer in the cement composition reduced the water demand of the cement composition by 35%.

• At the same time, the strength of cement increased by 21.1%.

• The combined introduction of super plasticizer and silica fume into the composition of cement leads to the formation of a dense structure of cement stone, accelerates cement hydration (Figs. 6 and 7), as a result of hydration, a structure consisting of low-base hydro silicates of different degrees of crystallization is formed. The results of FTIR spectra are in a good agreement with those of chemical and physic-mechanical properties of the investigated pastes.

• Using a complex additive based on silica fume and Megaplast JK-08 super plasticizer, it is possible to significantly affect the structure of cement compositions.

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Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020