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Improving Cement Characteristics for Structural Building Elements through Enhanced Fineness and Granulometric Composition

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ABSTRACT:

This study explores the effect of the SAFA plasticizing additive on the fineness, granulometric distribution, and mechanical performance of cement intended for use in structural building elements. Cement was produced by co-grinding clinker with varying proportions of SAFA in a laboratory ball mill. Optimal results were obtained with 0.05–0.10% SAFA by clinker weight, leading to a 15–17% increase in specific surface area and a finer particle distribution. Sedimentation analysis confirmed a shift toward a higher proportion of fine fractions (<20 μm), which are critical for early strength development. Strength tests on mortar bars demonstrated a compressive strength increase of up to 33% at 3 days and 21% at 28 days compared to control samples. The enhanced cement properties contribute to improved performance and reduced cement consumption in precast and cast-in-place structural components.

Key words: Structural building elements, SAFA additive, cement fineness, clinker grinding, granulometric distribution, strength development, plasticizer, sedimentation analysis, energy efficiency, precast concrete.

Introduction.

The production of both assembly and precast reinforced concrete structures is one of the most material, energy and labor-intensive areas of the construction industry . As domestic and foreign construction experience shows, one of the promising areas for improving concrete technology and one of the real ways to increase the strength of cement in the initial stages of hardening with economical cement consumption is to increase the specific surface of cement and use the plasticizing additive SAFA [2, 4]. In [3], the prospects of using plasticizing water-soluble resins as additives to cement concretes, characterized by a set of valuable properties, are indicated. The effect of additives is very complex, depends on the functional composition, structure and concentration, as well as on the mineralogical composition of cement. The study of the effect of surface-active additives on cement compositions and concrete mixtures showed the effectiveness of their use to improve the granulometric composition of cement.

In a simplified form, the mechanism of action of surfactants consists of their adsorption at the boundary of "water-air" or "water-solid substance" and reduction of surface tension at the boundary of the phase separation. It creates thin films on them that reduce the coefficients of internal friction between cement grains. Surfactant molecules, consisting of electrostatic charges of opposite signs, repel cement particles from each other, creating a water shell around them, preventing their adhesion. This determines the plasticizing effect of SAFA.

As is known, the initial period of cement hardening is significantly affected not only by the mineralogical composition, but also by the fineness of grinding and granulometric composition. Hydration proceeds more favorably and the strength increases most intensively in cements with a certain granulometric composition. The growth of cement strength depends not only on the size of the specific surface of the cement, but also on its grain composition.

Previously cited studies have established [3] that the value of cement strength after 1-2 days is determined by the presence of a fraction of less than 5-7 μm, after 7 days by a fraction of less than 18-22 μm, and after 28 days by a fraction of 23-27 μm, and in later periods by a fraction of more than 40 μm.

Research to determine the effect of the amount of SAFA additive on the fineness of clinker grinding and the granulometric composition of cement, as well as the strength properties of the resulting cement, was conducted in the laboratory of the Scientific Research Institute of Building Materials. Clinker from the Akhangaran Cement Plant was used for the experiment. Clinker was ground in a 10 kg ball mill. Metal balls of different diameters were used for grinding. Clinker was ground with and without the addition of additives in different quantities, and the grinding time was the same. As noted earlier, the fineness of grinding and the granulometric composition of cement are one of the main factors determining the physical and mechanical properties of cement. By introducing SAFA into the mill when grinding clinker, it is possible to increase the productivity of the grinding unit or increase the fineness of cement grinding with the same grinding time.

SAFA as a grinding intensifier and introduced it into the mill in the range from 0.02 to 0.2% of the ground mass. And the effect of the additive was determined by the grinding fineness and granulometric composition of the obtained cement. First, we determined the effect of the additive on the increase in the grinding fineness of cement at the same grinding time with different amounts of additives. The results obtained are shown in Table 1.

Table 1

SAFA additive amount on grinding fineness

No.	*Type of additive*	*Quantity additives, %*	*Time Grinding, min*	*Remainder on sieve 0.08, %*	*Specific surface area cm2 / g*	*Increase productivity mills, %*
1	2	3	4	5	6	7
1	*Control*		60	8.9	2870	100
2	Safa	0.02	$\frac{60}{50}$	$\frac{4.4}{9.1}$	$\frac{3489}{2865}$	117
3	Safa	0.05	$\frac{60}{47}$	$\frac{3.8}{9.8}$	$\frac{2870}{3655}$	128
4	Safa	0.10	$\frac{60}{45}$	$\frac{3.1}{9.6}$	$\frac{2870}{3865}$	131
5	Safa	0.15	$\frac{60}{45}$	$\frac{4,1}{9,6}$	$\frac{2870}{3470}$	126
6	Safa	0.2	$\frac{60}{50}$	$\frac{4,8}{9.9}$	$\frac{2870}{3050}$	121

It is evident from Table 1 that the greatest increase in grinding fineness is observed with the introduction of 0.05 and 0.10% of the additive based on the weight of the clinker loaded into the mill. In this case, the specific surface area of cement increased from 2850 to 3940 cm / g, i.e. increased by approximately 15-17%, with the introduction of 0.10% of the SAFA additive into the mill. In this case, the grinding time was the same (60 min). The results obtained can be explained by the fact that the SAFA additive, adhering to the surface of the clinker, reduces the surface tension [3] and helps to reduce its hardness. It is evident from the studies that the maximum decrease in hardness is achieved with the introduction of 0.05 and 0.10% of the SAFA based on the weight of the material being ground into the mill. With an increase in the amount of the additive above the optimum, the adsorption effect of reducing the strength of solids, as is known, decreases. This is apparently due to the appearance of the second adsorption layer.

As the dispersion increases during grinding, the speed of the grinding process decreases, which is associated with increased surface interactions of destructive particles. For a complete characterization of the resulting cement with the addition of SAFA, it is necessary to take into account its fractional composition, since, all other things being equal, including the same specific surface, the activity of cement is determined by its fractional composition.

The next stage of the research was to study the effect of different amounts of SAFA additive on the fractional composition of cement ground to approximately the same specific surface area.

Using the sedimentation analysis method, we determined the effect of the SAFA additive on the change in the fractional composition of cement obtained by grinding with and without additives. Table 2 shows the results of the sedimentation analysis.

2-table

The influence of the amount of additive on the fractional composition of cements

No.	Additive	Amount of additive %	Specific surface cm2 / g	Fractional composition of cement microns, %						
				< 80	80-60	60-40	40-20	20-10	>10	sum
1	2	3	4	5	6	7	8	9	10	11
1	-	-	2870	9.8 0	10.9 5	27.6 9	27.3 5	10.3 6	13.6 8	99.8 1
2	SAFA	0.02	288 2	8.5 1	8.4 8	22, 37	28.4 8	12.3 9	18.6 6	98.7 5
3	-,,-	0.05	28 88	7.52	5.1 7	19.4 6	31.6 7	14.3 4	20.6 5	99.6 7
4	-,,-	0.10	27 8 0	7.5 9	3.4 9	16.8 0	34.3 4	16.3 6	21,0 0	99.5 9

5	-,,-	0.15	28 75	8, 7	5.3 1	19.3 0	31.7 1	14, 8	19.8 5	99.7 1
6	-,,-	0.2	287 0	8.8 9	7.6 0	25.6 9	30.6 8	11.9 5	14.9 0	99.6 3

The obtained results show that in cement obtained by joint grinding of clinker with the addition of 0.10% SAFA, compared to the control, there is a decrease in the fraction size of 65-75 and 35-55 μm by 35-40% with a simultaneous increase in the fraction of 10 μm by 20%, the fraction of 10-20 μm by 35-45%, and the fraction of 20-40 μm by 10-12%.

Thus, the conducted studies have established that the best indicator of the fractional composition. The obtained cement is provided by joint grinding of clinker with the addition of SAFA in the amount of 0.1% of the clinker weight. The obtained cement was subjected to physical and mechanical tests. Normal density decreased by 4%, and water demand by 14-15%, the onset of setting decreased by 43-48 minutes, which satisfies the physical and mechanical properties of the requirements of RST Uz - 742-96. Improvement of the fractional composition obviously had a positive effect on the kinetics of structure formation of the cement paste, both in the early and subsequent periods of hardening.

Research was conducted to determine the strength properties of cements obtained by grinding clinker in a ball mill with and without the addition of SAFA additive. Beams 40x40x160 mm were molded from solutions of normal density. The samples hardened for 3.7 and 28 days in a humid environment. After the time had elapsed, the samples were tested for bending (MI 100), and the halves of the beams were tested for compression on a 10-ton press. The results obtained are given in Table 3.

Table 3

Strength indicators of cement,

obtained by joint grinding of clinker with the addition of SAFA

No.	View additives	Quantity introduced additives, %	Tensile strength $R_{bending}$, / $R_{compression}$ MPa of samples after 24 hours.		
			3	7	28
1	Control	-	3.1/33.3	4.2/44.4	5.6/48.1
2	SAFA	0.05	7.0/44.5	8.4/52.5	8.2/56.4
3	SAFA	0.10	7.2/49.4	8.8/58.1	8.3/67.6
4	SAFA	0.15	4.3/41.40	5.7/47.8	6.1/57.9

The data presented in Table 3 indicate that the strength of cements obtained by joint grinding of clinker with the addition of SAFA in an amount of 0.05-0.10% of the clinker weight, compared with control samples, after 3, 7 and 28 days of hardening under normal conditions increased by 28-33%, 21-23% and 19-21%, respectively.

Conclusion. By increasing the strength of cement samples with SAFA additives, it is possible to save 20-21% of cement to obtain the same strength as the control samples.

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