Effect of calcium sulfoaluminate additive on linear deformation at different humidity and strength of cement mortars

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Abstract. The effect of calcium Sulfoaluminate additives (CSA) on the compression and bending strength of mortar, as well as linear deformation of prism samples at different environmental humidity was studied. Test results indicate that bending strength of mortars with CSA and the referent at the age of 28 days are practically equal. Compressive strength of mortars with CSA reduced by 20 ... 23% for all dosages of CSA. Relative linear deformations depend on the humidity of the environment. At a humidity of 100%, the relative linear deformations are positive and the expansion increases with increasing dosage of the expanding additive. When hardening in dry air at a humidity of 55%, the greatest shrinkage deformations were observed for mortars with CSA. We can conclude that the expanding effect of CSA is fully manifested at high humidity, i.e. under construction conditions, this means very high-quality moisture care for concrete structures.

Keywords: Shrinkage, cracks, calcium Sulfoaluminate additives, expanding additives.

1 Introduction

The issue of concrete durability is one of the main issues in modern construction. It is well known that one of the most significant factors affecting the durability and security of monolithic and prefabricated structures is the appearance and development of various kinds of cracks. Different types of cracks and their causes are described in detail in the literature [1,2,3,4,5,8,9].

Generally, all cracks in concrete can be divided into 2 categories: cracks that appear in fresh concrete and cracks that appear after hardening of concrete.

Cracks in fresh concrete can appear as a result of plastic settlement and/or plastic shrinkage of concrete, as well as the result of both the movement of the formwork, foundation or other technological reasons. There are many reasons for cracking in hardened concrete.

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It can be chemical shrinkage (volume reduction due to cement hydration), autogenous shrinkage (typical for concrete with a low water/cement ratio), drying shrinkage (water loss of hardened concrete in an environment with low humidity). Shrinkage cracks can also be caused by temperature deformations of massive structures, by errors in structural design/manufacturing/ operation, corrosion of reinforcing bars (wedge effect of corrosion products), carbonization, etc.

It is obvious that depending on the composition, the conditions of hardening and care, the age of concrete, different types of shrinkage deformations will prevail. However, for ordinary concrete (W/C >0.4) the most significant contribution to the shrinkage deformation of the structure is the drying shrinkage [2].

Three most effective ways to combat drying shrinkage can be [4]:

- Implementation of high-quality moisture care of the concrete structure;
- Compensation of shrinkage with the help of expanding mineral additives;
- Reduction of shrinkage due to Shrinkage Reducing Admixtures (SRA) based on glycols.

The use of the first method is of the most preferable, but it is not always feasible in construction.

Thus the most reliable and widespread way is the use of expanding mineral additives, that are used for concrete, mortar dry mixes, grouting etc. Expanding additives act due to the formation of ettringite (Sulfoaluminate additives) or calcium hydroxide (additives based on CaO). Sulfoaluminate additives, which are safer for humans than CaO-based additives, are most prevalent in the world and in Belarus. CSA-expanding additives have been used since the 80s of the last century [6]. Many years of experience in their use have revealed some of the disadvantages of using these modifiers. They are supplied only in dry form and have high dosages (usually 10% by weight of cement). There is also literature date that concrete with CSA expanding additives is very sensitive to the quality of moisture care. In this regard, this research is related to its study of the effect of humidity on the expanding potential of CSA-expanding additives.

2 Experimental Investigation

Materials

The properties of the materials used in the experiment are shown in the tables 1-5.

Table 1 – Cement

Type, producer	Mineralogical composition, %				Specific Surface, m^2/kg	Density kg/m^3	Standard Consistency, **%**	Strength of Cement, 28 days MPa
	C_3A	C_4AF	C_3S	C_2S				
CEM I 42.5N Belorussian cement plant, Costukovichy	7.3	13.5	53.7	21.1	330	3150	31	52.1

Table 2 – Fine aggregate

Type, producer	Modulus of fineness	Density, kg/m^3	Bulk density, kg/m^3	Water absorption, %	Specific Surface, m^2/kg
Quarry sand, Crapugino	3.25	2650	1660	0.66	8.9

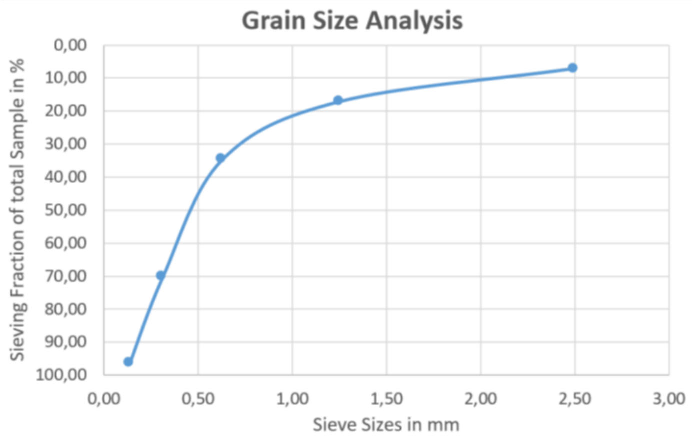

Figure 1 – Grain size distribution of used fine aggregate

Table 3 – Calcium Sulfoaluminate additive (CSA)

Type, producer	Humidity,%	Density, kg/m^3	Specific Surface, m^2/kg	Content, %		
				Al_2O_3	SO_3	Cl
Expanding Sulfoaluminate Modifier «ESAM»,	< 0.1	2850	450	10	30	< 0.1

Table 4 – Polycarboxylate-based admixture Relamix PK

Type, producer	pH	Density, kg/m^3	Dry content,%
Polycarboxylate-based admixture Relamix PK, Polyplast	8.2	1080	30

Table 5 – Water

Content, mg/l,			
Soluble salts	SO_4^{-2}	Cl^{-1}	Suspended particles
< 3000	< 2000	< 600	< 200

3 Experimental Methods

Prism samples for determining compressive and bending strength, linear deformation were made in accordance with the requirements of Self-stressing cement - technical conditions - 1335 [7]. In accordance with Self-stressing cement - technical conditions - 1335, the ratio of cement/sand=1. All compositions had the same water/binder ratio and workability, which was achieved due to the adding of the polycarboxylate-based admixture Relamix PK into the mortar mixture.

3.1 Experimental Program

Table 6 - Experimental program

№	Modifier	W / B	Dosage CSA,% by weight of Binder	Storage
1.1	Referent (without CSA)	0.3		Storage at humidity 55% ± 5
2.1	CSA	0.3	5	
2.2			10	
2.3			15	
10.1	Referent (without CSA)	0.3		Storage in the water
20.1	CSA	0.3	5	
20.2		0.3	10	
20.3		0.3	15	

3.2 Experimental Results

The results of experimental studies are shown in tables 7 - 11 and Figures 2-5.

Table 7 – Results of Cone Spread

NO		Cement (gm)	Sand (gm)	CSA(%)	Water (gm)	W/Binder ratio	Cone Spread (mm)
1.1	10.1	1000	1000	-	150	0.3	113
2.1	20.1	1000	1000	5	150	0.3	111
2.2	20.2	1000	1000	10	150	0.3	110
2.3	20.3	1000	1000	15	150	0.3	108

Table 8 – Flexural strength

No	Flexural strength, MPa at age, days		
	1	3	28
Referent	4.8	6.52	9.1
5 % CSA	5.6	6.7	8.9
10 % CSA	5.5	6.9	8.2
15 % CSA	5.9	7	9.2

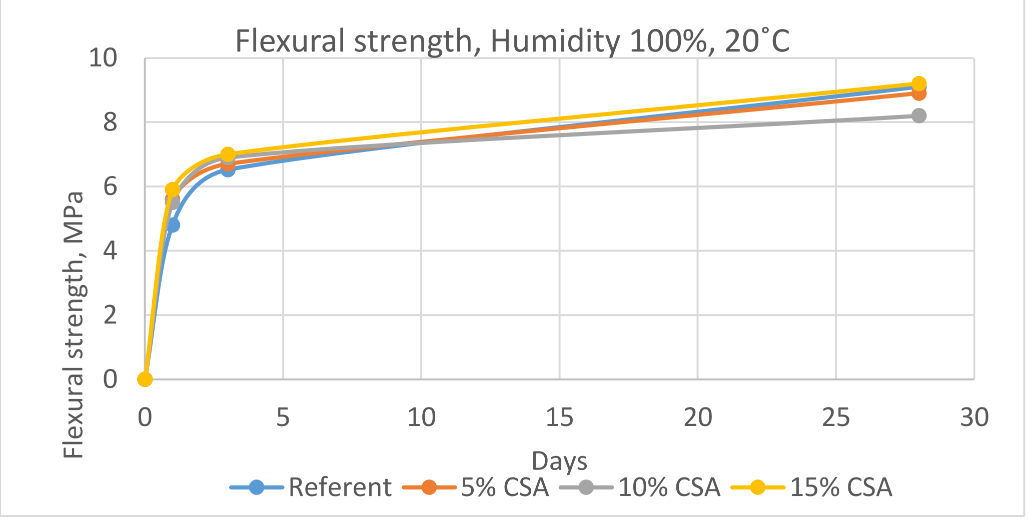

Figure 2 – Flexural strength results

Table 9 – Compressive strength

No	Compressive strength, MPa at age, days		
	1	3	28
Referent	33	54.1	65.5
5 % CSA	32.2	50	52.1
10 % CSA	29.5	46.8	51.8
15 % CSA	28.5	42.8	49.9

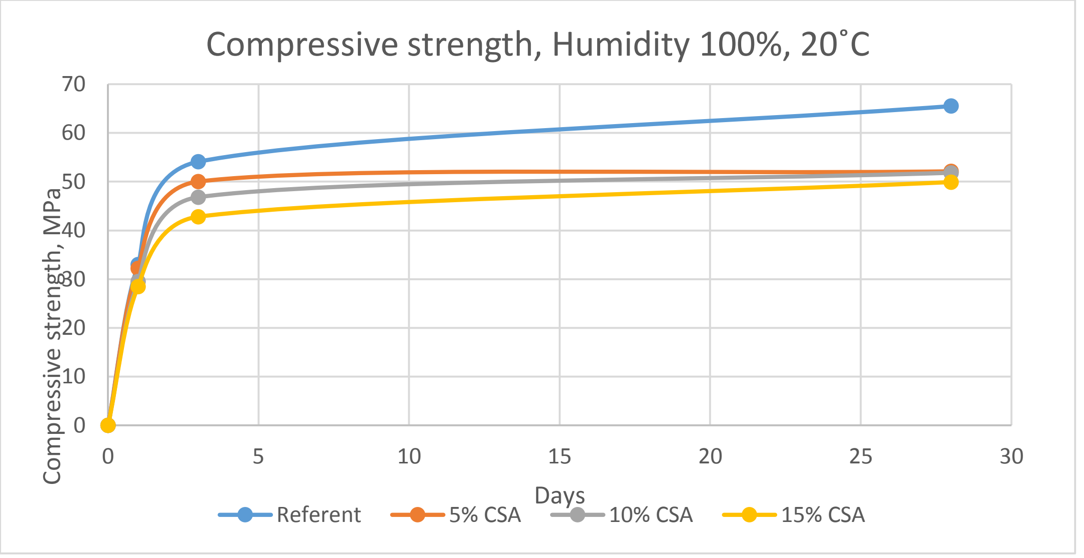

Figure 3 – Compressive strength results

Table 10 – Relative Linear Deformation Humidity 55 %

No	Relative Linear Deformation, %						
	1	2	3	7	14	20	28
Referent	0	0.006	-0.03	-0.045	-0.04	-0.03	-0.02
5 % CSA	0	0.01	-0.065	-0.09	-0.065	-0.065	-0.062
10 % CSA	0	0.012	-0.066	-0.093	-0.049	-0.054	-0.051
15 % CSA	0	0.015	-0.085	-0.12	-0.1	-0.07	-0.07
Referent	0	0.01	-0.065	-0.09	-0.065	-0.065	-0.06

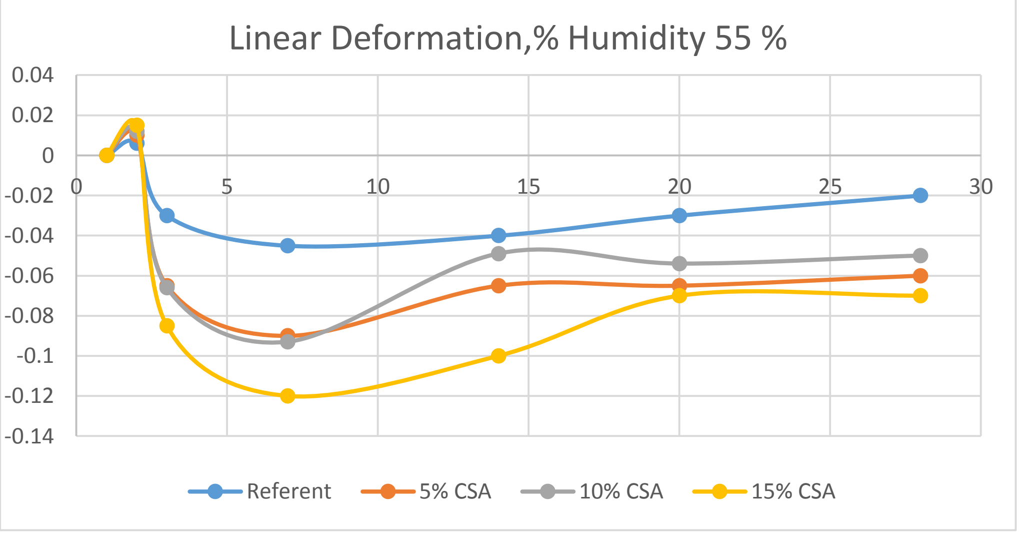

Figure 4 – Relative Linear Deformation at Humidity 55 %

Table 11 – Relative Linear Deformation Humidity 100 %

No	Relative Linear Deformation, %						
	1	2	3	7	14	20	28
Referent	0	2	3	7	10	14	28
5 % CSA	0	0.0889	0.1	0.12	0.05	0.03	0.01
10 % CSA	0	0.13	0.19	0.27	0.27	0.25	0.2
15 % CSA	0	0.17	0.19	0.32	0.32	0.27	0.23

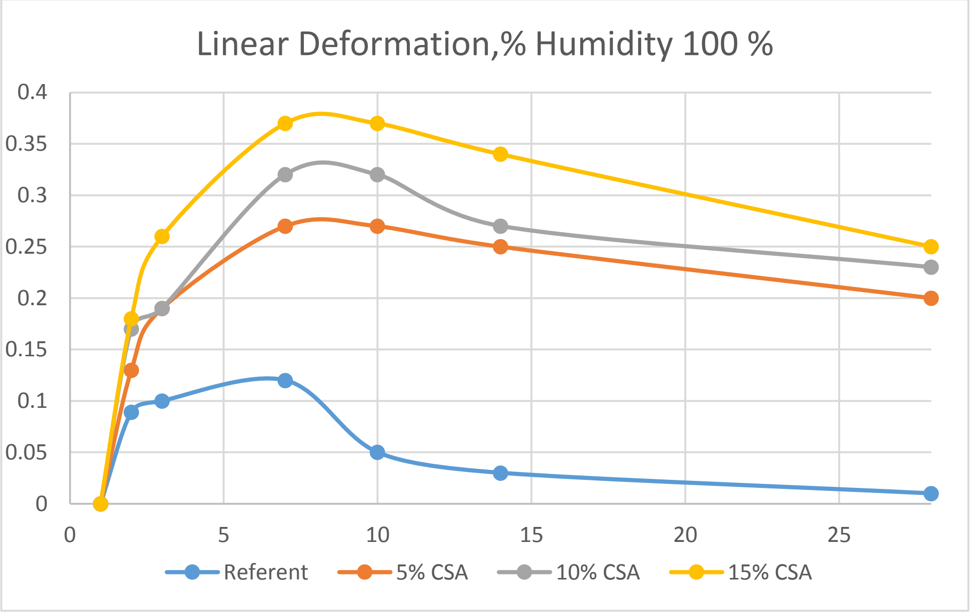

Figure 5 – Relative Linear Deformation at Humidity 100 %

4 Conclusions

1. The initial stage of the study on the influence of expanding additives on the crack resistance of concrete is to determine the effect of Sulfoaluminate based additives on the main properties of a mortar - compression and bending strength, as well as linear deformation of prism samples at different environmental humidity.

2. As a result of the work, the following patterns were identified:

- Bending strength of mortars with CSA increased at the age of 1-3 days by 12.5...20% compared with referent mortar. Moreover, the strengths at the age of 28 days of mortars with CSA and the referent are practically equal.

- Compressive strength of mortars with CSA reduced by 20...23% for all dosages of CSA.

- Relative linear deformations depend on the humidity of the environment. At a humidity of 100%, the relative linear deformations are positive and the expansion increases with increasing dosage of the expanding additive. Peak expansion occurs on 5...10 days of hardening.

- When hardening in dry air at a humidity of 55%, the greatest shrinkage deformations are characteristic for mortars with CSA. Moreover, with an increase in CSA dosage, shrinkage increases.

- Based on the results of shrinkage deformations, we can conclude that the expanding effect of CSA is fully manifested at high humidity, i.e. under construction conditions, this means very high-quality moisture care for structures.

In the case of hardening of structures in low humidity, i.e. when it is impossible to provide high-quality moisture care, for example, for vertical structures, the use of expanding additives is impractical and harmful.

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