

Properties of cement stone structure depending on the dispersion of calcium sulfoaluminate

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Abstract. Effect of expanding aluminate hardening additives dispersity on formation of cement stone structure is studied. It is shown that the greatest expansion effect in combination with stone high strength is due to $4\text{CaO} \cdot 3\text{Al}_2\text{O}_3 \cdot \text{CaO} \cdot \text{SiO}_2$ mineral fractions of 45-63 μm in size. Large crystals of ettringite are gradually formed in hardening stone, when finely ground component of Portland cement becomes highly strong due to its rapid hydration. Under these circumstances, ettringite crystallization results in system expansion.

1 Introduction

Cement stone structure depends on many factors. The main ones are the amount of hydrates and porosity [1-5]. The structure always varies depending on composition and amount of crystalline hydrates formed. Crystalline hydrates formation is determined by such factors as presence of impurities in minerals, hardening conditions, and hardening system dispersity.

Various materials are used as expanding additives [6-12]. Currently, aluminate hardening materials are widely used as expanding additives [13-18]. Calcium sulfoaluminate (SAC) is used as an expanding additive for this paper.

2 Materials and methods

Effect of expanding component dispersity on the formation of cement stone structure was studied on Portland cement (OPC) mixtures with an expanding component of calcium sulfoaluminate fractions of various sizes: < 28 μm , 28-45, 45-63, 63-80 and < 80 μm . Portland cement clinker was ground to a specific surface area of 2700 m^2/g . and 3.500 m^2/g . Gypsum was ground to a specific surface of $S = 3.500 \text{ m}^2/\text{g}$. Cements were prepared by mixing components in the following ratio: Portland cement clinker – 80%, expanding additive (of a certain fraction) – 10% and gypsum – 10%. Ready mixes were flooded with water at a Water cement ratio of 0.4. Produced samples of cement grout were hardening under normal conditions for 1, 3, 7, 14, and 28 days and tested for strength and expansion. The samples were also subjected to physical and chemical analysis.

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3 Results

Sample degree of hydration was estimated by the change in the intensity of main analytical peak of $4\text{CaO}3\text{Al}_2\text{O}_3\text{CaOSiO}_2$ mineral — ($d = 0,372 \text{ nm}$), Portland cement clinker degree of hydration was estimated by alit.

The following results were obtained for mixtures. Characteristics of $4\text{CaO}3\text{Al}_2\text{O}_3\text{CaOSiO}_2$ mineral and Portland cement clinker peaks are shown in Table 1.

Table 1. Characteristics of $4\text{CaO}3\text{Al}_2\text{O}_3\text{CaOSiO}_2$ mineral and Portland cement clinker peaks.

Characteristics of minerals	SAC ($4\text{CaO}3\text{Al}_2\text{O}_3\text{CaOSiO}_2$)				OPC			
	d, nm	Int	half-width	peak area	d, nm	Int	half-width	peak area
source materials	0,3754	505	0,19	209	0,2797	208	0,31	67
sieve residue R0063	0,3746	233	0,2	177	0,2786	445	0,25	136
sieve residue R0045	0,3738	502	0,19	205	0,2782	102	0,32	65
undersize	0,3736	510	0,18	210	0,2780	97	0,32	42

Hydrated samples X-ray phase analysis showed that $4\text{CaO}3\text{Al}_2\text{O}_3\text{CaOSiO}_2$ particles of fine fractions ($<28 \mu\text{m}$ and $28-45 \mu\text{m}$) were fully hydrated by the 14th day, and particles of middle fractions ($45-63 \mu\text{m}$) – by the 28th day. Traces of non-hydrated calcium sulfoaluminate particles are seen in hydrated samples containing coarse fractions ($63-80$ and $>80 \mu\text{m}$). The degree of hydration is shown in the figure 1.

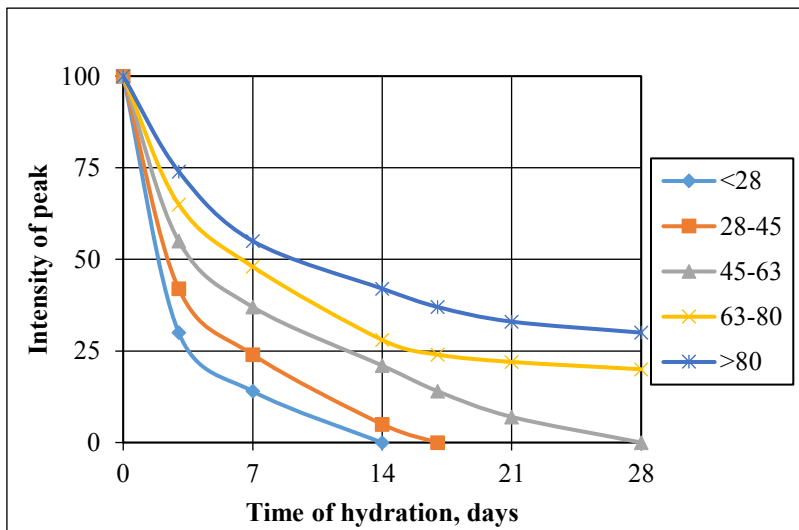


Fig. 1. The degree of hydration.

Cement stone pore structure analysis showed that the combination of fine ground calcium sulfoaluminate and fine ground Portland cement clinker contributes to formation of a low porosity structure (Fig.1), which facilitates cement stone strengthening and low expansion.

The system expands most of all in the samples containing medium and coarse fractions (>80 μm , 63-80 μm , 45-63 μm). The best results are obtained in mix with Portland cement clinker ground to a specific surface $S = 3500 \text{ m}^2/\text{g}$.

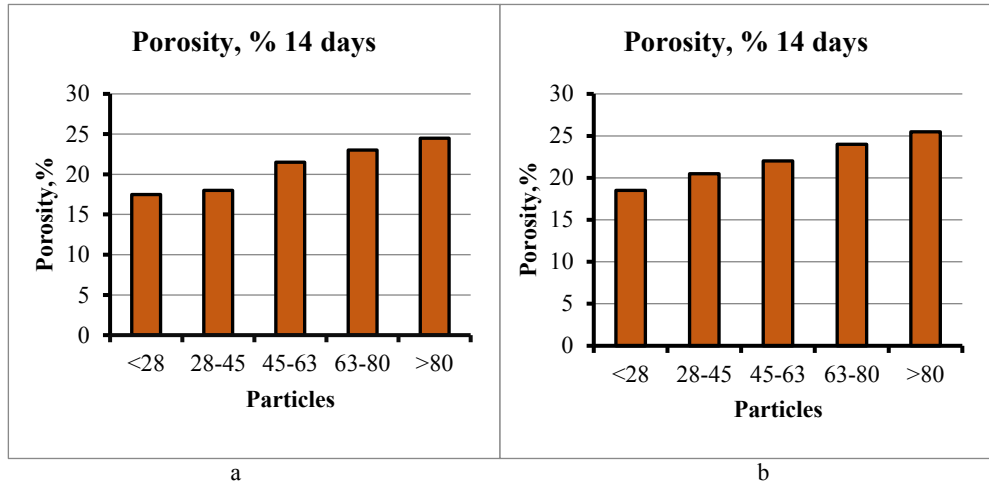
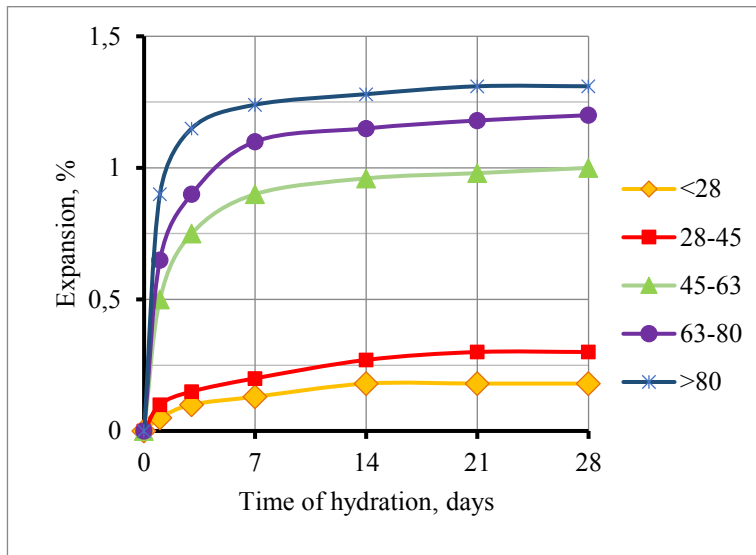
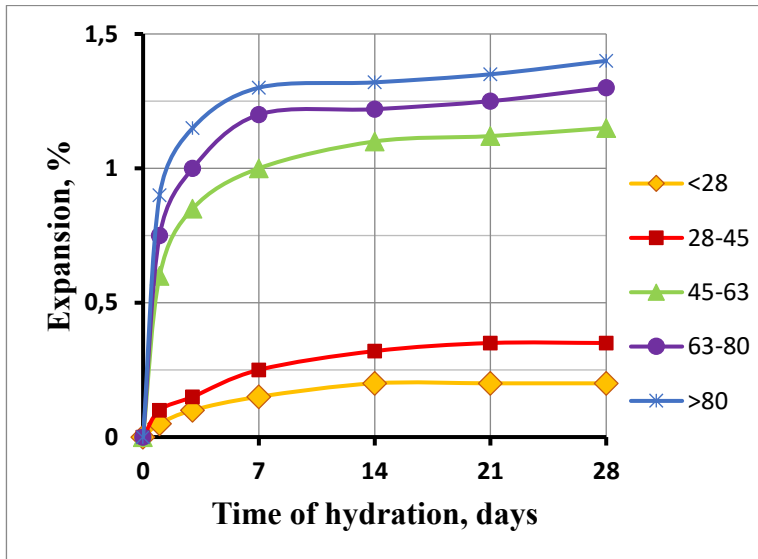


Fig. 2. Total porosity of the samples. (a - $S_{(OPC)} = 2.700 \text{ m}^2/\text{g}$, b - $S_{(OPC)} = 3.500 \text{ m}^2/\text{g}$).



a

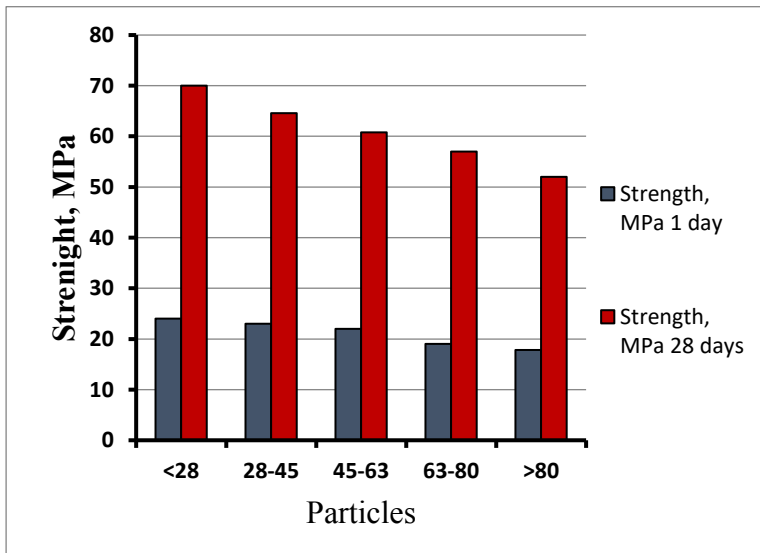


b

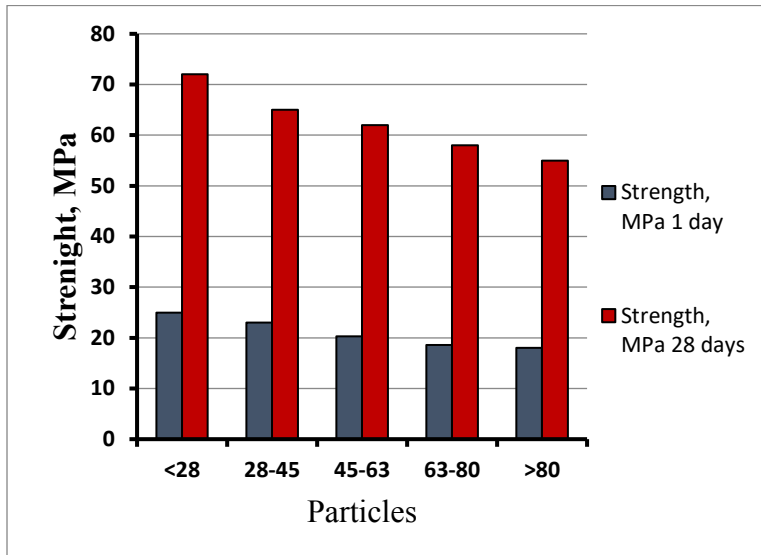
Fig. 3. Expansion of produced cement with expansive admixture (a - $S_{(OPC)} = 2.700 \text{ m}^2/\text{g}$, b - $S_{(OPC)} = 3.500 \text{ m}^2/\text{g}$).

Electron microscopic studies of cement stone structure showed that ettringite small crystals, which fill the intergranular space, compact the stone, while the large ones, which fill the pore space, form a strong stone frame (Fig. 2, Fig. 3).

The studies have shown that grinding fineness and cement grain size distribution have a great influence on formation of cement stone structure. Dispersity of both Portland cement component and expanding component is important.



a



b

Fig. 3. Strength of mixed cements for different fractions. (a - $S_{(OPC)} = 2.700 \text{ m}^2/\text{g}$, b - $S_{(OPC)} = 3.500 \text{ m}^2/\text{g}$).

Thus, for calcium sulfoaluminate expanding component, the greatest expansion effect in combination with stone high strength is due to the fractions of this mineral of 45-63 μm in size. While fine component of Portland cement gets highly strong due to its rapid hydration, ettringite large crystals gradually form in hardening stone.

Under these circumstances, ettringite crystallization results in system expansion.

4 Conclusion

We can conclude that the expanding additive containing calcium sulfoaluminate should be ground to fractions of 45-63 μm . This allows obtaining expanding cement with a large expansion effect.

The Portland cement component must be ground to a specific surface of 3,000 m^2/g to obtain dense and durable cement stone.

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