

## **SURFACE CRACK SELF HEALING BEHAVIOUR OF MORTARS WITH EXPANSIVE ADDITIVES**

K. Sisomphon<sup>1</sup>, O. Copuroglu<sup>1</sup> and E.A.B. Koenders<sup>1</sup>

<sup>1</sup>Delft University of Technology, Microlab, Faculty of Civil Engineering and Geosciences,  
Stevinweg 1, 2628 CN, Delft, The Netherlands  
Email: [k.sisomphon@tudelft.nl](mailto:k.sisomphon@tudelft.nl), [o.copuroglu@tudelft.nl](mailto:o.copuroglu@tudelft.nl), [e.a.b.koenders@tudelft.nl](mailto:e.a.b.koenders@tudelft.nl)

**Keywords:** Calcium carbonate, Crack, Ettringite, Expansive additive, Self-healing

### **INTRODUCTION**

In previous study, the self-healing potential of mortars incorporating calcium sulfoaluminate based expansive agents (CSA) was studied. In an effort to enhance the self-healing potential of cement-based materials, the mortar mixtures incorporating CSAs with different chemical compositions were evaluated. The effect of additives on surface crack closing ability and microstructures of pre-cracked specimens was investigated.

### **EXPERIMENTAL**

Mixtures of synthesized calcium-aluminate crystal, anhydrite and free lime – a ternary blend expansive additive (CSA) were studied in this research. Two types of CSA additives (CSA $\alpha$  and CSA $\beta$ ) with different chemical composition were used. The mineral composition of CSA $\alpha$  was 32% C<sub>4</sub>A<sub>3</sub>S<sub>2</sub>, 20% f-CaO and 40% CS, while CSA $\beta$  consisted of 10% C<sub>4</sub>A<sub>3</sub>S<sub>2</sub>, 50% f-CaO and 10% CS. It has to be noted that CSA $\alpha$  is an original commercial expansive additive product normally for shrinkage compensation, while CSA $\beta$  is a modified one which contains more free-CaO. Three mixtures (control mortar, mortar with CSA $\alpha$  and mortar with CSA $\beta$ ) were designed based on water-to-cementitious ratio (*w/cm*) of 0.25 and sand-to-cementitious ratio (*s/cm*) of 2.0 by mass. For those mortars with CSA addition, the replacement ratio was controlled at 10% for both mixes. The disc-shape specimens were cast in plastic containers with 75 mm diameter and a height of about 20 mm. After 28 days, the specimens were pre-cracked in the manner of splitting tensile strength test to crack width of about 100-400 microns. After pre-cracking, the specimens were fastened by a 75mm diameter PVC pipe bracket to create a confinement. Then, all specimens were submerged into water which was replaced once every 7 days. The residual surface crack widths were measured at 1, 4, 7, 14 and 28 days wetting periods. To evaluate the water permeability through crack, water passing test was conducted with a constant water head of 100±5 mm.

### **RESULTS AND DISCUSSIONS**

The surface cracks of mortars before and after self healing process were investigated by using stereo optical microscope. After wetting period, the formation of calcium carbonate crystals can be observed. The width of crack was measured on 20 different locations at 0, 3, 7, 14 and 28 days wetting period. The initial crack width of all specimens was found in a range between about 50 and 400 microns. The change of crack width was used as an indicator of quantitative evaluation of self crack healing. The reduction of crack width is demonstrated in Figure 1(a-c) for control mortar, CSA $\alpha$  mortar and CSA $\beta$  mortar, respectively.

The results indicate that the cracks of all mixtures were healed with different rates. For control specimen, the surface crack with the width up to about 150 microns can be sealed within 28 days. For larger crack width, the residual crack width of the control mortar was about 50% of the initial width after 28 days wetting. It is clearly seen that the use of CSAs is beneficial with respect to crack closing phenomenon. Up to 28 days wetting period, the ability of crack closing was in the order of Control < CSA $\beta$  < CSA $\alpha$ . At 56 days, however, the surface cracks of both CSA mortars were completely sealed.

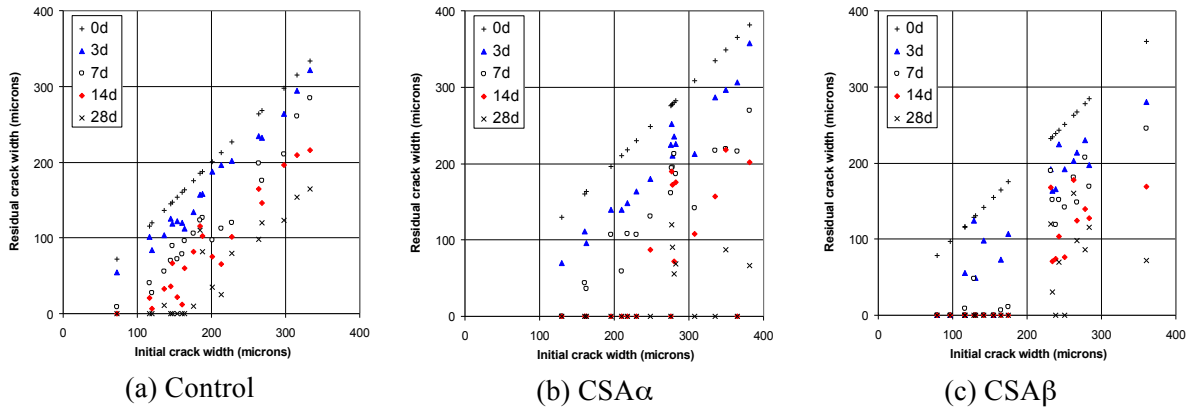


Figure 1: Surface crack width corresponding to wetting period.

Figure 2 shows the result of water passing rate of pre-cracked mortars corresponding to wetting period. At the beginning of the test, the initial water passing rates were measured. Thereafter, the reduction of water passing rate was presented in relative values to the initial water passing rate. For the control mortar, slight reduction of water passing rate can be observed in the early period, while those mortars with CSA showed rapid reduction of water passing ability at the first 5 days. In the beginning period, it was clearly seen that CSA $\alpha$  mortar has a more rapid crack closing ability compared to the CSA $\beta$  mortar. A similar tendency has been obtained from the surface crack closing ability investigated by stereomicroscope. After 28 days wetting, however, it seems that CSA $\beta$  had a slightly lower relative water passing rate than that CSA $\alpha$ . An explanation to this finding could be the slower reaction of free-CaO expansion compared with the formation of ettringite. The mass fraction among three oxides (CaO, Al<sub>2</sub>O<sub>3</sub> and SO<sub>3</sub>) indicated that ettringite would be a sole major product of CSA $\alpha$  reaction. The limited amount of C<sub>4</sub>A<sub>3</sub>S in CSA $\beta$  mix would cause a less formation of ettringite compared with that CSA $\alpha$  mix. It can be hypothesized that the formation of ettringite plays a major role on early healing period, while the presence of excess free-CaO in CSA $\beta$  would react and seal the crack in later ages.

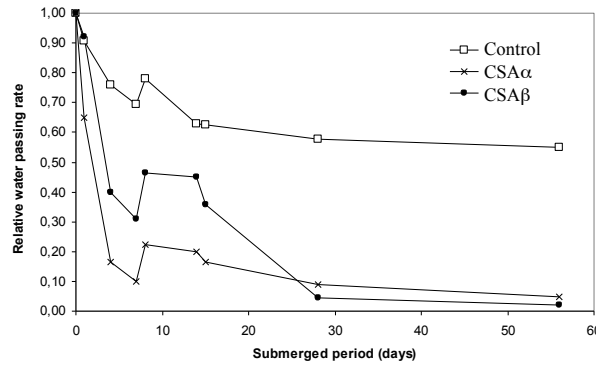


Figure 2: Relative water passing rate of pre-cracked mortars.

## CONCLUSIONS

This paper presents the results on the crack closing potential of mortars incorporating calcium sulfoaluminate based expansive agents (CSAs). The results indicated that the use of CSA is beneficial with respect to surface crack self-closing phenomenon. It seems that the formation of ettringite plays a role on early healing period. In case of CSA $\beta$ , the presence of excess free-CaO would react and seal the crack in later period.

The authors would like to thank Agentschap NL for the financial support granted for the projects SHM08729 and SHM08707, as well as materials and technical supports from Denka Chemical GmbH.