Superabsorbent polymers to promote and stimulate autogenous healing in cementitious materials

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Keywords: Self-healing, multiple cracking, durability, hydrogels, CaCO₃.

ABSTRACT

Concrete cracking is in some cases inevitable. Autogenous healing may prove to be useful to limit repair works caused by concrete cracking. Further cement hydration, pozzolanic activity by fly ash and calcium carbonate crystallization will hereby heal the cracks if crack widths are limited, and if sufficient building blocks and water are present. Synthetic microfibres may be used to limit the crack width, leading to strain-hardening cementitious materials. The water can be provided by the use of superabsorbent polymers, which are extracting moisture from the environment. This moisture can be used for autogenous healing and may lead to a regain in mechanical properties. As the crack seems to be completely visually closed at the surface, one may ask whether this healing also is present in the interior of the crack. Thin section analysis was therefore used to study the extent of autogenous healing perpendicular to the surface, through a crack. The autogenous healing in a cementitious material is dependent on the crack depth. Only the first part of the crack is closed by crystal formation in case of wet/dry cycles. In combination with superabsorbent polymers, the extent of healing was more substantial, even in the interior of the crack. The smart cementitious material with superabsorbent polymers thus is an excellent material to use in future building applications.
1. INTRODUCTION

It is sometimes hard to repair cracks in buildings or bridges due to the inaccessibility for maintenance crews. The costs to repair structures and labor time are also of importance as big measures need to be taken when concrete is severely damaged. One way of counteracting this concrete deterioration is by optimally using the autogenous healing capacity of the concrete itself. By providing the building blocks through a well-thought mixture, by limiting the crack width below 30-50 µm by means of synthetic microfibres, and by providing water through the inclusion of superabsorbent polymers (SAPs), this can be achieved [1].

2. MATERIALS

The mortar mixtures contained CEM I 52.5 N, Class F fly ash (FA/CEM = 1), fine silica sand M34 from Sibelco (M34/B = 0.35), water (W/B = 0.30), polycarboxylate superplasticizer Glenium 51 (Spl/B = 0.0097), 2 volume-% of Polyvinyl-alcohol (PVA) fibres from Kuraray, and 1 mass-% (m%) relative to the cement weight of SAP. The SAP used is a polyacrylate type of polymer. Additional water was used to compensate for the loss in workability.

3. METHODS

Cracks were created by means of a four-point-bending test (Walter+Bai DB 3) at the age of 28 days until 1% of strain was reached (1 µm/s). After cracking, samples were cured at 20 ± 2°C by applying wet/dry cycles (alternately 1 h stored in water and 23 h at 60% RH). After another 4 weeks, thin sections perpendicular to the crack plane were made to study the new-formed products. The thin sections were analyzed with a Leica DMLP microscope with a DFC 295 camera. Scanning Electron Microscopy (SEM) equipped with an EDS (Energy Dispersive Spectroscopy) detector was used for elemental analysis of the formed autogenous healing products.

4. RESULTS

Figure 1 shows micrographs of thin sections of the interior of a crack of a specimen with and without SAPs at the crack mouth after being stored in wet/dry cycles.

![Figure 1. Thin sections of a crack in a reference cementitious material (a) and in a cementitious material with superabsorbent polymers (b) under cross-polarized light after being stored in wet/dry cycles. The scale bar amounts to 50 µm.](image-url)
As the strain was limited to 1%, only small cracks were formed. The crack width was always limited to 50 µm for all test series. The healing mechanism of CaCO$_3$ crystals shows teeth-like structures in the interior of a crack, expanding towards each other and eventually making a solid bridge in the crack. The amount of crystals is higher in specimens containing SAPs compared to specimens without SAPs. This is possibly due to the slow release of water to the cementitious matrix during dry periods by the swollen SAP particles near the crack face. At the crack mouth, the crystals are able to bridge the crack, leading to the regain in mechanical properties [2].

Figure 2 shows a crack in a specimen with SAPs. At the lighter parts (i.e. the sand particles) at the crack faces, there is less crystal formation. As CaCO$_3$ primarily needs Ca$^{2+}$ ions, those cannot be provided by the siliceous sand particles, explaining the lower amount of crystals found at the sand particle edges. Also, a small difference in colour can be seen in different crystal clusters. The darker crystal formation is likely to be a mix of CaCO$_3$ and Ca(OH)$_2$, formed by further hydration. The pure white crystals are likely to be pure CaCO$_3$.

The crystals are formed from 400 till over 1000 µm inside the crack. In the interior of a crack, the amount of crystals is less and only at some distinct places the crystals bridge a crack, mostly in the vicinity of a fibre (as they act as a nucleation site for the CaCO$_3$ crystals). As the crack is sealed at the surface from intruding water, the crystallization comes to a hold in the interior of the crack. Also, the closer to the crack tip, the more further hydration compared to CaCO$_3$ crystallization is found as the CO$_2$ will preferably be present at the surface where it dissolves in the water layer during the wet/dry cycles. Also Fan & Li [3] showed that the region close to the surface had a high amount of crystalline products (CaCO$_3$). At greater depths, there were less healing products formed (occurring healing products resulted from further hydration and pozzolanic reactions). This was also confirmed by means of X-ray computed microtomography [4].

EDS spectra (Figure 3) showed that the formed material was mainly composed of calcium carbonate (CaCO$_3$). In the inner crack less CaCO$_3$ was formed, but, further hydration occurred, especially at the crack tip. This led to a regain of tightness and a regain in the available cross-sectional area and thus mechanical properties.
5. CONCLUSIONS

- The combination of microfibres and superabsorbent polymers enhances the autogenous healing capacity. SAPs are able to extract moisture from the environment and provide the moisture to the matrix for self-healing.
- More healing products in the interior of the crack are found in specimens with superabsorbent polymers.
- Analysis of thin sections and Energy Dispersive Spectroscopy showed that crystals are mainly formed near the crack mouth and are likely to be calcium carbonate.

ACKNOWLEDGEMENTS

As a Postdoctoral Researcher of the Research Foundation-Flanders (FWO-Vlaanderen), D. Snoeck wants to thank the foundation for the financial support.

REFERENCES