Use of encapsulated polyurethane in concrete to limit chloride penetration through cracks

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Chloride-induced corrosion of reinforcing steel is one of the most important damage mechanisms of reinforced concrete structures. The appearance of cracks in reinforced concrete structures will accelerate the onset of corrosion and its propagation. In this research the application of self-healing concrete by means of encapsulated polyurethane in the concrete matrix is investigated as a possible method to autonomously heal cracks in concrete elements. In this way, fast ingress of chloride to the steel reinforcement through cracks is prevented and the service life of the concrete elements can be extended.

In this research, cylindrical concrete specimens (ϕ = 100 mm; h = 50 mm) with and without self-healing properties were produced. The specimens with self-healing properties contained capsules filled with a polyurethane precursor which were positioned at a fixed location within the concrete specimens. Cracks with a target crack width of 300 μm were created in the specimens by means of a crack width controlled splitting test. For the specimens with the self-healing properties, the capsules broke due to the creation of the crack and the encapsulated polyurethane precursor was released in the crack. Subsequently the healing agent hardened in the crack due to reaction with moisture.

All specimens were partially coated to ensure unidirectional chloride ingress and were subsequently immersed in a 165 g/l NaCl solution. After 7 and 19 weeks of exposure, chloride profiles of uncracked, cracked and healed specimens were determined by collecting powders in layers around the crack and measuring their total chloride content by means of potentiometric titrations.

Figure 1 shows the average chloride profiles of (un)cracked and healed specimens for the two exposure times. First of all, the presence of a crack has a big influence on the chloride penetration, especially at depths below the surface higher than 10 mm.

At the deepest measured layer (18-20 mm) the chloride content was 27 times higher due to the presence of a crack at both exposure times. The proposed autonomous healing mechanism was capable of reducing the chloride ingress through cracks. Close to the exposed surface (at depths from 0-8 mm) the chloride content in the specimens with a healed crack is lower than for uncracked concrete at both exposure times. This can mainly be attributed to the fact that some of the polyurethane leaked from the crack and hardened on the concrete surface. From a depth of 10 mm onwards, the chloride penetration in concrete with a healed crack is slightly higher than in uncracked concrete, but much lower than in the concrete with an untreated crack. The healing of the crack is thus not perfect, but it does reduce the chloride concentration to a large extent. In order to make a quantitative analysis, the self-healing efficiency (SHE) was determined for each layer. The SHE was defined as the ratio of the difference between the mean chloride content of the cracked and the healed specimens over the difference between the mean chloride content of the cracked and the uncracked specimens. At an exposure time of 7 weeks the SHE was 82% at a depth of 10-12 mm and decreased to a value of 70% at a depth of 18-20 mm. After 19 weeks of exposure the SHE at these depths amounted to 78% and 73%, respectively.

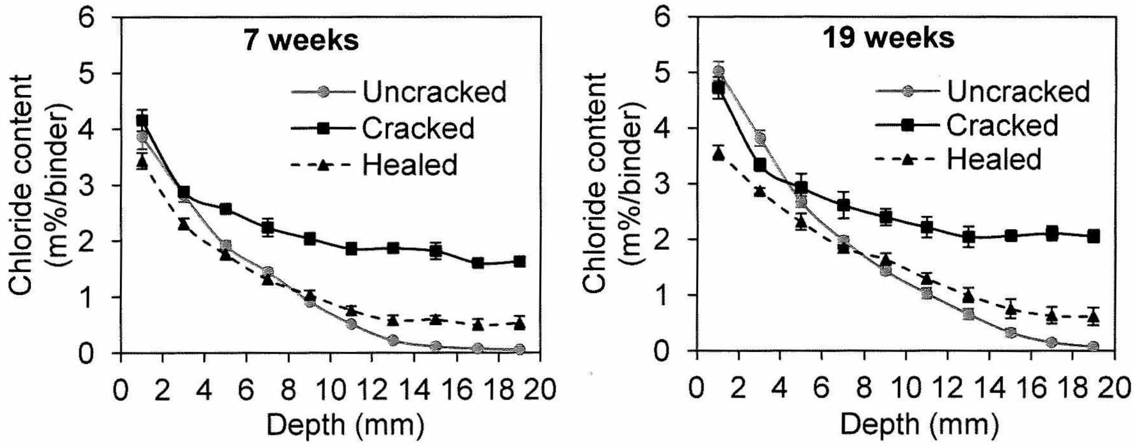

Figure 1: Profiles of the average total chloride content for uncracked, cracked and healed specimens after 7 and 19 weeks of exposure.

From the discussed results it can be concluded that autonomous crack healing forms a partial barrier against immediate ingress of chlorides through the cracks. Perfect healing of the crack, so that the concrete would behave as uncracked, could not be achieved so far. However, the large reduction of chloride content due to the healing mechanism will have important benefits for the durability of reinforced concrete since a much lower amount of chlorides will reach the steel reinforcement through the cracks.