POSSIBILITY OF SELF-HEALING BY USING CAPSULES AND VASCULAR SYSTEM TO PROVIDE WATER IN CEMENTITIOUS MATERIALS

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ABSTRACT

Since self-healing of cracks is able to improve the durability of concrete structures, it has attracted much attention in the recent years. As known, in concrete matrix there are large amounts of cement grains remaining unhydrated, particularly in high performance concrete. Further hydration of these unhydrated cement grains has potential to heal cracks when additional water is available.

By now, using capsules or vascular system are the main approaches to supply liquid healing agents inside the materials for self-healing. However, it is still uncertain about the possibility of these two approaches for the supply of water for self-healing in concrete. For this question, self-healing in concrete by using capsules or vascular system to provide water was investigated. Self-healing triggered by water was simulated and consequently, the filling fraction of a crack as a function of healing time was calculated. Moreover, the probability of the crack hitting capsules was calculated as well. Based on this information, the possibility of self-healing by using capsules to provide water was determined. Meanwhile, in the case of using vascular system, ultrasonic pulse velocity measurements were carried out to evaluate the self-healing efficiency in concrete.

From the results, it was found that using capsules to supply water for self-healing has very low efficiency. In comparison, the recovery of ultrasonic pulse velocity through the cracked sample can achieve 80% after supplying water for self-healing for 330 hours by vascular system. Thereby, using vascular system to supply water for self-healing is more feasible than using capsules.

1. INTRODUCTION

It is well known that there are large amounts of cement grains remaining unhydrated in concrete matrix, particularly in high performance concrete. Further hydration of these unhydrated cement grains has potential to heal cracks when additional water is available. By now, using capsules or vascular system are the main approaches to supply liquid healing agents inside the materials for self-healing. However, it is still uncertain about the possibility of these two approaches for supply of water to trigger self-healing in cementitious materials. In this paper, the possibility of self-healing in cementitious materials by using capsules and vascular system to provide water was compared. In previous study [1], the filling fraction of a crack as a function of healing time was determined when the cracked sample was cured in water for self-healing under sealed condition. Moreover, the probability of the crack hitting capsules was
calculated as well [2]. Based on this information, the possibility of self-healing by using capsules to provide water will be determined. For the case of using vascular system, ultrasonic pulse velocity measurements were carried out to evaluate the self-healing in concrete.

2. SELF-HEALING OF CRACKS BY USING CAPSULES

2.1 Amount of water released versus capsule dosage

Since the capsules are randomly dispersed inside the matrix, only some parts of them are ruptured by cracks and thereby only the water in the ruptured capsules can be released into cracks. The amount of water released as a function of capsule dosage was calculated in previous study [2], as present in Figure 1.

![Fig. 1. Amount of water released versus dosage of capsules](image)

2.2 Filling fraction of cracks versus capsule dosage

When certain amount of water is released from ruptured capsules, the water in cracks will be absorbed by the bulk cement paste matrix and the amount of water in the crack decreases. Once the water in cracks is consumed, the self-healing stops. Therefore, the period of crack saturation with water is actually the self-healing time. According to the water transport laws in porous media, the crack saturation time versus the amount of water provided was determined, as shown in Figure 2.

![Fig. 2. Filling fraction of cracks versus healing time (10 μm crack)](image)

In previous study [1], self-healing of cracks due to further hydration as a function of healing time was simulated by a reactive transport model, which was based on ion diffusion and thermodynamic laws. As shown in Figure 3, the filling fraction of cracks by reaction products of self-healing is predicted. By coupling the results in Figure 2 and 3, the filling fraction of cracks versus amount of provided water is determined, which is displayed in Figure 4. As discussed in Section 2.1, the amount of water provided by capsules is governed by the capsule dosage added in matrix. Therefore, with the combination of Figure 1 and 4, the filling fraction of cracks by reaction products as a function of capsule dosage is addressed in Figure 5. As shown in Figure 5, the filling fraction increases with the increase of the dosage and the size of
capsules in cement paste matrix. Only 4% of the crack can be healed when dosage of capsules is 5% and the diameter of capsules is 200 μm. This value is even smaller when the size of capsules decreases. From the results, it can be learned that the efficiency of self-healing by using capsules to provide water is quite low.

3. SELF-HEAKING OF CRACKS BY USING VASCULAR SYSTEM

In addition to the capsules, it is also possible to use vascular system to provide healing agents for self-healing from the outside of the materials. In this section, the potential of self-healing by using vascular system to supply water was investigated. Reinforced concrete beams were cast and in each beam a glass tube with outside diameter of 5 mm and the wall thickness of 1 mm was embedded for the supply of water. At the age of 28 days, the initial ultrasonic pulse velocity was measured. After that, the specimens were cracked by three-point bending until crack width ranged between 0.8 mm to 1 mm. The ultrasonic pulse velocity was measured again after the cracking. Extra water was injected into cracks through the tubes for self-healing. In
comparison, the reference samples were cured without extract water. Figure 6 shows the ultrasonic plus velocity of the specimens at different stages: before cracking, after cracking and after healing. From Figure 6 it can be seen that the ultrasonic plus velocity through the specimens decreases sharply after cracking. The reason is that the transmission of ultrasonic plus through cracks is much slower than that through the concrete matrix. As being cured for a certain time after cracking, the ultrasonic plus velocity increases gradually. The recovery of ultra pulse velocity through the sample healed by water is much higher than the reference samples, which reaches almost 80% of the initial value before cracking. From the results, it is found that compared to the method of using capsules, using vascular system to supply water for self-healing is more efficiency.

4. CONCLUSIONS

In this paper, the possibility of self-healing in cementitious materials by using capsules or vascular system to provide water was compared. From the results, it can be learned that the capacity of self-healing by using capsules to provide water is very low. In comparison, the recovery of ultrasonic pulse velocity through the cracked sample can achieve 80% after supplying water for self-healing for 330 hours by vascular system. Thereby, using vascular system to supply water for self-healing is more feasible than using capsules. This principle can be applied when other liquid healing agents are used.

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REFERENCES