Performance comparison of two bacteria-based additives used for self-healing concrete

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ABSTRACT

Bacteria-based self-healing concrete as a relatively new technique is important to improve the concrete durability. However, researches on this topic mainly focus on crack self-healing capacity of concrete and the influence of bacteria-based additives on concrete matrix has been little studied. Therefore, the objective of this work was to investigate the effects of bacteria-based additives on the properties of cement paste matrix.

Two bacteria-based additives (Type 1 and Type 2) were respectively used to improve concrete self-healing capacity mainly achieved by bacteria induced mineral precipitations. First, the mineral precipitations induced by two types of bacteria-based additives in the liquid medium were analyzed with SEM and XRD. Then, the crack-healing capacity of cement paste specimens with each bacteria-based additive was evaluated by image characterization method. Moreover, the mechanical and carbonate resistance properties of cement paste specimens were compared.

Experimental results showed that both bacteria-based additives could be used to achieve the goal of concrete crack self-healing. Incorporation of Type 1 additive in cement paste resulted in about 14.7%, 6.8% and 0.1% decrease in compressive strength after 3, 7 and 28 days curing respectively. However, incorporation of Type 2 additive in cement paste resulted in about 1.6% and 2.2% decrease in compressive strength after 3 and 7 days curing respectively and 8.1% increase after 28 days curing. The carbonation depths of control specimens, specimens with Type 1 additive and specimens with Type 2 additive were 6.6, 7.0 and 6.5 mm respecively after 3 days of accelerated carbonation. The results above suggested that both additives showed potential for developing self-healing concrete, but the peoformance of Type 2 additive seemed to be better.

1. INTRODUCTION

Bacteria-based self-healing concrete as a relatively new technique is important to improve the concrete durability. However, researches on this topic mainly focus on crack self-healing capacity of concrete and the influence of bacteria-based additives on concrete matrix has been little studied. Therefore, the objective of this work was to investigate the effects of bacteria-based additives on the properties of cement paste matrix.

2. MATERIALS AND METHODS

Two types of bacteria-based additives (Type 1 and Type 2) were used in this study. Type 1 additive was consisted of calcium lactate and bacteria spores and Type 2 additive was consisted of calcium formate and bacteria spores. The mineral precipitations induced by two types of bacteria-based additives in the liquid medium were analyzed with Scanning Electron Microscope (SEM) and X-ray Diffraction (XRD), respectively. Then, cement paste specimens with dimensions of 40 × 40 × 160 mm were prepared by mixing ordinary Portland cement, bacteria-based additives and tap water. The mixing proportion is shown in Table 1. After 24 h curing specimens were unmolded and kept in standard curing room (RH=90%, T=20±3℃).

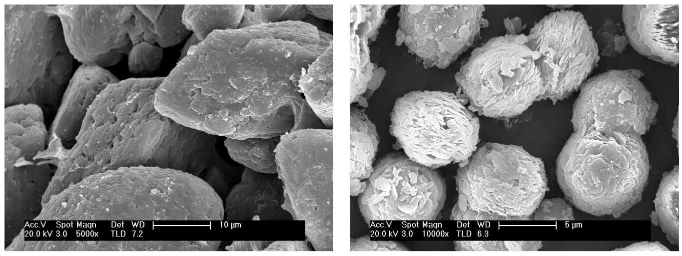
For crack healing quantification, specimens were taken out at the age of 3 days and cracks with average width of 0.5 mm were created by the embeded method.The cracked specimens were immersed in water for repairing 7 days. The image characterization method was used to evaluate the crack healing efficiency. Specimens were removed from water every few days to observe and record the changes of cracks width using the digital camera. The image processing of specimen surface cracks before and after healing were carried out. In order to determine the influence of bacteria-based additives on compressive, sets of 3 replicate test specimens were tested for compressive strength after 3, 7 and 28 days curing. For accelerated carbonation tests, specimens were taken out at the age of 7 days. The accelerated carbonation tests were performed in a CO_2-box at a temperature of 20±3℃, a R.H of 70±5% and a CO_2 concentration of 20±3%. After 3 days of carbonation, the test specimens were split and 1% phenolphthalein alcohol solution was sprayed on the fresh side to test the carbonation depth.

Table1: Mixing proportion of cement paste

Cement (g)	Water (g)	Bacteria-based additive (g)
1450	580	0
1450	580	30 (Type 1)
1450	580	30 (Type 2)

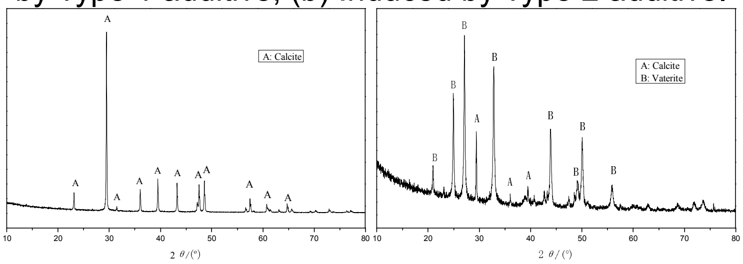
3. RESULTS AND DISCUSSION

SEM pictures of bacteria induced mineral precipitations are presented in Figure 1. The results showed that the precipitations induced by Type 1 and Type 2 additive showed differences in morphology and size. The XRD diffraction spectrums of the precipitations are presented in Figure 2. The analysis results showed that the mineral precipitations induced by Type 1 additive are calcite crystal and the mineral precipitations induced by Type 2 additive are vaterite and calcite mixed crystal, which suggest that precipitations formation was related to additive types.



(a) (b)

Figure1: SEM pictures of bacteria induced mineral precipitations. (a) Induced by Type 1 additive; (b) Induced by Type 2 additive.



(a) (b)

Figure 2: XRD spectrums of bacteria induced mineral precipitations. (a) Induced by Type 1 additive; (b) Induced by Type 2 additive.

The images of cracked specimens before and after healing is presented in Figure 3. It can be seen that the cracks were healed by precipitations. The crack of specimens with Type 1 and Type 2 additive was nearly fully healed after 7 days of immersion in tap water , while the crack of control specimens was only partially healed.

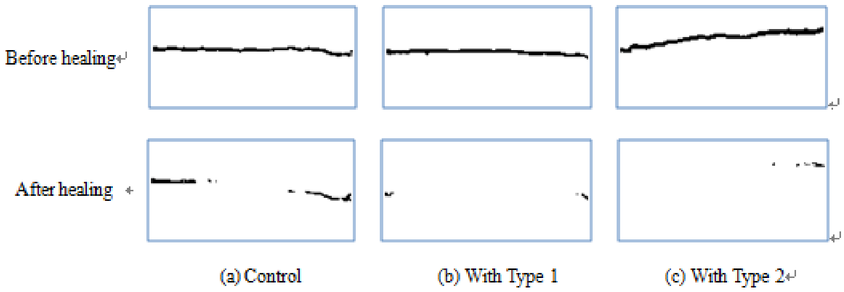


Figure 3: Surface images of cracked specimens before and after healing.

The compressive strength development of cement paste samples in time is presented in Figure 4. Incorporation of Type 1 additive in cement paste resulted in about 14.7%, 6.8% and 0.1% decrease in compressive strength after 3, 7 and 28 days curing respectively. However, incorporation of Type 2 additive in cement paste resulted in about 1.6% and 2.2% decrease in compressive strength after 3 and 7 days curing respectively and 8.1% increase after 28 days curing. The results aboved indicated that both bacteria-based additives could result in a slight of compressive strength loss in early curing age and almost no influence in 28 days curing, even increase.

In addition, the carbonate resistance properties of cement paste specimens with bacteria-based additives were researched. The effect of bacteria-based additives on carbonate resistance proprety was shown in Figure 5. The carbonation depths of control specimens, specimens with Type 1 and specimens with Type 2 were 6.6, 7.0 and 6.5 mm respecively after 3 days of accelerated carbonation, which indicated that both bacteria-based additives had little effect on carbonate resistance property.

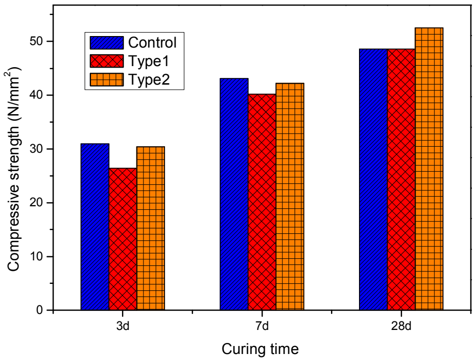


Figure 4: Compressive strength development of cement paste samples in time

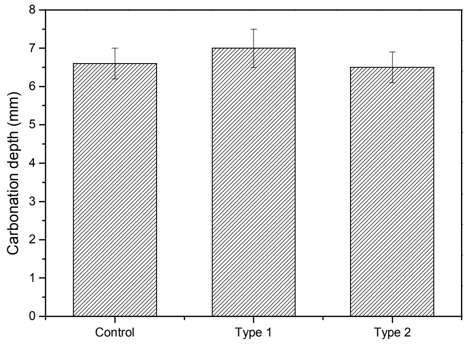


Figure 5: The effect of bacteria-based additives on carbonate resistance proprety

4. CONCLUSION

In Conclusion, the results showed that both bacteria-based additives could be used to achieve the goal of concrete crack self-healing and the peoformance of Type 2 additive seemed to be better. Both bacteria-based additives had little effect on compressive strength and carbonate resistance property, which suggested that both additives showed potential for developing self-healing concrete.

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