

EVALUATION OF A MICROCAPSULE BASED SELF-HEALING SYSTEM FOR CEMENTITIOUS MATERIALS

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ABSTRACT

An international cooperation research project has been financially supported by China Nature Science Foundation, which consists of three relatively independent, but strategically integrated research sub-programs, aiming at the formation of a self-healing system based on the microcapsule principle for the cementitious composites. In this paper, a self-healing system triggered by physical process (cracking) is introduced. The healing material mainly consists of epoxy like materials. The discussion concerning microcapsule techniques are presented in another paper in this conference. This study mainly focuses on the two healing mechanisms: i.e. the mechanical recovery and the permeability related recovery. The primary test results concerning these healing mechanisms are presented and the healing effects on the relevant properties are further discussed.

1. INTRODUCTION

Self-healing system applied in concrete will have special advantages in comparison with the traditional post-damage repair methods. Since it can self-detect and self-recover the degraded performance, the self-healing system in concrete has been attracting more and more research interests.

In this paper, a self-healing system triggered by physical process (cracking) is introduced. The healing material mainly consists of epoxy like materials. The discussion concerning microcapsule techniques are presented in another paper in this conference. This study mainly focuses on the two healing mechanisms: i.e. the mechanical recovery and the permeability related recovery. The primary test results concerning these healing mechanisms are presented and the healing effects on the relevant properties are further discussed.

2. MATERIALS

Cementitious composites consist of Portland cement, slag, quartz sand, PVA fibre and water. The urea formaldehyde resin was used for the shell of microcapsule, and bisphenol – an epoxy resin E-51 diluted by n-butyl glycidyl ether (BGE) was adopted as the healing-agent inside the microcapsule. A combination of latent curing agent

MC120D and tetraethylene penamine (TEPA) – a type of liquid curing agent functioning at normal temperature was used for curing the healing product.

3. TEST METHODS

Firstly, cement, slag, quartz sand and MC120D were mixed for one minute. Then water and TEPA were added into the mixer. Afterwards, PVA fibre and microcapsule were put in and mixed until a uniform mixture was obtained. Prisms of $40 \times 40 \times 160$ mm were prepared for the mechanical test and cylinders of $\Phi 100 \times 100$ mm were cast for the permeability test. After 60 days one group of specimens were loaded to failure to obtain the compressive strength. Another group of specimens were prepared and tested to obtain the chloride diffusion coefficient by means of RCM method. The rest of specimens were pre-loaded at different stress/strength ratios. Then the specimens were unloaded and put into the curing room for 7 days with a curing temperature of 50°C . Then one group of tests was carried out mechanically to evaluate the healing effect of the mechanical performance. The other one was used for testing the chloride diffusion coefficient with the help of RCM. Then the performance recovery concerning the impermeability could be evaluated accordingly. The healing efficiency was evaluated by using equation (1), where η is the healing efficiency factor; P_{healed} is the performance index after healing and $P_{initial}$ is the performance index before healing:

$$\eta = 100 \times \frac{P_{healed} - P_{initial}}{P_{initial}} \quad (1)$$

4. RESULTS

The healing efficiency regarding the mechanical performance and permeability performance of one group of tests are shown in Figure 1 and Figure 2, respectively. Two types of composites with different contents of microcapsule are evaluated. The major variable in the comparison is the size of used microcapsule, where the pre-loading level and curing condition is kept constant. In general, the increase of the adopted size of microcapsule results in an increase of healing efficiency for both evaluated performance indexes. It is also illustrated that the healing efficiency related to the permeability index is relatively higher than that related to the strength index. One interesting point to be noticed is that too large size of microcapsule could hamper the increase rate of healing efficiency. This might be due that the large microcapsule introduces large voids its self, which need to be filled in by the healing agent when the healing mechanism is excited. Thus less healing agent will be available for the effective healing. As a result the healing efficiency is reduced.

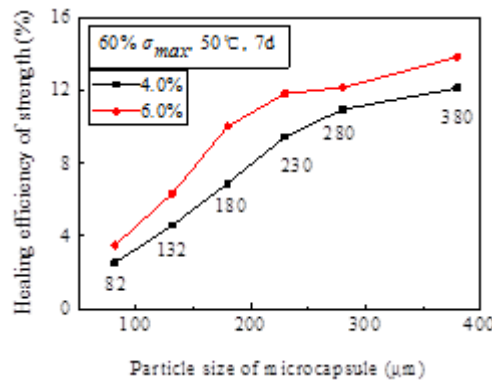


Figure 1: Healing efficiency of strength index with different microcapsule sizes

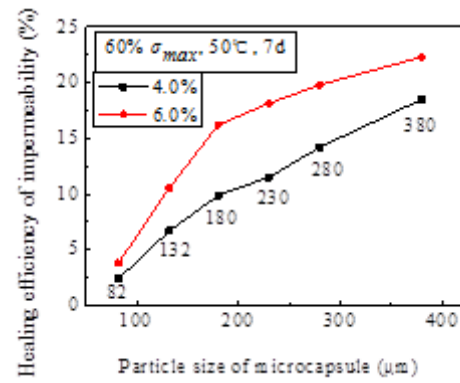


Figure 2: Healing efficiency of permeability index with different microcapsule sizes

The influence of the microcapsule content on the healing efficiency of the strength index and permeability index is illustrated in Figure 3 and 4, respectively. It is shown that the healing efficiency increases proportionally with the content of microcapsule. Again the recovery is more significant for the permeability index than that for the strength index.

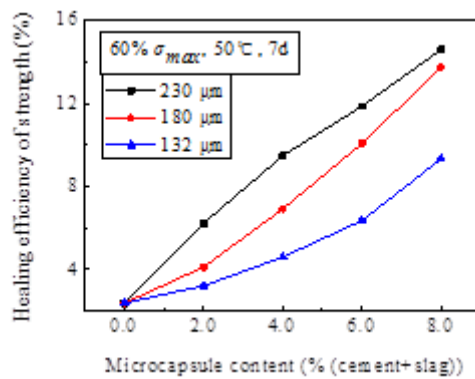


Figure 3 : Healing efficiency of strength index with different microcapsule contents

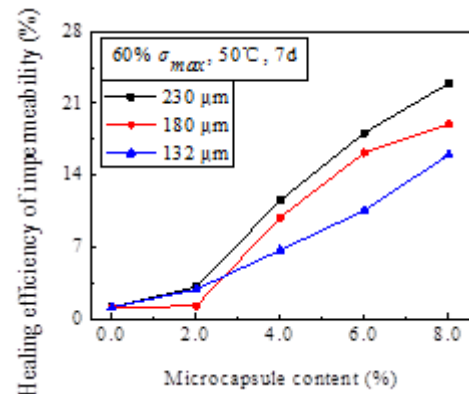


Figure 4 : Healing efficiency of permeability index with different microcapsule contents

Figure 5 and Figure 6 show the influence of pre-load levels on the healing efficiency of the two evaluated performance indexes, respectively. Generally speaking, the higher the pre-load level is the higher the healing efficiency will be. This could be related to the trigger mechanism in this self-healing system. High pre-load level means more cracking, resulting in more participating of microcapsule in the healing process. Thus a high healing efficiency will be realised. At a pre-load level less than 40%, the healing efficiency of the permeability index increases at a high rate. As the pre-load level further goes up the increase rate of healing efficiency will be reduced.

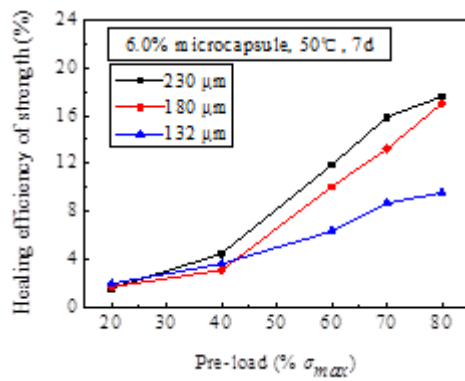


Figure 5 : Healing efficiency of strength index with different pre-load levels

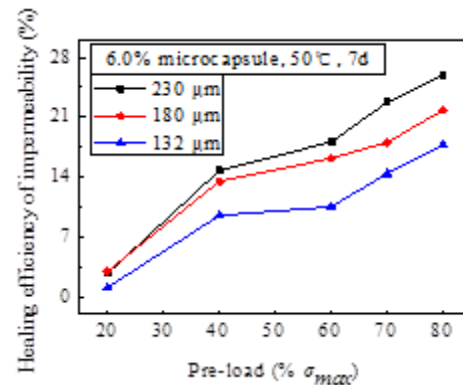


Figure 6 : Healing efficiency of permeability index with different pre-load levels

5. CONCLUSIONS

Microcapsule can be used in cementitious composites to achieve self-healing function. The content and size of microcapsule, as well as the pre-load level, have remarkable influences on the healing efficiency of two performance indexes, namely strength recovery and impermeability recovery.

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