A waterproof epoxy resin microcapsule for the encapsulation of self healing bacterium

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ABSTRACT

A waterproof material was used to fabricate microcapsule by interfacial curing reaction to encapsulate an alkaliphilic spore-forming bacterium. The technical feasibility of encapsulated spores and the influence of three kinds of curing agent for the fabrication of microcapsule were studied by calcium precipitation activity (CPA) of the bacterium. Micro-morphology of microcapsules was observed by Scanning Electron Microscopy (SEM). The CPA of broken/unbroken microcapsules was evaluated. Water resistance was evaluated by adding microcapsules in the water more than one month. Therefore, we put forward that this waterproof epoxy resin microcapsules could be potential for the application of self-healing concrete.

1. INTRODUCTION

In recent years, the development of self-healing technique in concrete based on microbial calcium carbonate precipitation has been becoming more and

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more promising. However, it is necessary to set up a waterproof protection strategy for embedded self-healing bacteria in the concrete during casting, hydration period and service life before cracks occur. Epoxy resin has been widely used in concrete as the crack repairing agent, but so far no microcapsule was made from epoxy resin to encapsulate bacteria for concrete self healing purpose[1-5].

2. MATERIALS AND METHODS

2.1 Preparation of microcapsules

Under the condition of double oil phase, suspension dispersion method was applied to prepare the waterproof biomicrocapsule. Microcapsules were fabricated by using a waterproof material, Epoxy Resin (ER), and an alkaliphilic spore-forming bacterium , *Bacillus pseudofirmus* DSM8715.

Trimethoxy silane [3-(2-Aminoethyl) aminopropyl] was employed as silane coupling agent KH792. The influence factors on DSM8715 spore production and activity, such as the optimum pH value to induce mineralization, the optimum germination agent, the optimum buffer, the influence of three kinds of curing agent (silane coupling agent KH792, DMP-30 and m-Xylylenediamine), which were used as curing agent for the fabrication of microcapsule, were studied by monitoring the calcium precipitation activity (CPA) of the bacterium before encapsulation.

In addition, microcrystalline cellulose (MCC) which was used as filling skeleton was mixed with spore to prepare the core material. The mixture was formed into pellets with a cold extrusion rounded pelletizing machine. In order to obtain a suitable curing for the shell of microcapsule, silane coupling agent KH792 was used. Suspension dispersion process was carried out to form the outer coating of the microcapsules.

2.2 Characterization of the microcapsules

Micro-morphology of microcapsules was observed by Scanning Electron Microscopy (SEM). Afterwards, the thermal stability and thermolysis temperature were determined by TGA thermal analyzer. Moreover, the CPA of broken/unbroken microcapsules was evaluated. In addition, water resistance was evaluated by adding microcapsules in the water for 0 h, 15 days and 30 days.

3. RESULTS AND DISCUSSION

About spores, our experiment results showed that DSM8715 had a strong mineralization ability and grew fast at 30℃, pH 9.5-11.The influence factors on DSM8715 spore production were evaluated. The results showed that the optimum germination agent is inosine with the suitable concentration of 80mmol/ L; The optimum buffer is N-cyclohexyl-3-amino propylsulfonic acid (CAPS); the optimum pH for DSM8715 to induce mineralization was 10 with spore mineralization activity being 86.8%.

Three curing agents showed nearly similar influence on the spores, while KH792 performed relatively better, and thus was used to fabricate microcapsule. The microcapsule has a very good spherical shape and the size is about 500μm in diameter. The shell is smooth and compact with the thickness of about 50μm and the core/shell weight ratio of 1:1(Figure 1). Compared with unbroken microcapsules, the results showed that higher CPA was achieved by breaking the microcapsule to release the bacterium, suggesting good protection for the encapsulated spores. Our results also indicated that ER microcapsules could keep unbroken in the water for more than one month as there were no any change in shape, size and color observed (Figure 2). Therefore, we put forward that this waterproof epoxy resin microcapsules could be potential for the application of self-healing concrete.

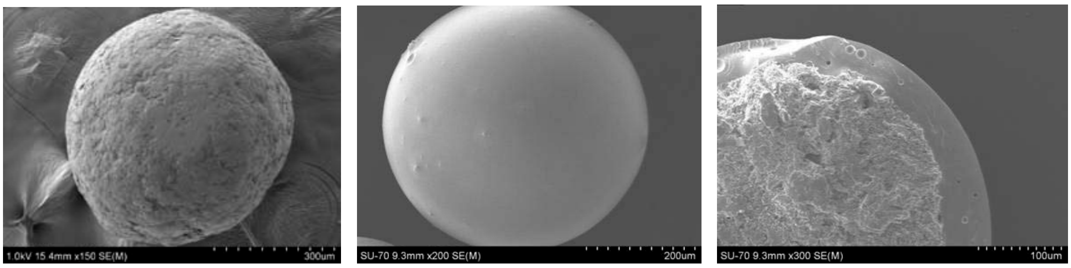

Figure1: The SEM images of microcapsules before and after encapsulation.

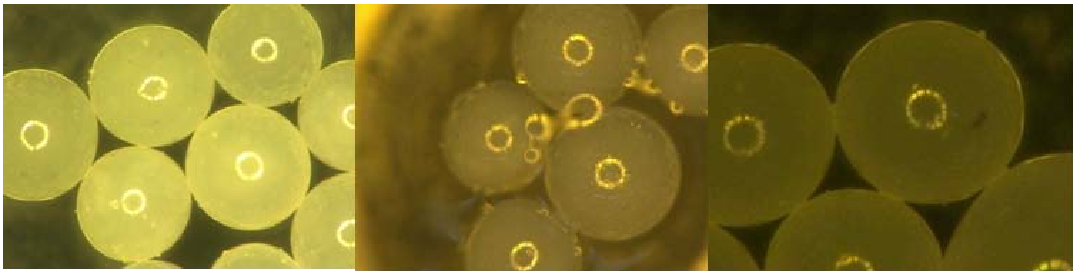

Figure2: Micrograph of waterproof process of ER microcapsules before, after 15days and after 30days.

4. CONCLUSION

In this study, a microcapsule-based microbial self-healing system with Epoxy Resin and an alkaliphilic spore-forming bacterium was designed and fabricated, and the physical properties and morphology of spore and microcapsules were evaluated for self-healing system. It can be concluded the microcapsules have excellent waterproof performance.

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REFERENCES

[1] W. De Muynck, N. De Belie, W. Verstraete, Microbial carbonate precipitation in construction materials: a review, Ecological Engineering 36 (2010) 118-136.
[2] H. M. Jonkers, A. Thijssen, G. Muyzer, O. Copuroglu, E. Schlangen, Application of bacteria as self-healing agent for the development of sustainable concrete, Ecological engineering 36 (2010) 230-235.
[3] K. Van Tittelboom, N. De Belie, Self-healing in cementitious materials - A review, Materials 6 (2013) 2192-2217.
[4] J. Xu, W. Yao, Z. Jiang, Non-ureolytic bacterial carbonate precipitation as a surface treatment strategy on cementitious materials, Journal of Materials in Civil Engineering 26 (2013) 983-991.
[5] J. Y. Wang, H. Soens, W. Verstraete, N. De Belie, Self-healing concrete by use of microencapsulated bacterial spores, Cement and Concrete Research 56 (2014) 139-152.