SELF-HEALING BITUMEN BY MICROCAPSULES CONTAINING REJUVENATOR

J.F. Su[1], J. Qiu[1] and E. Schlangen[1]

[1] *Department of Materials and Environment, Faculty of Civil Engineering & Geosciences, Delft University of Technology, Stevinweg 1, 2628CN Delft, The Netherlands – e-mail: J.Su@tudelft.nl; J.Qiu@tudelft.nl; H.E.J.G.Schlangen@tudelft.nl*

Keywords: Self-healing, Microcapsules, Bitumen, Rejuvenator

ABSTRACT

Preservation and renovation bitumen of pavement is a big problem for the whole world. Traditionally, application rejuvenators is the only one method that can restore the original properties of the pavements. However, some puzzles still restrict its successful usage. Microencapsulation is a promising method to apply rejuvenator in bitumen. These microcapsules can break and leak the oily-liquid rejuvenator into microcracks and self-healing the aged bitumen. The aim of this work was to synthesize and characterize the physicochemical properties of novel microcapsules containing rejuvenator by in-situ polymerization of methanol-melamine-formaldehyde (MMF) prepolymer. A two-step coacervation (TSC) was successfully applied to enhance the thermal stability and compactability of shells with the help of styrene maleic anhydride (SMA) as surfactant. Thermal stability, mechanical stability and interface stability of microcapsules in bitumen were investigated. The results showed that these microcapsules containing rejuvenator survived in melting bitumen and in a violent repeated temperature changes. Mechanical properties indicated that the bitumen had the self-healing ability with the released rejuvenator from microcapsules. Microcapsules containing rejuvenator will be a promising product to realize the smart pavements.

1. INTRODUCTION

The aging problem of bitumen leads to pavement failure, including surface raveling and reflective cracking. It therefore increases the cost of renovating and preserving bituminous pavements. Rejuvenating agents have the ability to reconstitute the binder's chemical composition and they consist of lubricating and extender oils that contain a high proportion of maltene constituents. Rejuvenator can soften the aged binder and provide comprehensive rejuvenation that replenishes the volatiles and dispersing oils while simultaneously promoting adhesion. However, for a rejuvenator to be successfully applied the difficulty in penetrating the pavement surface still remains a significant problem. The method of encapsulating rejuvenators inside the bitumen may be an alternative approach worthy of consideration. In view of the above, the objective of this work was to fabricate microcapsules containing rejuvenator by in situ polymerization using MMF-resin shells and to then investigate their properties in bitumen.

2. MATERIALS

The shell material was commercial prepolymer of melamine-formaldehyde modified by methanol (solid content was 78.0%) purchased from Aonisite Chemical Trade Co., Ltd. (Tianjin, China). The rejuvenator was a commercial product. Styrene maleic anhydride (SMA) copolymer (Scripset® 520, Hercules, USA) was applied as dispersant. A small percentage of the anhydride groups have been established with a low molecular weight alcohol and it is fine, off-white, free flowing power with a faint, aromatic odor. The bitumen used in this study was 70/100 pen obtained from Kuwait Petroleum in a 4.5% by weight. The material used as rejuvenator is dense, aromatic oil obtained from Petroplus Refining Antwerp (800DLA, Belgium).

3. METHODS

The fabrication and investigation methods have been reported in our previous work [1,2]. A thermal absorbing-releasing process was performed to investigate the thermal stability of bitumen/microcapsule composites using a temperature-controlled chest [3]. The state of microcapsules in bitumen could be observed by the fluorescence microscope. Fig.1 shows the testing method of the mechanical properties recovery of bitumen.

4. RESULTS

Fig.2(a) shows the optical morphologies of microcapsules in emulsion fabricated by emulsifying rejuvenator with a stirring rate of 4000 $r \cdot min^{-1}$. Fig.2(b-c) and Fig.2(d) show the SEM surface morphologies of dried microcapsules with core/shell ratio of 1/1 fabricated by 4000 and 2000 $r \cdot min^{-1}$ emulsion stirring rates. Their mean sizes are about 10 and 20 μm. The dried microcapsules still keep the regular global shape. There is no adhesion and impurity substance between microcapsules. The shells are compact without holes and cracks. To determine the shell thickness, microcapsules were embedded in epoxy resin as shown in Fig.2(e-f). Microcapsules were uniformly dispersed in epoxy. The cross-section SEM morphologies of a typical single microcapsule are presented in Fig.2(g).

Fig.3 shows the microcapsule states in bitumen with cracks. As shown in Fig.3(a), microcapsules are keeping compact structure in bitumen without defects and microcapsule has the mean size about 10 μm. Microcapsules survived in the bitumen under a temperature of 200 °C. The microcapsules retained their global shape with no cracks or thermal decomposition. These results indicate that these microcapsules can resist the thermal effects of asphalt for common applications

In Fig.3(b,c), microcracks were generated by liquid nitrogen quickly with a width of 10-20 μm. With the cracks propagation, the shell had been split by the tip stress of cracks (Fig.4(d)). Interestingly, it was found that the rejuvenators had rapidly filled the cracks under the capillary action (Fig.3(e)). Then the rejuvenator had permeated through both sides of cracks and the cracks were healed (Fig.3(f)).

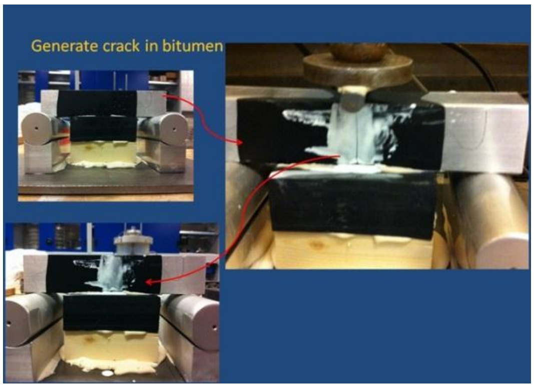

Figure 1: Testing method of the mechanical properties recovery of bitumen

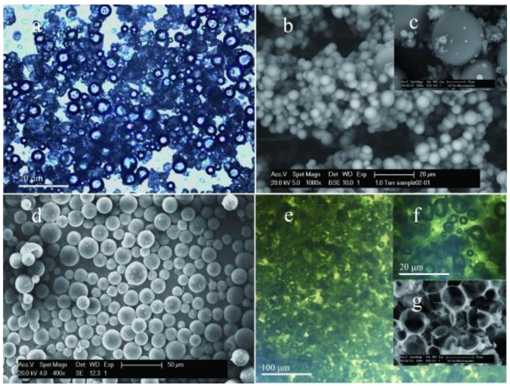

Figure 2: Morphologies of microcapsules containing rejuvenator

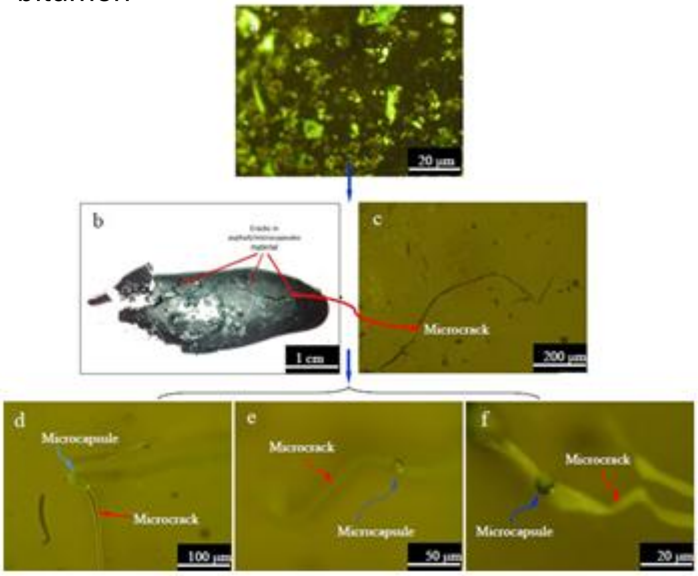

Figure 3: Morphology of bitumen/microcapsules sample treated by liquid nitrogen, (a) cracks appeared in bitumen sample by the low temperature brittleness treatment of liquid nitrogen, (b) original fluorescence microscope morphology of microcapsules in bitumen with cracks, (c-f) fluorescence microscope morphology of microcapsules in bitumen with cracks during 2 h.

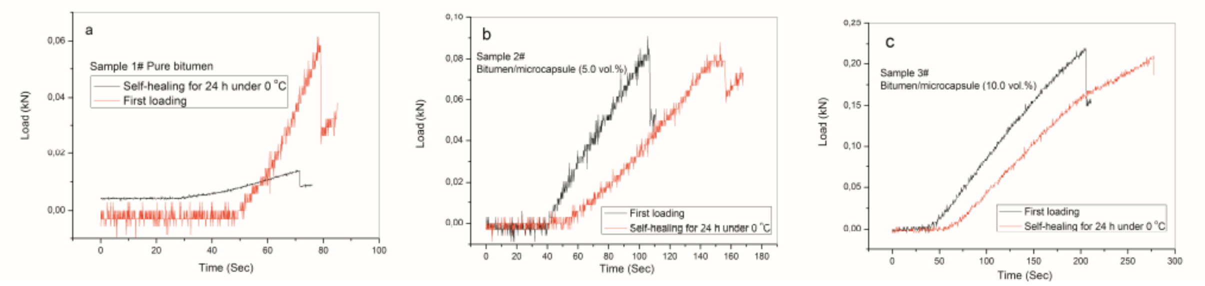

Figure 4: Mechanical test of self-healing bitumen/microcapsule composites under temperature 0 ^{o}C for 24 h. (a) pure bitumen, (b) bitumen/microcapsule (vol. 5.0%), (c) bitumen/microcapsule (vol. 10.0%), (d-e) fluorescence microscope morphologies of samples b and c. The microcapsules have a mean size of 20 µm, core/shell weight ratio is 2/1, bitumen and microcapsules mixing temperature is 160 ^{o}C.

Fig.4 shows the mechanical test of self-healing bitumen/microcapsule composites under temperature 0 ^{o}C for 24 h. It is clear that the bitumen samples with microcapsules (vol.5% and 10%) have a mechanical properties recovery.

5. CONCLUSIONS

Microcapsules had survived in bitumen under temperature of 200 ^{o}C, which indicates that these microcapsules can resist the thermal effect of bitumen in application. With the microcracks propagation, the shell had been split by the tip stress of cracks and the rejuvenators had rapidly filled the cracks under the capillary action. Later, the rejuvenator had permeated through both sides of cracks and the cracks were healed. Mechanical properties of bitumen has a recovery. Microcapsules containing rejuvenator will be a promising product to realize the smart pavements.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support from the Delft Centre for Materials (DCMat) in the form of Project IOP Self-Healing Materials SHM1036, ‘‘Encapsulated rejuvenator for asphalt’’. Dr. Jun-Feng Su also thanks the previous financial support of the National Natural Science Foundation of China (No. 50803045).

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