Self-healing Concrete by Using MgO Based Pellets Enclosed by PVA Film Coating

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ABSTRACT

This paper studies the potential of using magnesium oxide (MgO) based pellets to improve the crack self-healing capability of concrete. Two types of pellets with (1-2) mm diameter were utilized in this study. The first was developed in the laboratory from expansive minerals such as reactive MgO and Bentonite and the other type is a commercial MgO pellets. Both types were coated of polyvinyl alcohol (PVA) film layer to sequester the core materials until the crack time. The coated pellets were replaced the fine lightweight aggregates by 10% in mortar concrete samples. The self-healing efficiency was verified through different tests e.g. three point flexural strength and monitoring cracks closure using optical microscope images. It was shown that the addition of 10% of the both types of pellets increases the compressive strengths at 7, 28, and 56 days. Furthermore, the coated fabricated pellets and the commercial ones presented ~35% and 8% strength recovery respectively, in contrast to the reference samples which showed less than 2% strength recovery at the same age. The microscopic investigation showed complete cracks closure for concrete samples contained any of the two coated pellets types. Overall, the fabricated MgO/ Bentonite pellets showed promising results in both crack sealing and strength regain compared with the reference samples and those contained the commercial MgO pellets.

1. INTRODUCTION

Concrete is the most widely used building material all over the world. However, it is susceptible to cracking, a phenomenon that endangers the material's structural integrity and durability. Therefore, repairing of these cracks is very essential and inevitable. Over the last few years, the concept of concrete structures able to heal their cracks without human intervention has emerged as a possible cure to enhance durability and serviceability, improve safety and reduce maintenance costs [1,2]. Many different approaches and materials have been extensively developed. For example the hydration of un-hydrated clinker available at the crack surface and normally aided by carbonation of calcium hydroxide, which called improving the natural mechanism of autogenous crack healing. Other methods are designed to modify concrete by embedding microcapsules or hollow fibers containing adhesives or any suitable healing agent, to heal the cracks autonomously. Another mechanism is based on bacteria which can produce calcium carbonate to plug the crack and reduce permeability [3].

Self-healing of cementitious composites could also be realised by addition of expansive agents and mineral admixtures. Although, concrete shows a promising healing capability with some mineral admixtures, there were some disadvantages in this approach, such as the loss of the workability of fresh concrete and reduction in the self-healing efficiency of hardened concrete [4]. Therefore, this study aims to pelletise or granulate some expansive materials as promising healing agents and enclose them by a film coating to control them until crack occur.

2. MATERIALS

CEM 1 (52.5N) Portland cement supplied by Hanson, UK was the principal material for all the concrete mixes. Fine lightweight sintered fly ash aggregates, referred to as LYTAG (LYTAG Ltd., UK) with particle sizes less than 4mm were used. The commercial hard burnt MgO pellets was obtained from Martin Marietta Magnesia Specialties, USA. For the fabricated pellets, light burnt MgO 92/200 obtained from RBH Ltd., UK and bentonite clay supplied by Kentish minerals were utilized as cargo materials.

Polyvinyl alcohol (PVA) was used as a coating material for both commercial and those fabricated at the laboratory. The PVA was obtained from Fisher Scientific as a 98-98.8 % hydrolysed powder and an average molecular weight of 31,000-50,000.

3. METHODS

a) Pelletisation and coating: The cargo materials of pellets which manufactured at the laboratory were MgO 92/200 and Bentonite with 50% for each from the total solid. Water was used as a binder. The device used is DP-14 “Agglo-Miser” which is a disc pelletiser supplied by Mars Mineral, USA. The produced pellets and commercial ones were coated with 10% aqueous solution of PVA by using the spray coating method associated with simultaneous drying by blowing a stream of hot air onto the surface of the pellets. The PVA coating was (10-50) μm thick as the process was repeated for three times. Hereinafter the coated fabricated pellets and the commercial pellets are referred as FP and CP respectively.

b) Mortar concrete mixes: Four mixes of mortar concrete specimens with water-to-cement ratio (w/c) of 0.4 and 1:1 cement to fine LYTAG proportions were prepared for this study. The pellets were partially replaced the fine LYTAG by 10%. The mixes were the reference, the mix containing FP pellets, the mix with CP pellets, and the mix included uncoated CP. These mixes are refereed as M1, M2, M3 and M4 respectively. For each mix 9 cube samples (40 mm X 40 mm X 40 mm) were prepared for compressive strength analysis and 3 prism samples (40 mm X 40 mm X 160 mm) were prepared for crack forming through a three point flexural test, and crack healing analysis overtime. The samples were demoulded after 1 day of curing and then cured in a water tank at temperatures of 20°C ±2°C and a relative humidity 60°C ±2°C until the designed testing age.

c) Verifying self-healing performance: Controlled cracks of width (80-130) μm were introduced in the prism samples after 7 days in water curing using three point bend test. Thereafter, the cracked samples were vertically setup into the water tank in order to keep the crack surface in contact. Digital microscope images were used to analyse cracks healing of specimens at different ages. The healed samples were cracked again after 28 days from the first crack for monitoring the recovery of the flexural strength. In order to study the effect of the addition of pellets on the mechanical properties of concrete, the compressive strength testing was carried out at ages of 7, 28, and 56 days.

4. RESULTS AND DISCUSSION

a) Pelletisation and coating: Scanning electron microscope (SEM) images in Figure 1 show the PVA coating of an individual pellet and a coated pellet inside the concrete specimen respectively. The thickness of the PVA shell varies between 10 μ to 50 μm.

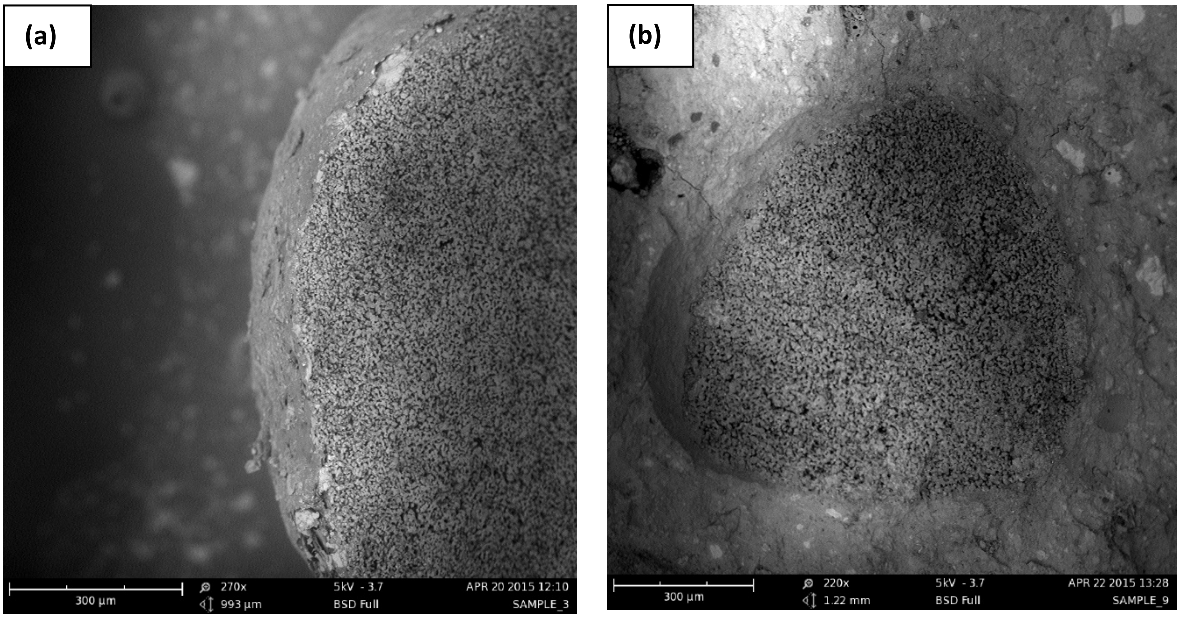


Figure 1: SEM images of coated MgO pellets: (a) PVA coating for individual pellet, and (b) Coated pellet inside concrete matrix

b) Unconfined compressive strength (UCS): as can be seen in Figure 2 that the addition of both FP and CP had a positive influence on UCS for all ages. For instance, the 56 days UCS value of M2 exceeded the reference value at the same age by ~ 6 MPa.

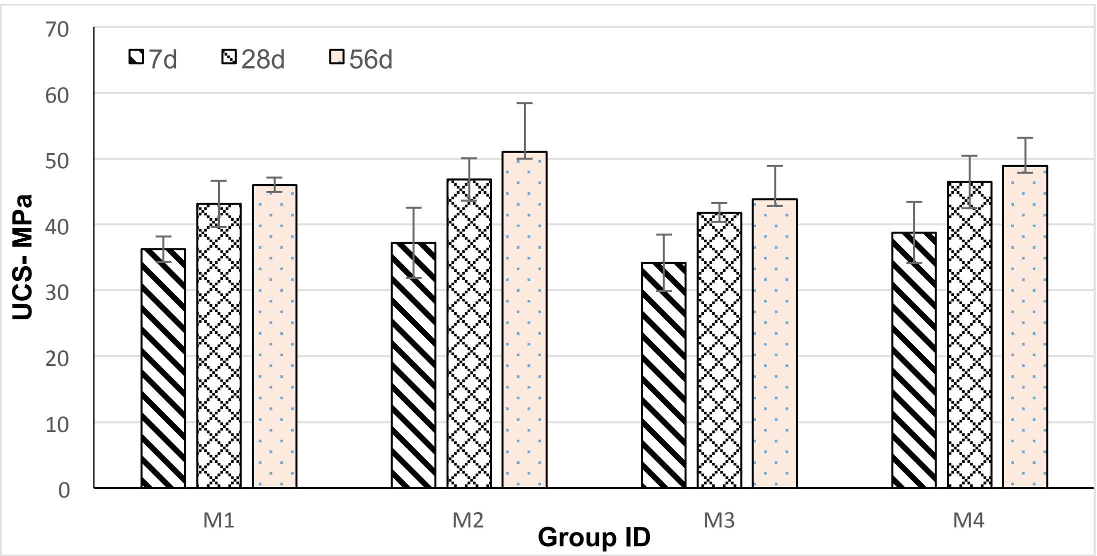
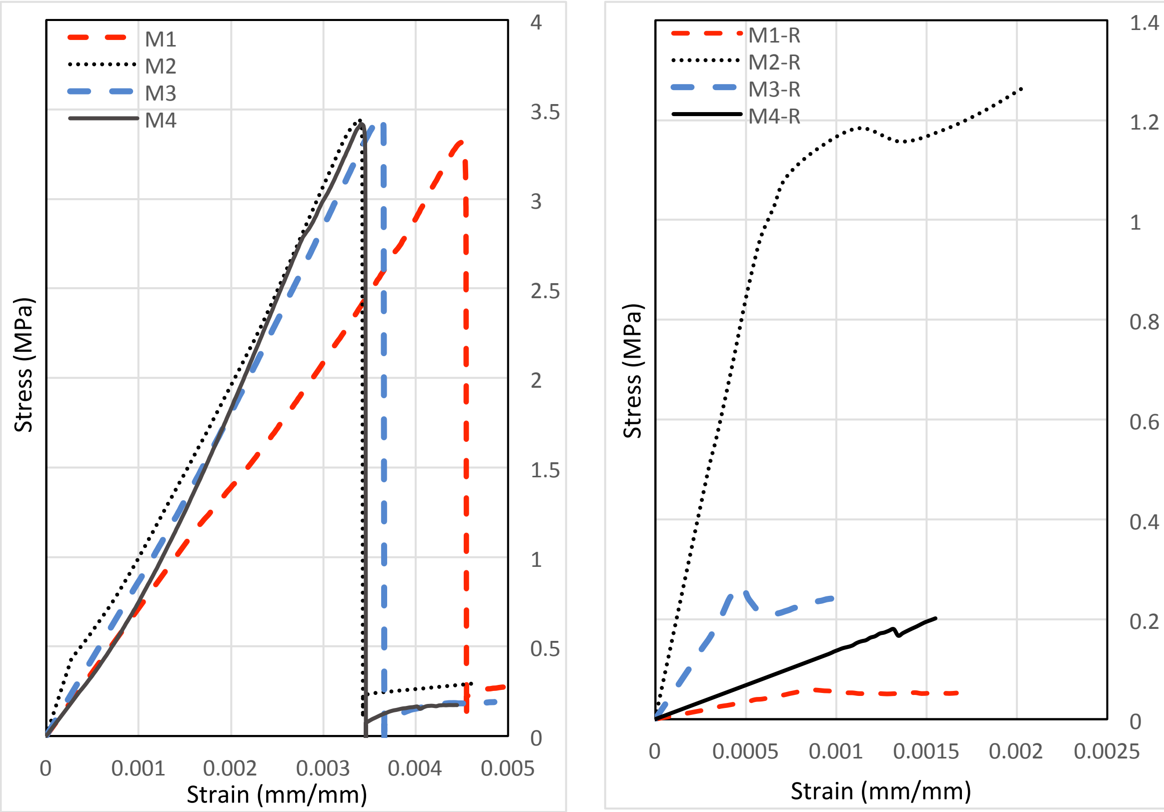


Figure 2: UCS of mortar samples for different mixes

c) Three-point flexural strength: M2 samples with FP pellets show ~ 35% strength recovery after 28 days water curing from the first crack which is a significant recovery compared to the reference samples (less than 2%). For M2 and M3 samples, the strength regain is also limited i.e., 8% and 6% respectively. Typical flexural strength curves for all mixes and their recovery are presented in Figure 3.



(a) (b)

Figure 3: (a) typical flexural strength curves @ 7 days for all mixes, and (b) typical flexural strength curves @ 28 days for all mixes.

d) Analysis of digital microscope images: the microscopic image analysis was conducted out to monitor the change in the widths of the cracks induced in the prism mortar specimens. The crack-sealing process is used as an indication for efficiency of the self-healing cementitious composites. The crack widths were measured in different ages counted from the first crack date (0, 7, 14, and 28) days. Figure 4 presents typical optical microscope images for crack sealing after 28 days curing in water. The cracks widths were controlled to be between 80 to 130 µm. The completely crack closure was mainly observed at M2 and M3 samples. This in turn backs up the strength regain results and shows the significant effect of addition coated self-healing pellets to the concrete compared to the pristine samples and those contained uncoated pellets.

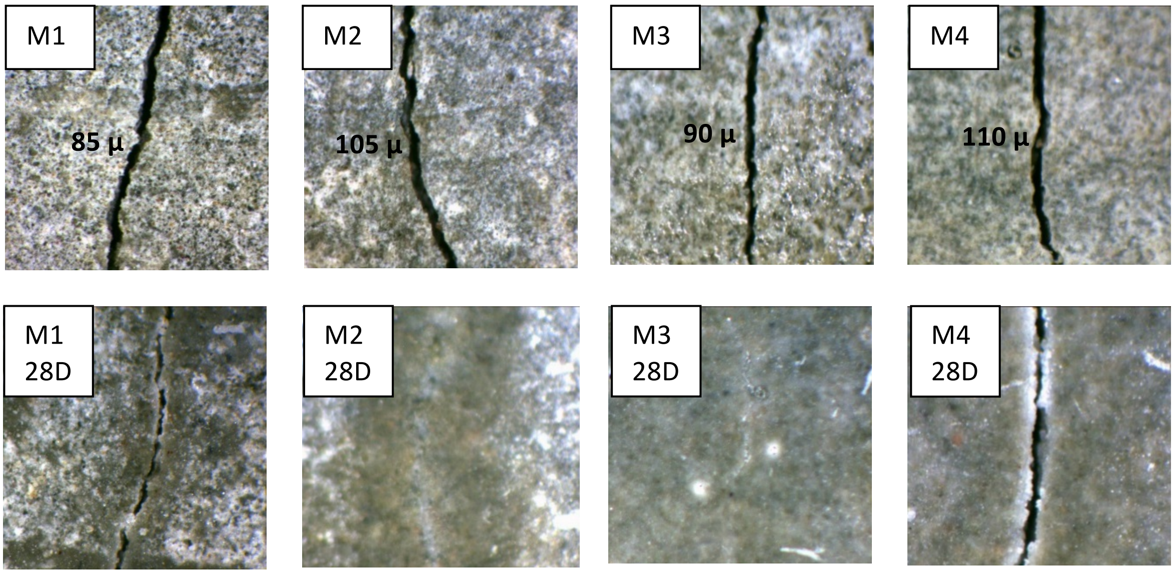


Figure 4:Microscope images of cracks clousre after 28 days water curing

5. CONCLUSION

The fabricated coated MgO pellets show promising results in both sealing the cracks and regain the flexural strength of concrete samples. This may be attributed to the relatively high reactivity of the core materials. However, the commercial pellets with low reactive MgO demonstrated less efficiency particularly in strength regain. Moreover, PVA presents an adequate film coating for controlling the time of autonomic healing. It could withstand the friction between pellets and the mixer blade in fresh concrete mixing due to its stiffness.

It can therefore be concluded that the pelletisation of expansive materials such as MgO and enclosing them in a film coating looks a promising approach for enhancement the self-healing capabilities of concrete.

6. REFERNCES

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