XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

Two-Part Bio-Based Self-Healing Repair Agent for Cement-Based Mortar

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Keywords: *Self-Healing, Biomineralization, Diatomaceous Earth, Pumice, Mortar.*

1 Introduction

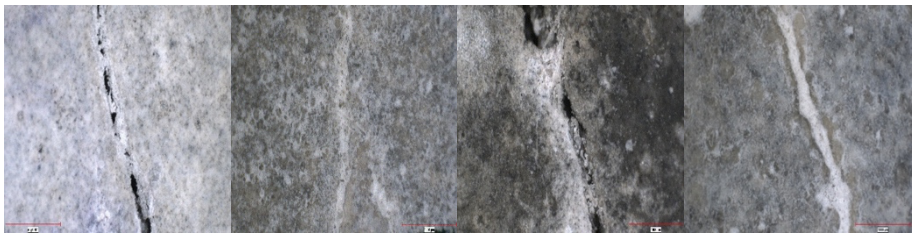
Recent studies in the field showed that it might be possible to develop a bio-based self-healing system where bacterial cells are being used to remediate cracks by triggering microbial induced calcium carbonate precipitation (MICP) (Zhang *et al*. 2015). The main challenge of the application is to find a microorganism that can tolerate highly alkaline conditions of cement paste, can survive the mixing process, and can remain viable with limited access to nutrients (Tiago *et al.* 2004). Previously, Bundur *et al.* (2017) showed that vegetative *S. pasteurii* cells could survive in mortar up to 11 months when they were added to the mix without any encapsulations. These remaining cells were found to be effective in remediation of the microstructure when internal microcracks (Liu *et al*. 2016) and flexural surface cracks in 7 day old samples (Amiri *et al.* 2018). However, limited viability and lack of O_2 decreased the performance of $CaCO_3$ yield through all crack the depth. The precipitation was found to be limited to the crack mouth in microscale cracks (Amiri *et al.* 2018). However, considering the larger surface cracks, the amount of retained viable cells may not be able to precipitate sufficient biogenic $CaCO_3$ to seal the cracks. A correct choice of the protection barrier and application methodology are of crucial for further development of self-healing concrete. This study presents a comparative study on the possible use of a mineral additive (DE) and a porous lightweight aggregate (pumice) as protective barriers for bacterial cells.

2 Materials and Methods

To achieve this goal, *S. pasteurii (DSMZ 33)* cells were grown in a Urea-corn steep liqueur - sodium acetate nutrient medium aerobically at 30°C. For immobilization, the cells were collected from the culture by centrifuging and resuspended in a phosphate buffer solution. Then, protective barriers were added to the suspension and immobilization was achieved with shaking conditions at 30°C for 24 hours. Mortar samples were prepared by incorporating the 2-part bio-additive during mixing. While DE was used as an addition by 5% of cement weight, pumice was used as aggregate replacement such that 5% of the sand used. After 28 days of mixing, the samples were cracked under flexural loading. A set of cracked samples were cured in water and another set was cured in nutrient medium. Curing process was done by subjecting the samples to wetting and drying cycles.

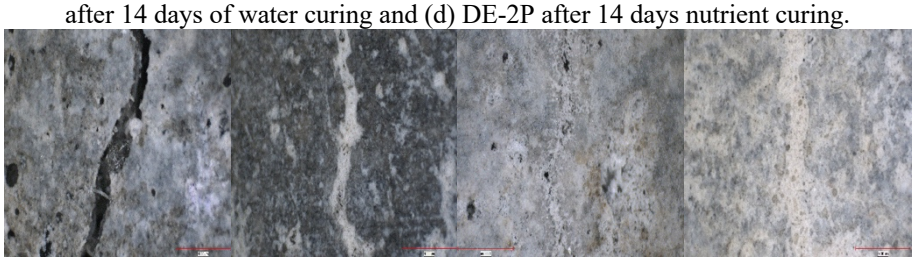
3 Results and Discussion

Upon 14 to 28 days of curing, the cracks were visually sealed in specimens containing bacterial cells when additional nutrients were provided with curing (see Figure 1 and Figure 2.) Based on the visual crack evaluation, both DE and pumice was found to be effective in terms of immobilizing the bacterial cells and trigger self-healing. In addition, it could also be noted that additional nutrients as urea and [Ca^{+2}] source should be provided either during the mixing or in the curing solution. Cracks with an average width of 0.4 mm in 28-day old mortar specimens were almost completely filled by bio-based precipitate depending on the curing regime.



(a) (b) (c) (d)

Figure 1. Stereomicroscopy images of the cracks (0.3 to 0.4 μm) in 28-day old specimens containing diatomaceous earth (a) DE-Bac after 28-days of water curing (b) DE-Bac after 28-days nutrient curing (c) DE-2P after 14 days of water curing and (d) DE-2P after 14 days nutrient curing.



(a) (b) (c) (d)

Figure 2. Stereomicroscopy images of the cracks (0.3 to 0.4 μm) in 28-day old specimens containing pumice (a) Pum-Bac after 28-days of water curing (c) Pum-Bac after 28-days of nutrient curing (c) Pum-2P after 14-days of water curing and (d) Pum-2P after 14-days of nutrient curing.

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