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Bacteria-based self-healing agent for masonry repair: applicability to cement-lime mortars

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Abstract. In the pursuit of introducing bacteria-based self-healing mortar for masonry repair, this study examined the potential of incorporating a poly-lactic acid (PLA) agent—already established in concrete repair—into cement-lime mortars, typical of historical constructions. Testing prisms constructed with varying lime/cement ratios revealed decreased flexural and compressive strength in high-cement-concentration mortars upon the addition of the agent; for mortars with high lime concentration, however, the agent led to an increase in both strengths. Furthermore, the agent's potential to self-repair was confirmed by allowing the remaining portions of tested samples to heal under humid conditions. Irrespective of mortar composition, cracks were resealed thus confirming the aesthetic, and potentially watertightness, restoration.

Introduction

Addressing the modern concern for structural durability, a recent pilot study showcased the potential of bacteria-based self-healing mortars for masonry repair [1]. The employed pure cement-based self-healing mortar, marketed for concrete repair under the brand *Basilisk* [2], autonomously repaired masonry couplets. These were systematically tested with a computer-controlled bond wrench setup. As a result, induced cracks were filled, and the flexural bond capacity was recovered. Yet, the potential of the incorporated agent with cement-lime mortars remains unexplored. Therefore, this follow-up study aims to investigate the effect of the healing agent on the mechanical properties of hardened mortar and its potential to aesthetically seal cracks. This study lays the groundwork for a more comprehensive (ongoing) work, which will quantify the recovery in terms of mechanical properties and watertightness, verify bacterial activity, and characterize the mineral precipitation.

Materials and Methods

The employed agent consists of a poly-lactic acid (PLA) derivative matrix, Bacillus cohnii-related bacterial spores, and essential nutrients [2]. The agent was explored in combination with four cement-lime mortar compositions featuring increasing lime/cement ratios by volume (0, 0.3, 1, 1.33) at a concentration of 10% of the total mortar's binder volume. The selection of mortar compositions was guided by a transition from pure cement mortar to a cement-lime formulation suitable for heritage conservation. The binders used were Ordinary Portland Cement (CEM I 42.5 N) and commercial aerial lime (CL80S – EN 459-1) with an apparent density of 0.52 g/cm³. Standard river sand, with a particle size distribution between 0.08 and 2 mm, was utilized in a volumetric proportion of 1:2.5 (binder: sand). Per mortar composition, two series of prisms (40x40x160 mm³) were cast: one with the added-in agent (*Bacteria-based* **[B]**) and the other as a plain reference (*Reference* **[R]**).

All specimens underwent 3-point bending tests, followed by compression testing on the resulting halves, each with dimensions of 40x40x80 mm³ [3]. During compression tests, the

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40x40x40 mm^3 tested portion (which constitutes half of the compression-tested sample and a quarter of the original sample) crumbled and detached from the sample. The parts remaining from the two tested halves were reassembled with an elastic band and left to heal under humid conditions (20 ± 2 °C, 95 ± 5 % RH) for 115 days. Subsequently, samples were examined using a Keyence VHX 6000 digital microscope to observe aesthetic recovery.

Agent's effect and aesthetic recovery

Experimental results showed that the added agent influences the flexural and compressive strength of mortar after a 46-day hardening period (Fig 1). Up to a lime/cement ratio of 1, the addition of the agent resulted in [44% - 29%] decreased strength. Conversely, in samples with higher lime content (lime/cement ratio above 1), the addition of the agent yielded strength enhancements of 66% and 28% for flexural and compressive strength, respectively. Furthermore, the agent's potential was confirmed by exposing the remaining portions of the samples to healing under humid conditions (Fig.2). Notably, cracks in bacteria-based samples were effectively filled, nearly disappearing visually, regardless of mortar composition. Post-healing imaging displayed enhanced behavior in bacteria-based samples with higher lime concentrations, characterized by substantial precipitation.

These findings confirm the potential applicability of the agent and serve as the basis for further investigation, delving into the restoration of mechanical properties and water tightness, alongside the verification of bacterial activity and mineral formation.

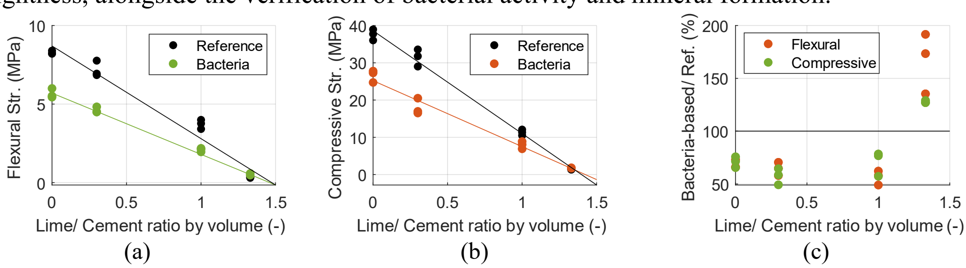

Fig. 1. Effect of the agent on (a) flexural strength, (b) compressive strength, and (c) ratio of bacteria-based to reference specimens for both mechanical properties.

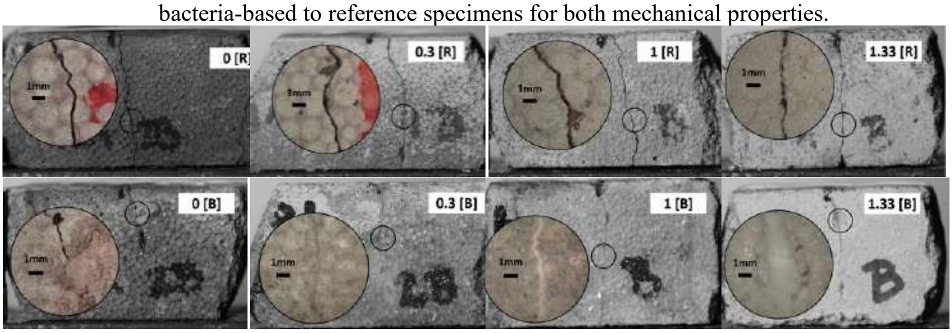

Fig. 2. Aesthetic recovery and crack filling observed in Reference[R] and Bacteria-based [B] specimens after 115 days of healing. Microscope magnification: x30.

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