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# Bacteria-based self-healing agent for masonry crack repair

## Assessing watertightness restoration

*M. Belen Gaggero, Paul A. Korswagen, Rita Esposito, Jan G. Rots*

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The preservation and long-term durability of masonry structures, particularly in the context of built heritage, are strongly affected by water ingress. Cracking in mortar joints or at the brick–mortar interface compromises watertightness, accelerates decay mechanisms such as salt crystallisation and freeze–thaw damage, and increases maintenance demands. Traditional repair strategies, such as repointing, are effective but require repeated interventions and monitoring.

In this context, autonomous self-healing mortars are currently gaining increasing attention as a complementary approach to conventional repair. Inspired by developments in self-healing concrete, bacteria-based healing agents have recently been explored for masonry applications. Previous pilot studies demonstrated that a polylactic acid (PLA)-based bacterial agent can promote crack filling in masonry couplets, contributing to aesthetic recovery and partial restoration of bond strength. However, the ability of such systems to restore watertightness, a performance aspect directly linked to durability, has not yet been systematically investigated.

Assessing watertightness recovery in masonry presents methodological challenges. Existing standards typically focus on large-scale wall assemblies or surface water penetration tests, which are not well suited for early-stage material evaluation. Consequently, there is a need for adapted, small-scale methods capable of quantifying changes in permeability associated with cracking and healing. This study addresses this gap by introducing an adapted permeability test derived from research on self-healing concrete and applying it to evaluate watertightness recovery in masonry containing the above-mentioned agent.

The investigated self-healing system consisted of a commercially available PLA-based healing agent containing alkaliphilic bacterial spores and nutrients. Upon crack formation and water ingress, the content of the agent is released, enabling bacterial activity, which promotes calcium carbonate precipitation. Masonry specimens were constructed using solid clay bricks representative of historic masonry in the Netherlands and a cement–lime mortar with a volumetric ratio of 1.5:5:16 (cement:lime:sand), commonly used in conservation practice. Two mortar variants were produced: a reference mortar without healing agent and a self-healing mortar containing the PLA-based agent. Masonry stack prisms were built by a professional mason, cured under laboratory conditions, and later cored to obtain cylindrical specimens including the brick–mortar interface.

Watertightness was assessed through an adapted constant-head permeability test (Figure 1-a b). Each core was sealed laterally and subjected to a hydraulic head equivalent to a one-meter water column (approximately 0.1 bar) (Figure 1-c d). Water flow through the specimen was continuously measured by collecting discharged water and recording mass over time. Flow rate was used as an indicator of permeability.

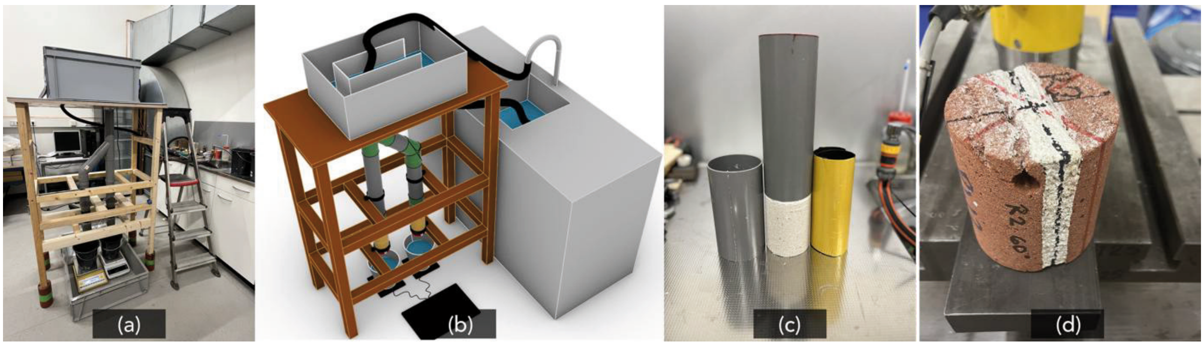


Figure 1: Permeability test set-up: (a) experimental arrangement; (b) schematic of the test configuration; (c) masonry cores and sealing system.

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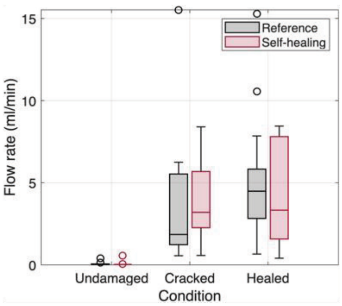
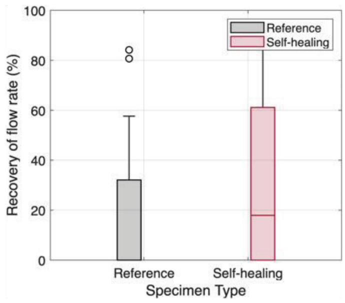
Specimens were tested in three conditions: intact, cracked, and healed. Cracking was induced by shear loading, producing irregular cracks with widths varying approximately between 0.1 and 1.3 mm. After cracking, specimens were stored under high-humidity conditions (95 ± 5% RH, 20 ± 2 °C) for approximately four months to promote healing. Separate specimen sets were used for each condition to avoid premature activation or wash-out of the healing agent during testing.
Experimental results are reported in Figure 2, including the measured water flow and a recovery parameter defined by normalising the flow rate of each healed specimen with respect to the average flow rate of the cracked specimens. As can be observed, crack formation resulted in a marked increase in water permeability for both reference and self-healing specimens, with flow rates increasing by approximately one order of magnitude compared to the intact condition (Figure 2-a). After the healing period, specimens containing the bacterial healing agent exhibited a reduction in permeability relative to the cracked state. On average, permeability recovery reached up to 40% of the original watertightness, although significant scatter was observed (Figure 2-b). Reference specimens also showed some degree of recovery, attributable to autogenous healing mechanisms, but with lower average values compared to specimens containing the healing agent. Visual inspection revealed that healing predominantly occurred through localised crack filling (Figure 2-c). This partial and non-uniform sealing explains the incomplete recovery of watertightness and the variability of test results.



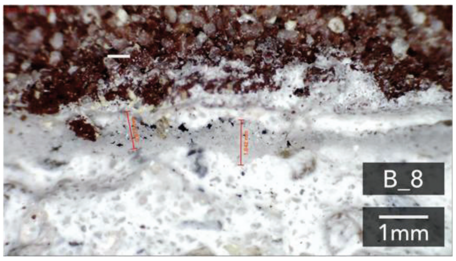




Figure 2: Permeability test results on masonry cores: (a) water flow in intact, cracked, and healed conditions; (b) recovery parameter normalised to the cracked state; (c) localised crack filling after healing.

This study demonstrates that a PLA-based bacterial self-healing agent can contribute to the partial restoration of watertightness in cracked masonry. By adapting permeability testing methods from concrete research to masonry cores, a practical laboratory approach was established to quantify watertightness recovery.

The results show that, beyond aesthetic crack closure and mechanical effects, bio-based self-healing mortars can address water-related durability concerns, which are critical in masonry repair. At the same time, the findings emphasise the need for improved control of crack characteristics and for further refinement of testing methodologies. Future research should focus on controlled crack widths, longer healing periods, and the integration of permeability assessment with mechanical and microstructural analyses, to better define the conditions under which autonomous self-healing can effectively enhance masonry durability.