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Bio-concrete: Next Generation of Self-Healing Concrete

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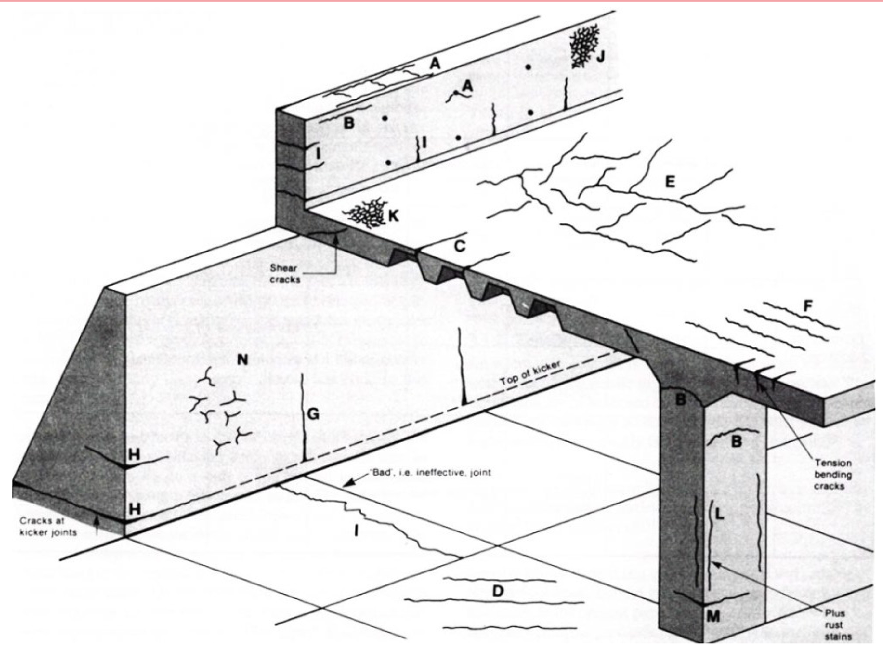
Research Background

Concrete is widely used in construction but is prone to cracking, which compromises structural integrity and increases maintenance costs (Achal *et al.*, 2011). Traditional repair methods such as epoxy injection are costly and unsustainable. Bio-concrete, incorporating bacteria such as *Bacillus pseudofirmus* (B.P.) and Lysinibacillus *sphaericus* (L.S.), offers a self-healing solution by precipitating calcium carbonate to seal cracks (Jonkers *et al.*, 2010). This study investigates the mechanical and healing properties of bio-concrete using expanded clay (EC) and perlite (PL) as bacterial carriers, aiming to enhance durability and sustainability in construction.



OBJECTIVES

- Evaluate the effectiveness of bacterial self-healing agents in sealing cracks (0.3–0.5 mm in width).
- Compare the performance of expanded clay (EC) and perlite (PL) as bacterial carriers.
- Assess the impact of bacterial concentrations (10^6 vs. 10^8 cells/mL) on mechanical properties.
- Determine optimal formulations for balancing microbial healing and structural integrity.

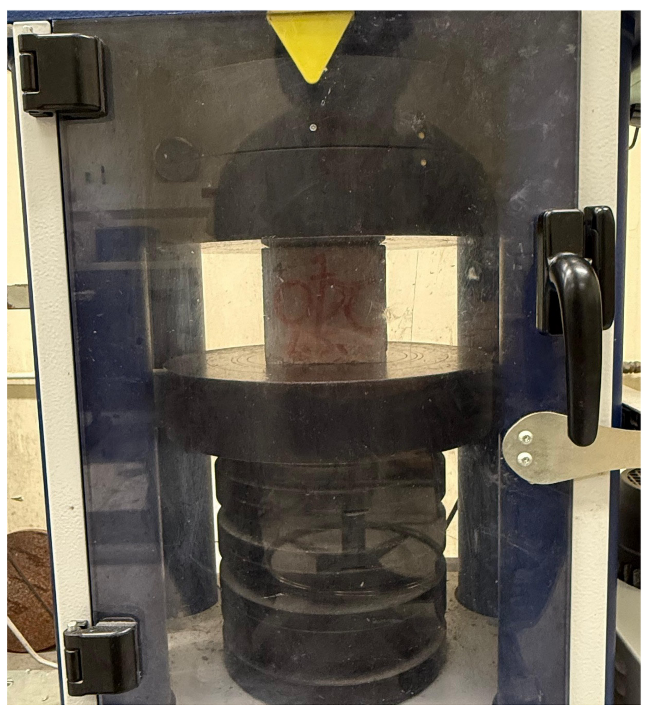
Carriers (Lightweight aggregate and Expanded clay)

Bacteria solution

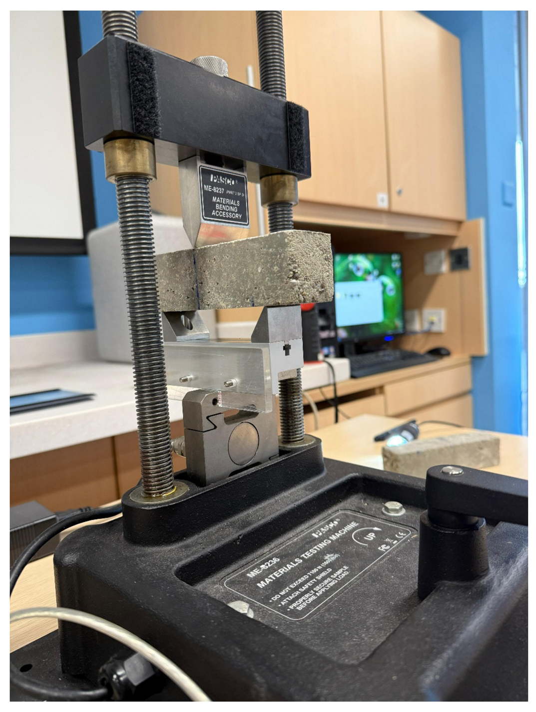
METHODOLOGY

A total of 42 specimens (28 cubes and 14 beams) were cast using a water-cement ratio of 0.5, with 20% of aggregate replaced by either expanded clay (EC) or perlite (PL) as bacterial carriers. Two bacterial strains—*Bacillus pseudofirmus* and *Lysinibacillus sphaericus*—were tested at concentrations of 10^6 and 10^8 cells/mL. The concrete mix included Ordinary Portland Cement (52.5N), river sand, and 12.5mm coarse aggregate. After 28 days of curing, controlled cracks (0.35–0.5 mm) were induced using compressive and three-point flexural tests. Healing performance was assessed through visual inspection, water absorption tests, and Scanning Electron Microscopy (SEM) to measure crack closure and calcium carbonate precipitation. Compressive strength was tested on cubes, while flexural strength was evaluated on beams. The data were analyzed to compare healing efficiency, mechanical performance, and the influence of bacterial concentration and carrier type on bio-concrete properties. Statistical validation ensured reproducibility.

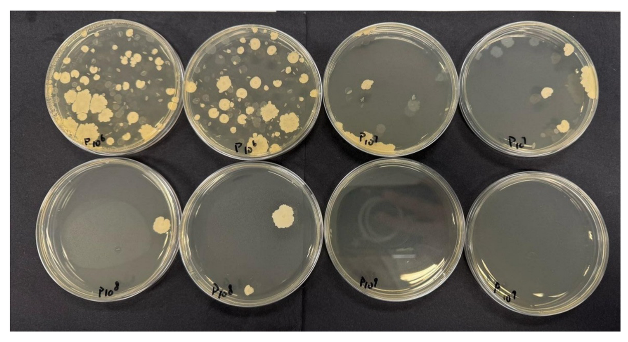
Compressive strength test

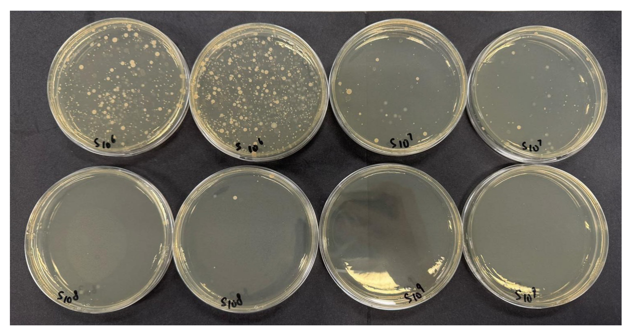


Three-point bending test



Bacteria strains



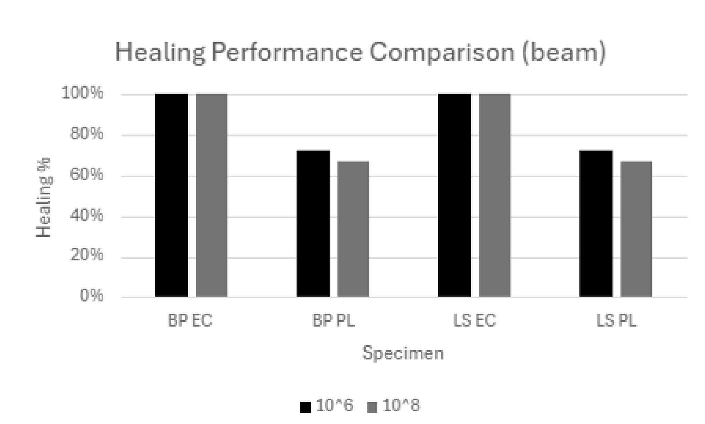


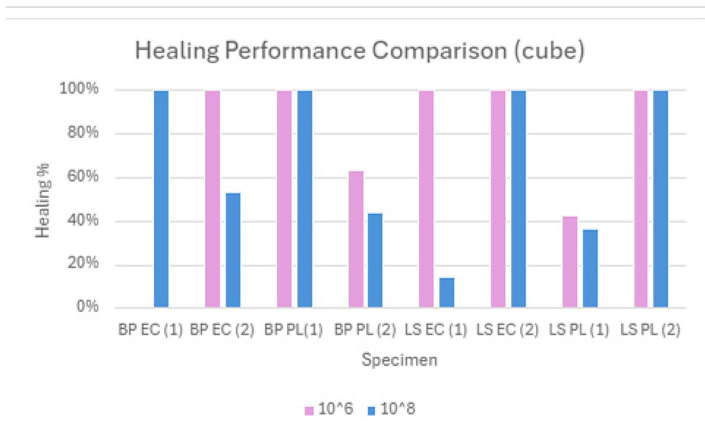
FINDINGS

Healing Performance

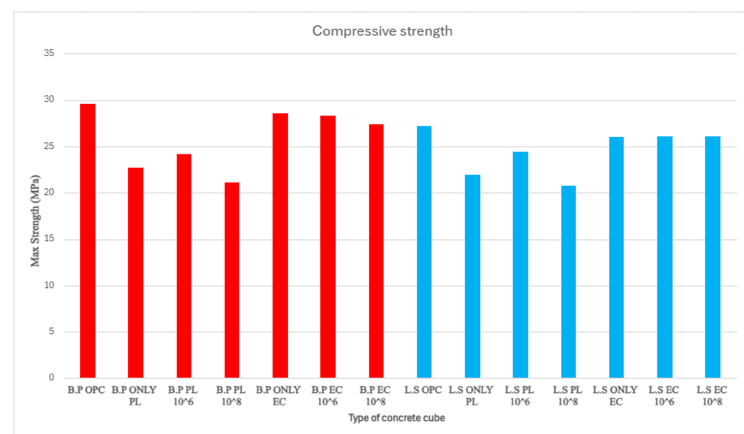
- Expanded Clay (EC): Achieved 100% crack closure in most specimens, particularly with *Lysinibacillus sphaericus* at 10^6 cells/mL . EC's porous structure enhanced bacterial viability and nutrient retention (Han *et al.*, 2019).
- Perlite (PL): Showed variability (44–100% healing), likely due to uneven bacterial distribution.
- Bacterial Concentration: Higher concentrations (10^8 cells/mL) improved healing but occasionally reduced strength due to pore clogging.

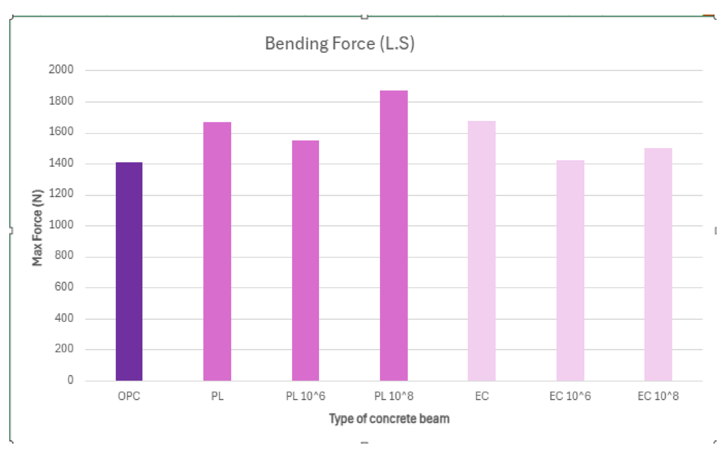
Healing performance





Compressive strength and Flexural strength of samples





Compressive Strength

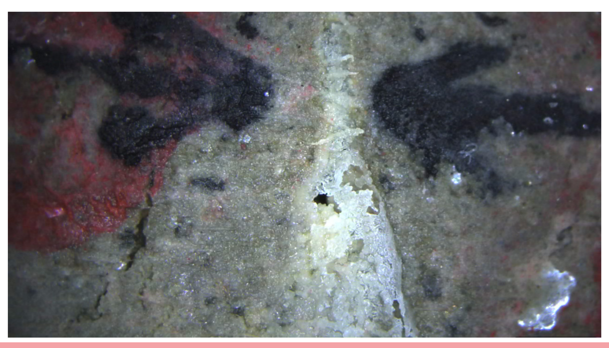
EC specimens outperformed PL, with B.P. achieving 28.59 MPa (EC-only) vs. 22.69 MPa (PL-only).

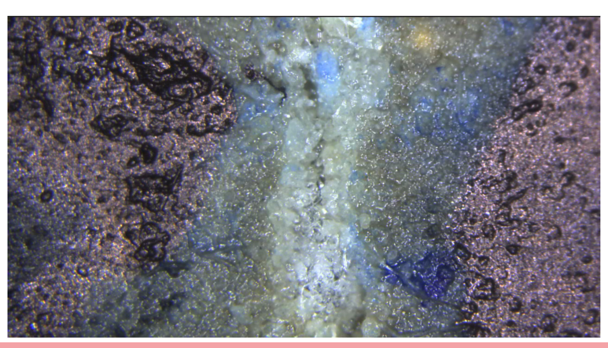
Lysinibacillus sphaericus demonstrated more consistent strength retention across concentrations.

Flexural Strength

Beams with EC and 10^6 cells/mL (B.P.) showed the highest bending force (1782 N), while PL with 10^8 cells/mL (L.S.) reached 1870 N, indicating strain-carrier compatibility influences performance.

100% Healing Performance (L.S and B.P. Samples)





CONCLUSION

Bioconcrete with *Lysinibacillus sphaericus* and expanded clay demonstrated superior self-healing (100% crack closure) and mechanical performance. This sustainable solution reduces maintenance costs and environmental impact, though challenges in scalability and long-term viability under extreme conditions require further research.

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