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Bacterium Encapsulated In Alginate As A Self-Healing Agent In Autonomous Healing Mortar

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Crack formation is a common durability-related phenomenon in many concrete structures. While larger cracks compromise structural integrity, smaller sub-millimeter cracks can cause durability issues due to increased matrix permeability caused by particularly connected cracks. Routine manual maintenance and repair of concrete structures can be expensive and, in some cases, unattainable.

Therefore, including an autonomous self-healing repair mechanism would be highly beneficial as it would reduce maintenance while also increasing material durability. The autonomous healing concrete by microbially induced calcite precipitation has sparked a lot of interest in sustainable concrete repair and maintenance solutions. The biologically inspired material for self-healing concrete has been introduced with *Geobacillus stearothermophilus* encapsulated in alginate (AE-GS). In this study, the vegetative cells of *Geobacillus stearothermophilus* were encapsulated in alginate-hydrogel before it was added to mortar. Scanning Electron Microscopy (SEM) was used to examine the encapsulated strain and its characteristics to confirm the presence of encapsulated bacteria. The performance of AE-GS in mortar mixture as a self-healing agent was measured by compressive strength and crack-healing efficiency. The healing efficiency of AE-GS was used to determine its suitability as a crack repair material. When comparing it to those with a lower replacement level of AE-GS and a lower concentration of bacteria, the results showed that incorporating 15% AE-GS with 1×10^{11} cfu/ml bacteria concentration resulted in maximum crack healing of 80%. *Geobacillus stearothermophilus* was found to be capable of inducing self-healing by utilising the available nutrients in its environment. The combination of *Geobacillus stearothermophilus* and alginate gel beads

provided an intriguing approach for crack remediation using the autogenous healing concept.

Thermophilic Type Bacterium

Geobacillus stearothermophilus is a thermophilic type bacterium capable of thriving in high temperatures (30°-75°C) which can be found in the geothermally heated region such as hot springs [1], [2]. In a harsh environment, *Geobacillus stearothermophilus* produce endospores [3] and its morphology and resistance properties allow it to be mobilised in the atmosphere and transported over long distances [4]. Furthermore, the longevity of *Geobacillus stearothermophilus* allows it to lie dormant but viable in extreme conditions for long periods.

- This study focused on 2 major issues:
- The development of autonomous healing concrete using *Geobacillus stearothermophilus* and
 - The suitability of AE-GS as a new smart material to be investigated for use in concrete repair and maintenance.

Concept of Autonomous Healing

The continuous ingress of water and chemicals in crack propagation would eventually cause premature matrix degradation and corrosion of embedded steel reinforcement if not properly treated [5]. In contrast, adding the bacteria-based healing agent during the mixing process would solve the problem. The bacteria-based healing agent would be activated by the crack and water entering the concrete, resulting in abundant mineral precipitation. This mineral precipitation aids in crack closure and prevents further entry of harmful materials, protecting the reinforcement from corrosion. This concept of self-healing is illustrated in Figure 1.

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