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Review

Bacteria based self healing concrete – A review

Kunamineni Vijay *, Meena Murmu, Shirish V. Deo

Department of Civil Engineering, National Institute of Technology, Raipur, India

HIGHLIGHTS

- Effect of bacteria on concrete properties.
- Bacteria are able to calcium carbonate precipitation in concrete.
- Micro organism based self-healing is a capable solution for sustainable improvement of concrete.

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ABSTRACT

This paper reviews the types of bacteria used in concrete and the ways it can be applied as a healing agents. This paper also gives a brief description of the various properties of concrete which vary with the addition of bacteria. Micro-cracks are inherently present in concrete. This causes degradation of concrete leading to ingress of deleterious substances into concrete, resulting in deterioration of structures. Due to this concrete needs to be rehabilitated. To surmount these situations self-healing techniques are adopted. By the addition of urease engendering bacteria along with calcium source results in calcite precipitation in concrete. Bio-mineralization techniques give promising results in sealing the micro-cracks in concrete. The freshly composed micro-cracks can be sealed up by perpetual hydration process in concrete. The ureolytic bacteria which include Bacillus Pasteurii, Bacillus Subtilis which can engender urea are integrated along with the calcium source to seal the freshly composed micro cracks by $CaCO_3$ precipitation. For the amelioration of pore structure in concrete, the bacterial concentrations were optimized for better results. The literature shows that Encapsulation method will give better results than direct application method and also shows that the use of bacteria can increase the strength and durability properties of concrete.

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* Corresponding author.
E-mail address: vijay.kunamaneni@gmail.com (K. Vijay).

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1. Introduction

One of the most widely used materials for construction is concrete. Concrete is weak in tension and strong in compression and cracks are inevitable in concrete. Once cracks form, in concrete it may reduce the life span of the concrete structures. Various repairing techniques are available to repair the cracks but they are highly expensive and time-consuming processes. There are moderate techniques to repair the cracks in concrete by itself called self-healing concrete. Bacteria with calcium nutrient source are added into the concrete at the time of mixing. If any cracks will be formed in concrete bacteria precipitate calcium carbonate. This will seal the cracks. The strength of the Bacterial concrete will be more than the normal concrete. Strength and durability of structural concrete can be increased by a biotechnological method based on calcite precipitation.

Crack size more than 0.8mm is more difficult to be repaired however with the use of bacteria cracks can heal with the calcite precipitation [5]. Lightweight aggregates added in the place of fine aggregate leads reduction of strength of bacteria based mortar. The strength of bacterial lightweight mortar was more than normal lightweight mortar. This can be used where light weight structures are required. These light weight aggregates are good carrier for bacteria, which increases the healing efficiency and structural durability [8]. The addition of bacteria in Rice husk ash concrete can increase strength properties of concrete due to calcite precipitation at all ages of concrete [10]. Maximum of 24% can be increased in the M50 grade concrete, with maximum calcium carbonate precipitation [12]. The strength of fly ash concrete can be increased by adding Sporoscarcina Pasteurii bacteria which also reduces the porosity and permeability. This results in an increase of compressive strength by a maximum of 22% and reduction in water absorption by four times of normal concrete [16].

Recently, the self-healing approaches have been exhibiting promising results in remediating the cracks in the earlier stages of formation of cracks [40]. On the other hand precipitation of calcite in the concrete specimens by hydro gel encapsulation, capsules, and vascular systems seem to be proficiently adept at self-healing in the construction activities and researches. Fig. 2 illustrates the possible self-healing mechanisms, by the application of cementitious materials in concrete. Different calcium sources may be adopted for the precipitation of calcite by the bacteria. For improving the properties of concrete such as durability the recent advances like Biotechnology and Nanotechnology are used. The objective of this study is to review the various properties of concrete which vary with the addition of bacteria. And the types of bacteria used in concrete for calcium carbonate precipitation.

2. Self healing approach and ways of applying bacteria in concrete

2.1. Self healing approach

A perfect self-healing system should sense the damage or cracks which can set of the release of the healing agent. Self-healing techniques are good approaches for rehabilitation of micro-cracks in concrete. The autogenously healing techniques show good results in healing of micro-cracks on the surface of the concrete. The addition of bacteria will form a pervious layer on the cracks of concrete, which conforms the precipitation of calcium carbonate [32,39].

Concrete is a highly alkaline material, the bacteria added is capable of withstanding alkali environment [24,26]. Micro biologically induce calcium carbonate precipitation helps to fill the micro cracks and bind the other materials such as sand, gravel in concrete [23]. The involvement of microorganism in calcite precipitation can increase the durability of concrete. By converting urea into ammonium and carbonate Bacillus Sphaericus can precipitate $CaCO_3$ in the high alkaline environment [22]. Cracks less than 0.2 mm in concrete can be filled by concrete itself. But if cracks are more than 0.2 mm then concrete fail to heal itself which create a passage to deleterious materials. In self-healing concrete, formation of any cracks, leads to activation of bacteria from its stage of hibernation. By the metabolic activities of bacteria, during the process of self-healing, calcium carbonate precipitates into the cracks healing them. Once the cracks are completely filled with calcium carbonate, bacteria returns to the stage of hibernation. In future, if any cracks form the bacteria gets activated and fills the cracks. Bacteria act as a long lasting healing agent and this mechanism

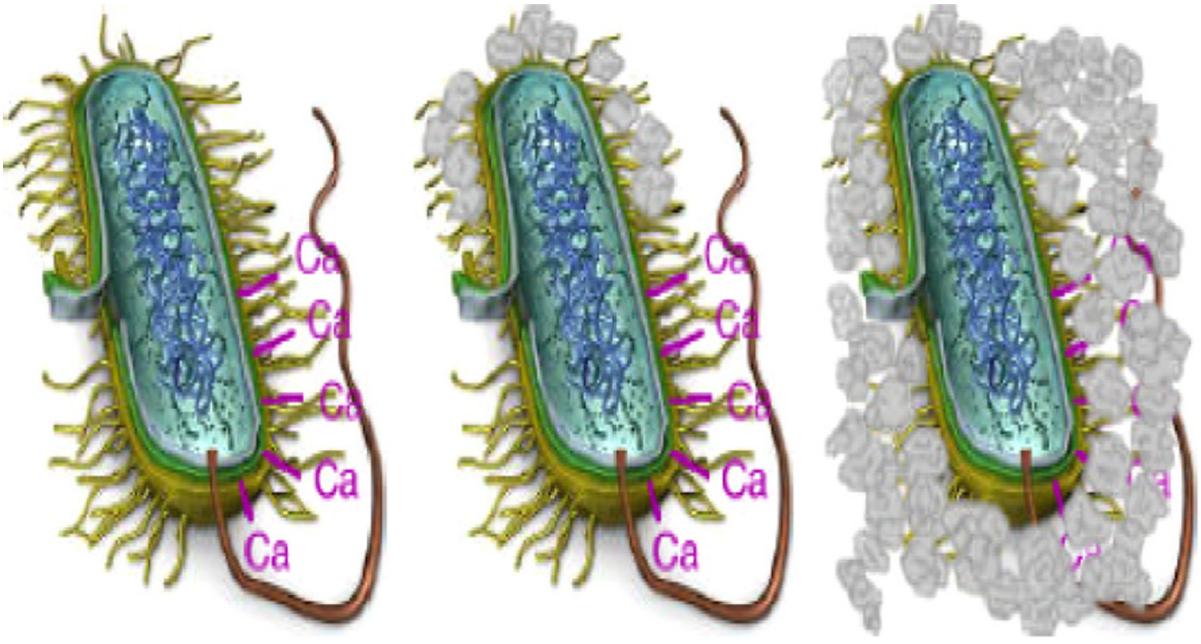

Fig. 1. Calcium carbonates formation on bacterial cell wall.