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Evaluation of crack healing potential of cement mortar incorporated with blue-green microalgae

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ABSTRACT

Microbial induced calcite ($CaCO_3$) precipitation (MICP) is a biochemical process that induces calcite precipitation. MICP is considered a solution for remediation of concrete cracks using bio-mineralization. This study aims to use microalgae as an agent in the healing of micro-cracks. Microalgae were used in cement mortar to induce the formation of calcium carbonate to seal the cracks. Two microalgae species, namely *Synechococcus elongatus (Syn. elongatus)* and *Spirulina platensis (S. platensis)*, were tested for their characteristics and then incorporated into the cement mortar. The specimens were cured under two different conditions, namely ambient and water curing. Next, the mechanical properties and crack healing of the cement mortar were examined. The cement mortars that were cured for 28 days in the air and water were subjected to a compressive load of 70% of its maximum threshold load, to induce micro-cracks. Subsequently, the specimens with pre-induced cracks were cured under ambient and water to check for the ability to seal cracks through bio-mineralization. The effect of replacing cement with 4, 8 and 12% of both species of microalgae were investigated. The results demonstrate that the mortars cured in water have a higher strength compared to the mortars cured in air. The investigation results also reveal that the mortars with *S. platensis* showed better strength and crack healing compared to mortars with *Syn. elongatus*. The water cured specimens with 12% *S. platensis* developed a compressive strength of 72% of the control specimen (100%), compared with 12% *Syn. elongatus* that exhibited only 36%. The healing potential was evident as the micro-camera images showed the narrowing of the induced cracks on the surface of the mortar after 14 days of water curing. Furthermore, the residual compressive strength of the biotically healed specimens showed 35% of the strength regain with 12% *S. platensis* as a cement replacement. The formation of crystalline calcium carbonate precipitates in the specimens with *S. platensis* and *Syn. elongatus* exhibits an increase in the derivatives of calcium ions; the enhancement in the strength of mortar due to the calcium carbonate (crystal) formation, which seals the surface of the crack, was supported by the SEM-EDS and XRD analysis. It was also found that the integration of microalgae into the cement had the effect of self-healing and could potentially improve the future direction of crack healing.

1. Introduction

The demand for concrete increases due to ever-rising population worldwide. The United States Geological Survey (USGS) reported that the consumption of cement by China during the period of 2011–2013 was 6.6 gigatons, which superseded the total cement consumption by United States (4.5 gigatons) in the whole of 20th century [1]. In 2019, the average global cement production was about 4.2 billion tons that resulted in a vast quantity of 35 billion tons of concrete [2]. Though, concrete has been widely used, one of the major problems that occurs in concrete structures is the formation of cracks due to over-stressing, improper construction practice, aggressive environment exposure and shrinkage in concrete, etc. [3]. Further, there is a new dimension to the sophistication in the construction technology and the recent research & development in the construction materials, enabled different types of concretes and products [4]. However, due to the lack of appropriate

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