Department of Concrete Structures and Bridges

SELF-HEALING TECHNOLOGY IN CONCRETE STRUCTURE DESIGN

Abstract: In EU countries and worldly, concrete is the most widely used building material in the world because of its strength and durability, among its other benefits. Concrete also has a certain amount of limitations. They mainly include crack formation over a period of lifetime. Crack formation in reinforced concrete constructions may result to loss of their durability. Ingress water and chemicals can cause premature matrix degradation and corrosion of embedded steel reinforcement in concrete. Regular maintenance and repair of concrete structures is costly and, in some cases, not at possible. One of possible solution for prevention a costly repair, reduce maintenance and increase material durability might be an inclusion of an autonomous self-healing repair mechanism in concrete design technology.

Introduction

Bacteria is a single cell organism. It is a prokaryotic cell that lack of a nucleus and other membrane enclosed structure. Typically, bacteria come in three basic shapes namely, sphere, rod-like and spiral. Some bacteria do not fit any of the preceding categories but rather have spindle shapes or irregular lobbed shapes. Bacteria can be found in every environment such as in the air, food, soil and water. Many bacteria benefits human and a few may cause disease to human. Bacteria play vital role in most of the environment cycle like biogeochemical cycle, water cycle, carbon cycle, nitrogen cycle and sulfur cycle. However, there are numbers of bacteria that is not fully characterized and only some of the bacteria have been grown in a laboratory for specific application (Irwan, 2013).

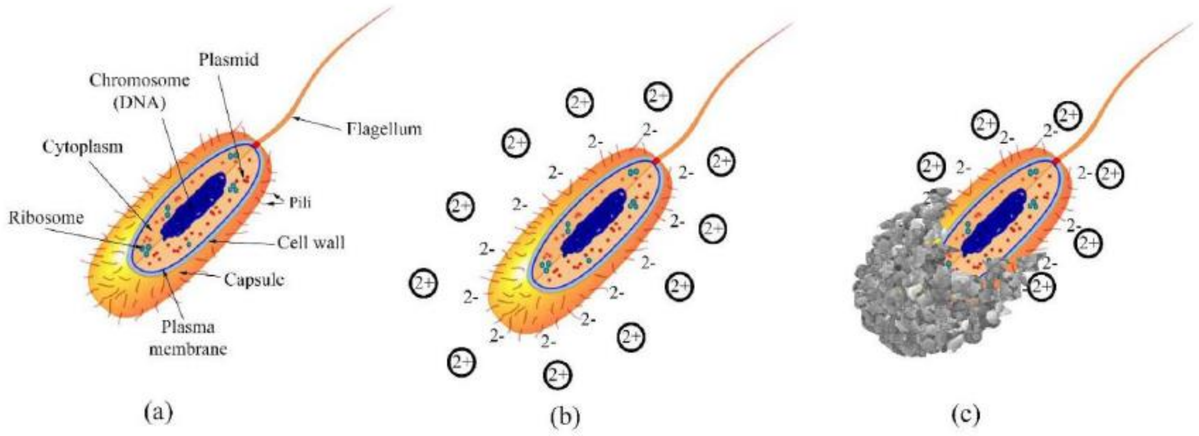

Fig. 1: (a) bacterial Structure. (b) cell membrane (Negatively charged) surrounded by cell wall (positively charged). (c) Production of bio minerals by combination of cell wall ions and surrounding ions (Jawaid,2018).

Role of bacteria in concrete

The selection of the bacteria is depending on the survive capability of bacteria in the alkaline environment. Most of the microorganisms die in an environment with pH value of 10 or above. Strains of the bacteria genus Bacillus will be found to succeed in high alkaline environment. (Luhar, 2015). One possible reaction of bacteria in the concrete can be described according to Eq.1 to Eq.6. (Seifan, 2016)

$$CO(NH_2)_2 + H_2O \xrightarrow{microorganism} NH_2COOH + NH_3 \quad (1)$$

$$NH_2COOH + H_2O \rightarrow NH_3 + H_2CO_3 \quad (2)$$

$$2NH_3 + 2H_2O \rightarrow 2NH_4^+ + 2OH^- \ (pH\ increase) \quad (3)$$

$$2OH^- + H_2CO_3 \rightarrow CO_3^{2-} + Ca^{2+} \quad (4)$$

$$Ca^{2+} + Cell \rightarrow Cell - Ca^{2+} \quad (5)$$

$$Cell - Ca^{2+} + CO_3^{2-} \rightarrow Cell - CaCO_3 \quad (6)$$

Precipitation of calcium carbonate crystals by Bacillus sphaericus and Bacillus subtilis are shown in Fig. 2

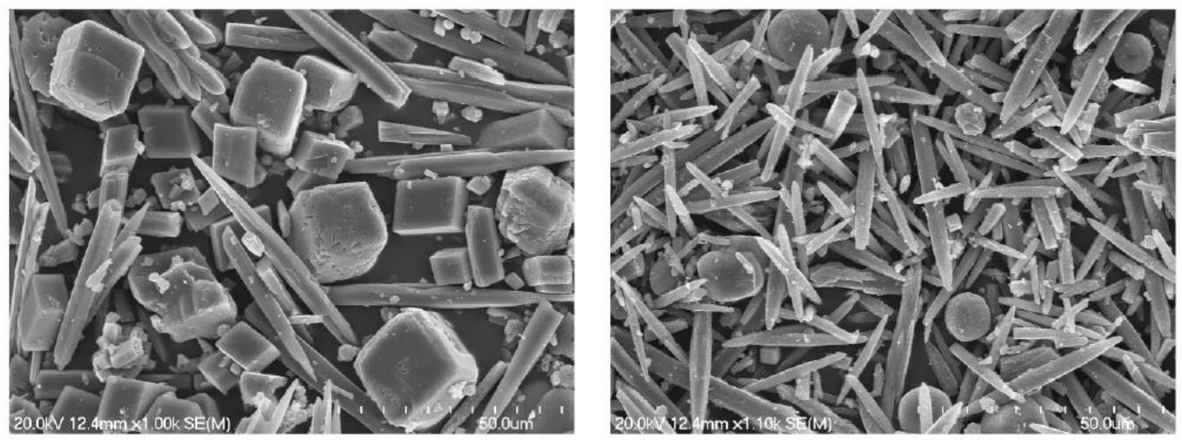

Fig. 2: (a) SEM micrographs of calcite precipitation by Bacillus sphaericus; (b) SEM micrographs of calcite precipitation by Bacillus subtilis (Seifan, 2016)

Effect of bacteria on concrete properties

Increasing the concrete strength and the concrete durability: Compressive strength plays important role in determining the durability of the concrete. Ghosh et al. (Ghosh et al., 2005) reported an increase in the compressive strengths of 17% and 25% after 7 and 28 days, respectively in mortars due to biocementation by Shewanella species.

Chloride ion permeability: De Muynck et al. (De Muynck et al., 2008) reported that bacterial deposition of a layer of calcite on the surface of the mortar specimens resulted in a decrease of capillary water uptake and permeability towards gas, they extended their work to study other permeation properties.

Reinforcement corrosion: Qian et. al [Qian et al., 2009] studied increasing Bacterially induced carbonate precipitation as a novel and ecologically friendly strategy for the protection of reinforcement corrosion in cement-based materials. Theirs results showed great improvement in the surface permeability resistance of mortars due to calcite precipitated on cement specimens induced by bacterial urease enzyme, which further resisted acid attack (pH > 1.5).

Conclusions:

The use of microorganisms in concrete technology is quite a new field of civil engineering. In watertight concrete structures, which reinforcement is designed to control cracks width, the quantity of this reinforcement is higher than the required static reinforcement. Adding of bacteria to concrete could reduce the reinforcement quantity in concrete designed to crack width control. Other benefits of bio concrete are higher strength and durability of concrete. Possible field of bio concrete applications in the future are water purifier tank, floor lining of water purifier in homes or industries, can be used for purifying water. Use of bio concrete technology in concrete structure design could help build more sustainable.

References

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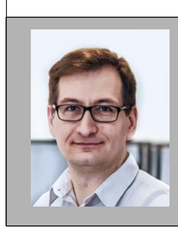

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