An Overview of Bioconcrete for Structural Repair

J.M. Irwan[1,a] , N. Othman[2,b]
[1,2] Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
[a]irwan@uthm.edu.my, [b]norzila@uthm.edu.my

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Abstract. In Malaysia and worldwidely, concrete is one of the most popular construction material because of it's strong, durable and inexpensive material. It has speciality of being cast in any desirable shape but plain concrete however is porous, possesses very low tensile strength, limited ductility and little resistance to cracking. These problem become more complicated in various environmental condition like Malaysia to which concrete is exposed. Conventionally, a variety of sealing agent namely, latex emulsions suffer from serious limitations of incompatible interfaces, susceptible to ultraviolet radiations, unstable molecular structure and high cost. Therefore, a novel and more environmental friendly technique is proposed for treating concrete material in structure by employing bacteria induced calcium carbonate precipitation in the form of calcite

Introduction

Concrete is the most widely used man made construction material in civil engineering. It has specialty of being cast in any desirable shape but plain concrete however possesses very low tensile strength, limited ductility and little resistance to cracking. As an attempt, advancement in concrete technology should look into the concrete strength. It is now realized that strength of concrete alone is not sufficient, the degree of harshness of environmental condition to which concrete is exposed over its entire life is very important. Therefore both strength and durability have to be considered at the design stage in construction especially to produce a more durable structure. Some of major forms of environmental attack are chloride and sulphate attack that would lead to corrosion of reinforced steel and subsequent reduction in strength, serviceability and aesthetics of the structure [1]). This scenario may lead to early repair of the structure in order to prolong service life of concrete structure.

Recent development, a stronger and more durable concrete has been invented incorporating a biological approach namely bacteria. This new approach is called a bio-concrete which utilizing bacteria mineral precipitation to increase the strength and durability of concrete. Furthermore, this crossbreed leads to more durable concrete and last longer. Therefore, the maintenance cost can be reduced. Microorganisms play an important role in promoting deterioration in porous materials, improve sand properties, repair of limestone monuments and sealing of concrete cracks to highly durable material and finally enhance the durability of building materials [2], [3].

Growth and Culturing Bacteria

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 [4]. 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 [5].

Cell division in bacteria unlike cell division in a high organism, usually occur by binary fission or budding. In a binary fission, a cell duplicates its components and divides into two cell. In cell division

two identical daughter cell are produced. The daughter cell become independent when a partition grows between them [4]. A bacteria population can be doubled as quickly as 9.8 min [5].

Bacteria growths in three phases. The first phase is called the lag phase or rapid growth when bacteria receive a lot of carbon sources and nutrient. The second phase of growth is the logarithm growth or exponential phase. In log phase the nutrient is metabolized until one of the nutrient deplete. The final stage of growth is the stationary phase and the nutrient is depleted.

Carbonate Mineralization

Mineralization is a process that allows precipitation of chemical in mineral phase. The process of mineralization is called biomineralization with immobilization of bacteria in concrete for chemical precipitation. In the concrete, the bacteria creates micro environment with the condition to allow carbonate precipitation in the form of calcite [5].

Bacteria precipitate calcium carbonate resulted from metabolic activities namely, photosynthesis, sulphate reduction or urea hydrolysis [6]. Most of the bacteria that are found in soil, sand, water or natural mineral have the ability to precipitate carbonate under desired optimum environment such as pH, temperature, nutrient and redox potential. Each of the environment condition must remain within the tolerance range of the bacteria to sustain basis in concrete environment.

The bacteria repair on structure through carbonate precipitation under three different mechanisms namely, dissimilatory sulphate reduction by sulphate reduction bacteria, degradation of organic acid and degradation of urea by ureolytic bacteria. Among the three pathways to precipitate calcium carbonate, degradation of urea is among favorable application method because it is easier to operate and control [7}. It must be noted that bacteria isolated from other metabolic process may have similar performance for improving life span of the concrete. Therefore a more comprehensive study should be carried out using both sulphate reduction and ureolytic bacteria.

Factors affecting biomineralization

Bacteria cannot tolerate with extreme pH value. Under highly alkaline or acidic condition some bacteria cell may be hydrolyzed or enzyme denatured. The pH of the environment affects microorganism and microbial enzymes and also influence the dissociation and solubility of many molecules that indirectly influence microorganism [4].

Bacteria has a characteristic, optimal growth temperature at which the bacteria exhibits the highest growth and reproduction rate. Considering that the temperature normally fluctuates, on a daily or seasonal basis, most of the bacteria can tolerate with this fluctuation [4].

The ability of bacteria to carry out oxidation and reduction reaction depends on the oxidation state of the environment. The proportion of oxidized to reduced components constitute redox potential [4].The redox potential greatly influenced by the presence or absence of oxygen.

Nutrient can be in the form of organic or inorganic compound. Some bacteria requires high organic compound whereas others grow only at low concentration. Many inorganic compounds are essential nutrients for bacteria. Some chemical forms of organic compound are as microbial nutrient or inhibitors [4].

Therefore, the application of bacteria in concrete is more promising if the bacteria is isolated from respected country. Thus, no evidence has been found indicating that the isolated strains from other countries are effectively used in the country like Malaysia with different environmental factors from other countries.

Role of bacteria in concrete

According to Siddiq and Chaal [5], the primary role of bacteria in the precipitation process is to create alkaline environment through physiological activities.Specific functional group of bacteria cell favors binding with divalent cations (calcium and magnesium) and making microorganism crystal nucleation site. Specific proteins present in biological extracellular subtance cause the formation of calcium carbonate. Bacteria deposition of a layer of calcite on the surface of the specimens resulted in a decrease of capillary water uptake and permeability towards gas. The type of bacteria culture and

medium composition determine marphology of calcium carbonate crystal. In the case of using ureolytic bacteria,enzyme urease will catalyst the hydrolysis of urea to carbon dioxide and ammonia resulting to increase pH and carbonate concentration in the bacteria environment.

Immobilization bacteria in concrete for crack healing through metabolic process will increse the alkalinity (pH and dissolve organic carbon) and favoring the calcium carbonate precipitation. Biomineralization of calcite crystal by bacteria has great applicable for restoration of deteriorated calcerous monumers. Bacteria deposited of a calcite layer on the surface of the specimen, resulted in a decrease of capillary water uptake and gas permeability. Biomineralization is one the strategies to remediate cracks in building material because cracks will influence service durability on concrete structure and harmful for structure safety.

One of the important measure to protect concrete against damage is diminishing the water uptake. Surface treatment play an important role in limiting the infiltration of water. Conventional surface treatment using organic or inorganic product such as pore blocker, water repellents and coaring. These method pose several disadvantages such as degraded over time, need constant maintenance, different thermal expansion coefficient of the treated layers and non environmental approach if solvent was used [7].

Microbial concrete also purifies water impurities after some time (two weeks), black muddy color is changed to clean color after two months. Smell of water also will be eliminated. Microbial concrete also offer few advantages such as it can be usable as water purifier tank, floor lining of water purifier in homes or industries, can be used for purifying water such as lake, river.

Effects of bacteria on concrete properties

Immobilization of bacteria in concrete resulted to improve material properties as discussed in Table 1

Table 1: Effect of bacteria on various parameters

Research	Bacteria used	Parameter tested	Result
Ramachandran et al [8]	*B. pasteurii*	Compressive strength	Increased compressive strength
Ghosh et al [9]	*Shewanella sp*		25% increased in 28 days compressive strength
Basher [10]	*B. pasteurii*	Permeability	Decrease in gas permeability
Muynck [11]		Water absorption	Increase in water penetration
Muynck [11]		Chloride ingression	Increased resistance towards chloride penetration

The improvement of material properties as stated in Table 1 will increse strength and durability of the concrete.

Concluding remarks

Taking into account that microbial mineral precipitation appear to be a promising technique for improving material properties.A focused research in a more comprehensive area is desired for more effective application of bacteria in concrete. This review has highlighted that bacteria is a potential method in structure repair.

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Corresponding Author

Corresponding author: Assoc. Prof. Dr. Mohd Irwan Juki; email: irwan@uthm.edu.my; tel: +6074564203

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