Ain Shams University
Faculty of Science
Chemistry Department

UTILIZATION OF BIO-PRECIPITATION TO IMPROVE THE PHYSICO-MECHANICAL PROPERTIES OF BUILDING MATERIALS

A thesis Presented by

Hamdy Abdel Aziz Ahmed Abdel Gawwad

(M.Sc. in Chemistry)

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Thesis For
Ph.D Degree of Science in Physical and Inorganic Chemistry, under supervision of

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Hamdy .A . Abdel Gawwad

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ABSTRACT

The microbes can hydrolyze urea by *urease enzyme* to produce ammonium as well as carbonate ions and in the presence of calcium ions. This will result in calcium carbonate precipitation; this process called "biocalcification" or microbial induced calcite precipitation (MICP). This technology is environmentally friendly. In this work, the phenomena of microbial induced calcite precipitation was applied for sand consolidation, mortar crack remediation, improvement physico–mechanical properties of cement mortars and its resistivity to 5% magnesium sulfate solution as well as the surface protection of cement pastes and its resistivity to 3 % magnesium chloride solution up to one year. It was found that, the compressive strength and bulk density of consolidated sand by bacterial cells and urea/calcium chloride increase with bacterial cells up to 1.5 OD_{600}, urea / calcium chloride concentration up to 1.5 M, up to 4 treatments (4 days) and decreasing particle size of sand grains up to 150-300 µm. Meanwhile, the water absorption values decrease. Calcium chloride was found to be the better calcium source which gives higher physico-mechanical properties than those of calcium acetate or calcium nitrate. The compressive strength of untreated

crack mortar was lower than that of the control sample by 43 % which improved after remediation leading to a lowering in strength of 10 % than that of the control sample. Also, the compressive strength of cement mortar mixed with bacterial cells increases with bacterial cell concentration up to 1.0 OD_{600} then decreases at 1.5 OD_{600}. Meanwhile, the water absorption values decrease with bacterial cells concentration up to 1.5 OD_{600}. The water absorption values of protected cement pastes by microbial calcite precipitation were lower than those of the unprotected cement pastes. The cement mortar mixed with bacterial cells was more resistive against magnesium sulfate than the control. On the other hand, the protected cement pastes by microbial calcite precipitation were more resistive against magnesium chloride than the unprotected cement pastes. The distinct phases precipitated by bacterial cells were identified and characterized by XRD, DTA, TGA, petrography and SEM techniques.

CHAPTER (1)
INTRODUCTION AND LITERATURE REVIEW

1.1. INTRODUCTION

Microbial communities and the mineral world are dancing a ‘geobiological tango’ **(Nealson & Ghiorse, 2001**). Dynamics of microbe–mineral interactions are important in carbonate production in both marine and non-marine environments. There is increasing evidence that many processes are traditionally considered as purely physico-chemical, such as carbonate mud production during whiting events (**Robbins & Blackwelder, 1992**).

Calcite is one of the most common and wide spread minerals on Earth constituting 4 wt% of the Earth's crust. It is naturally found in extensive sedimentary rock masses, as limestone, marble and calcareous sandstone in marine, fresh water and terrestrial environments **(Hammes and Vertraete, 2002, Klein and Hurlbut, 1999)**.

Microorganisms and microbially mediated mineralization processes are active in almost every environment on earth and possibly in extraterrestrial systems. In natural environments, chemical $CaCO_3$ precipitation ($Ca^{2+}+CO_3^{2-}\rightarrow CaCO_3\downarrow$) is accompanied by biological processes, both of which often occur simultaneously or sequentially. Microbes from soils and aqueous media have been frequently reported to induce the precipitation of calcium carbonate mineral phases in both natural and laboratory settings. Because of this, microbial activity is regarded as an important player in the formation of carbonate sediments and soil carbonate deposits. A number of studies have investigated carbonate mineralization induced by microbes, including that by soil bacteria. An endospore-forming soil bacterium, ***urease positive***, participates in calcite precipitation in the environment by producing the urease enzyme. Urease catalyzes urea to produce CO_2 and ammonia, resulting in an increase of pH in the surroundings where mineral ions (Ca^{2+} and CO_3^{2-}) precipitate as $CaCO_3$.

The precipitation of calcium carbonate is governed by four parameters; (1) concentration of calcium ion, (2) concentration of carbonate ions, (3) the pH of the environment (which affects calcium carbonate solubility) and (4) the presence of nucleation sites **(Hammes and**

Vertraete, 2002). Calcium carbonate may theoretically occur in natural environment by increasing the concentration of calcium and/or carbonate in solution or by decreasing the solubility of calcium and/or carbonate. Calcite precipitation may come about abiotically by evaporation or shift temperature or pressure or biotically through the action of microorganisms. Bacteria have themselves been shown to be excellent nucleation sites for growing minerals during the formation of rock **(Ferris et al., 1986, Ferris et al., 1987)**, with many studies confirming the precipitation of calcite on bacterial cell surface (**Fujita et al., 2000, Hammes et al., 2003c, Warren et al., 2001**). As there is no shortage of nucleation sites in bacterial culture, the first three parameters of calcium and carbonate concentration and pH are keys for microbial calcite precipitation (MCP).

1.1.1. Mechanism of microbial induced calcite precipitation:

Like other biomineralization processes, calcium carbonate ($CaCO_3$) precipitation can occur by two different mechanisms: biologically controlled or induced **(Lowenstan and Weiner, 1988)**.