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Innovative Ground Improvement for Civil Infrastructure Development

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ABSTRACT

Unstable soils, characterized by attributes such as looseness, erodibility, and collapsibility, present considerable engineering challenges due to their low bearing capacity and high compressibility. Such problematic soils are prevalent worldwide and impede the progress of civil infrastructure development, including building foundations, roads, railways, embankments, retaining walls, etc. Ground improvement is thus necessary for stabilizing these soils before construction, hence, preventing excessive post-construction soil deformations or failures and associated structural damages. However, conventional ground improvement relies on chemical soil treatment by additives such as lime or Portland cement. Despite their effectiveness, chemical additives are recognized for their notable environmental and, at times, toxic repercussions. This keynote lecture aims to introduce an innovative and environmentally friendly ground improvement alternative using bio-geotechnical engineering. The lecture discusses the principles and applications of this green and eco-friendly technology in civil infrastructure development. The anticipation is that this novel approach will gradually supplant soil stabilization involving chemical additives, paving the way for future superior and eco-friendly conscious ground improvement technology.

1. INTRODUCTION

Unstable soils encountered in most civil infrastructure projects possess poor geotechnical engineering characteristics such as low bearing capacity and high compressibility, hence, pose significant construction, maintenance, and safety issues. Ground improvement of such problematic soils before construction is necessary to increase soil strength and stiffness, hence, avoid post-construction failure. Among conventional methods of ground improvement that are widely employed is soil stabilization by chemical additives or grouts such as lime or Portland cement. However, most chemical grouts have serious environmental concerns as they contribute to the disturbance of ecosystems. For instance, acrylamide grout was associated with five cases of water poisoning in Japan resulting in the ban of nearly all chemical grouts (Karol 2003). More recently, American agencies have proposed to ban most synthetic grouting materials (DeJong et al. 2010), both because of their toxicity and contribution to global carbon dioxide emissions (Li et al. 2013).

In this keynote lecture, an eco-friendly soil stabilization alternative using bio-geotechnical engineering is introduced. This green technology is called “bio-cementation” via microbial-induced calcite precipitation (MICP), which involves injecting or mixing unstable soils with cultivated ureolytic earth-based bacteria, typically Bacillus pasteurii (also known as Bacillus sphaericus), in urea and calcium- rich solution. The microbial hydrolysis of urea generates carbonate which reacts with calcium ions to create precipitates of calcium carbonate (calcite) on the surfaces of the constituent soil grains. This process forms cementing bridges that bind soil particles together, leading to improved soils. Because generated calcite occurs on the soil grains, bio-cemented soils remain relatively permeable, which is desirable in most geotechnical engineering applications. It has been observed that calcite is as effective as other cementing agents and has proved its sustainability and capability to alter and improve soil engineering properties (Cheng et al. 2013). In principle, bio-cementation mimics the natural phenomenon of calcite precipitation that transforms soil deposits into sedimentary rocks (e.g., sandstone or limestone) but within a few days instead of thousands of years. This lecture presents some features of the research undertaken at Curtin University, Australia, on bio-cementation technology with special reference to civil infrastructure development.

2. EXPERIMENTAL RESULTS

The keynote lecture will present some experimental results carried out by the author and his co- workers, confirming the practicality of biocementation towards its usage for ground improvement. The effects of some salient factors affecting bio cementation will be discussed, including the degree of saturation of treated soils, initial pH of the soil, temperature impact, and treatment uniformity. In addition, the possibility of using seawater as a calcium source for commercial calcium chloride will also be presented, which can reduce the cost of biocementation treatment in marine environment applications. Moreover, the lecture will present some interesting results for using biocementation to produce “bio-bricks” as a construction material.

3. FINDINGS

The presented lecture demonstrated the potential use of biocementation as a promising technology for ground improvement in civil infrastructure development. However, it should be emphasized that the efficiency of biocementation in improving soil strength varies according to some physical and environmental treatment conditions. The findings confirmed that higher soil strength can be obtained at a lower degree of saturation (Cheng et al. 2013)., challenging the widely belief that bio-treated soils need to be treated under fully saturated conditions. The findings also indicated that biocementation can be reasonably processed in different environmental conditions, including pH and temperature (Cheng et al. 2017). It was also confirmed that it is possible to use seawater as a chemical reagent for biocementation after repeated treatments to replace commercial calcium chloride (Cheng et al. 2014). This finding extends the biocementation application to the marine environment at a lower cost in areas of offshore and onshore infrastructure protection and maintenance, as well as coastline erosion prevention. Finally, the findings demonstrated the successful use of biocementation for producing “bio- bricks” as a construction material (Cheng et al. 2020).

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