Bioclogging and Biocementation of Soil in Geotechnical Engineering

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1. INTRODUCTION

Microbial Geotechnology can be considered as a branch of Geotechnical Engineering aiming to improve the mechanical properties of soil so that it will be more suitable for construction or environmental purposes (Indraratna and Chu, 2005). There are two approaches in Microbial Geotechnology: bioclogging and biocementation (Ivanov and Chu, 2008; Mitchell and Santamarina, 2005). Bioclogging is the production of pore-filling materials through microbial activity so that the porosity and hydraulic conductivity of soil can be reduced. Biocementation is generation of particle-binding materials through microbial activity *in situ* so that the shear strength of soil can be increased.

Bioclogging could be used for the following construction and geotechnical applications: 1) to reduce drain channel erosion; 2) form grout curtains to reduce the migration of heavy metals and organic pollutants; 3) prevent piping of earth dams and dikes; 4) construction of aquacultural ponds; 5) construction of reservoirs (Ivanov and Chu, 2008). Biocementation could be used for the following construction and geotechnical applications: 1) to control erosion in coastal area and rivers; 2) construction of aquacultural ponds ; 3) construction of reservoirs; 4) construction of dams; 5) to reduce the liquefaction potential of soil; 5) to enhance the stability of slopes and dams; 6) to produce strong filling material from soft soil; 7) soil stabilization in land reclamation; 8) increasing the bearing capacity of foundations; 9) treatment of surfaces to reduce radioactive or toxic dust levels; 10) to increase the resistance of boreholes on oil and gas fields; 11) immobilization of the soil pollutants (Ivanov and Chu, 2008).

Bioclogging and biocementation can be considered as the specific types of soil grouting. Chemical grouting of soil is a common technique in civil engineering (Karol, 2003). However, chemical grouting could be more expensive than biogrouting and many chemical grouts are toxic for human and environment. Advantages of biocement in comparison with the conventional cement are as follows: 1) it is less energy consuming material; 2) the solutions of biocement have low viscosity and can penetrate into the porous soil by gravity.

Hypothetically, the most suitable microorganisms for soil bioclogging or biocementation are facultative anaerobic and microaerophilic bacteria, although anaerobic fermenting bacteria, anaerobic respiring bacteria, and obligate aerobic bacteria may also be suitable to be used in geotechnical engineering (Ivanov and Chu, 2008). Due to complexity, the applications of microorganisms in Geotechnical Engineering require an integration of microbiology, ecology, geochemistry, and geotechnical engineering. The aim of our research was to examine application of different microorganisms for biocementation.

2. MATERIALS and Methods

The beach sand with the grains from 4.75 mm to 0.075 mm and a porosity of 43% was used in experiments. The following biogrouts have been used:

1) anaerobic ferrous-containing solution produced by iron-reducing bacteria from iron ore (Ivanov et al., 2008; Stabnikov et al., 2005) separately from sand or inside the sand sample;
2) oligotrophic bacteria producing exopolysaccharides strongly binding sand grains (Ivanov and Chu, 2008);
3) nitrifying bacteria producing exopolysaccharides binding sand grains (Ivanov and Chu, 2008);
4) microbial polysaccharide xanthan;
5) conventional biogrout containing $CaCl_2$, urea, and urease-hydrolysing bacteria (Ivanov and Chu, 2008; Mitchell and Santamarina, 2005) .

The pores of the sand in plastic cylinder were filled with the biogrout, incubated for 1 -10 h, half of the samples was dried at 60^{o}C. When iron-reducing, oligotrophic or nitrifying bacteria have been cultivated directly in sand