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Study on Bio-Cementation of Ex-Coal Mining Soil as a Road Construction Material

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1 INTRODUCTION

Indonesia has hundreds of thousands hectares of ex-coal mining land that has been left without proper management by the government or mining companies. After Analisys, the soil in these former mining areas can still be used as a road construction material. However, this soil needs to be improved in terms of engineering properties such as CBR and Shear Strength values. Turning the ex- coal mining soil to a cement-like material using bacteria (biocementation) is considered one of the biogeotech technologies that is developing (Al Qabany & Soga, 2013). For geotechnical applications, microbial grouting is mostly utilized to strengthen the soils by means of increasing soil strength and stiffness through the biomineralization of CaCO3 crystals that act as a cementing agent, binding soil particles together inside the soil matrix (Cheng, Cord-Ruwisch, & Shahin, 2013).

Recent advances in soil stabilization using calcite-induced microbial precipitation techniques (CaCO3) (MICP) have been reported by Mujah, Cheng, & Shahin, (2019). Microbial-induced calcium carbonate presipitation (MICP) deposition is a naturally occurring biological process in which microbes produce inorganic material as part of their basic metabolic activity. This technology has been explored and promising with potential in a variety of technical applications (Dhami, Reddy, & Mukherjee, 2013)

However, coal mined soils contain heavy metals, so special attention needs to be paid in the process of applying biocementation using bacteria. Biocementation using bacillus subtilis bacteria has been studied extensively focusing on sandy and clay soils, no one has yet done research on soils containing coal.

2 MATERIALS AND METHODS

To provide detail of materials used in the experimental study, laboratory investigation program was carried out to evaluate the basic properties and mechanical properties of the untreated soil and stabilized soil, in this case, soil containing 15% of coal treated by microbially-induced calcite (CaCO3) precipitation (MICP). Based on the sieve analysis, this soil is a sand because 0% retained from the sieve No. 4 and only 2% of the material passed from the sieve No. 200. Microstructure analysis using XRD (X-Ray Diffraction) shows that minerals contained in soil with 15% coal are dominated by 92.5% Silicon oxide $ -alpha Quartz low (SiO2) as much as 92.5% and 7.5% Ilmenite (Fe O3 Ti) shown in Fig. 1 and Fig. 2.

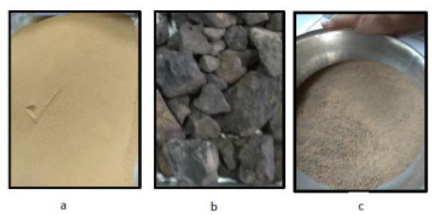

Fig. 1. a. sand; b. coal ; c. sand and coal after mix

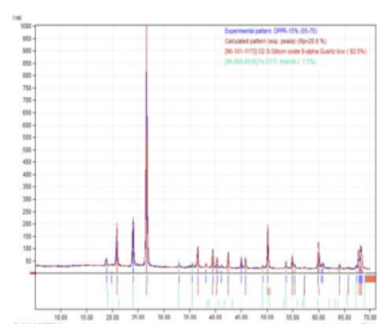

Fig. 2.XRD Data

2.2 Preparation of bacteria and media

Bacillus subtilis is a Gram-positive, rod-shaped bacterium that forms heat-resistant, dormant spores. It is commonly found in the soil (Piggot, 2009). B. subtilis can grow in a minimal medium containing only essential salts and carbon, nitrogen, and phosphorus sources. *B. subtilis* grows at temperatures ranging from 10° to 55°C, with fastest growth rates at about 42° C. At 37° C, *B. subtilis* grows with a doubling time of about 30 minutes in a rich medium.

In this experimental, *Bacillus subtilis* were cultured in B4 medium, which contained Urea (20 g/L), Nutrient Broth (3 g/L), NaHCO3 2.(12 g/L), CaCl2.2H2O 4.(14 g/L) and NH4Cl (10 g/L) dissolved in distilled water.

2.3 Methods

In this study, samples were treated under a different percentage of bacteria to evaluate the optimum bacterial concentration that yields the highest soil strength. Concentration used were 0%, 3% and 6% bacterial solution of the weight of the sample.

Direct Shear and California Bearing Ratio specimens ware remoulded according to standard method ASTM E-736-00 and ASTM D-1883 being 6 cm in diameter and 2 cm high for direct shear and 6 inches in diameter and 7 inches high for CBR. Specimens tested at curing times of 0 day, 3 days, 7 days, 14 days and 28 days.

3 RESULT AND DISCUSSION

The effects of different concentrations of bacteria on the strength of the MICP samples are shown in Fig. 3.

It can be observed that the MICP process using bacillus subtilis in coal-contaminated soils has succeeded in increasing the strength of the soil. After treatment, the shear strength value increased by more than 200% compared to untreated soil.

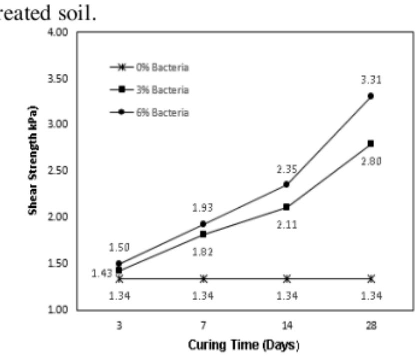

Fig. 3. Shear strength-curing time relationship after MICP treatment.

The value of shear strength after the addition of 3% solution *B. subtilis* increased from 1.34 kPa to 2.80 kPa while the addition of 6% bacteria increased to 3.31 kPa.

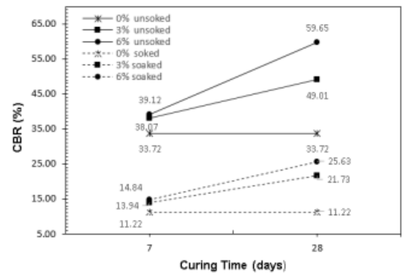

Fig. 4. CBR-Curing time relationship after MICP treatment

In the CBR test, MICP increased the CBR value by more than 150% compared to without treatment, from 33.72% to 59.65% CBR value unsoaked.

4 CONCLUSION

This paper has shown that the bacterium Bacillus subtilis can be used in the MICP process in coal-contaminated soils. After treatment, the shear strength value increased by more than 200% compared to untreated soil. In the CBR test, MICP increased the CBR value by more than 150% compared to without treatment.

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