Improving soil surface resistance and stability using EICP process

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ABSTRACT

In recent years, soil surface erosion, especially by wind, has increased the area of deserts and increased problems for the ecosystem. Using biological methods to strengthen the soil's surface is a new way to prevent soil erosion. In this study, crude extract of soybean shoots has been used as a rich source of urease enzyme in the process of enzyme induced calcium carbonate precipitation (EICP). In this process, urea is hydrolyzed by urease enzyme and then the produced carbonate is combined with calcium in the EICP solution to produce calcium carbonate which acts as a binder for soil particles. The plant extract is a suitable substitute for pure urease enzyme or enzyme obtained by bacteria, which is costly to prepare. Three types of soils have been sprayed with EICP solution for biocementation using the EICP process and soil strength measurement test has been performed on the soil using a penetrometer. The thickness of the crust formed by the spraying of the solution has been measured. The results show that the method used increases the soil surface resistance and is a suitable method to prevent soil erosion.

KEYWORDS

EICP, Erosion, Retrofitting, Penetrometer, Sand

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1. Introduction

In recent years, numerous applications for biocementation technology have been reported. These applications cover a wide range of fields, such as pollutant removal [1], soil improvement [2], self-healing of conventional concrete [3], preservation and restoration of historic structures [4], and prevention of surface soil erosion [5].

Wind erosion significantly contributes to the degradation of soil and the environment, as well as to air pollution, the movement of suspended particles, and their accumulation in irrigation and drainage systems.

In this research, a plant extract formulated with phosphate buffer (as a source of urease enzyme) was used in the biological biocementation process by the enzyme induced calcium carbonate precipitation (EICP) method. The effectiveness of the crude plant extract as an economical alternative in comparison to other established sources in the EICP process was assessed.

Three types of soil were evaluated to investigate the performance of the EICP process using the spray method. Soil surface resistance testing was performed on the treated soils using a pocket penetrometer and the thickness of the formed crust was measured. Unconfined compressive strength testing was also performed on the soil samples.

2. Test methods and results

2.1. Soil surface resistance measurement test

In this study, soybean aerial part extract with urease enzyme activity 9.355×10^(-3)(ΔAbs 340nm)/(µg protein ml^(-1)) was utilized. For the extraction of soybean aerial parts, phosphate buffer at a concentration of 20 mM was utilized [6]. The characteristics of the treated soils are evident in Figure 1.

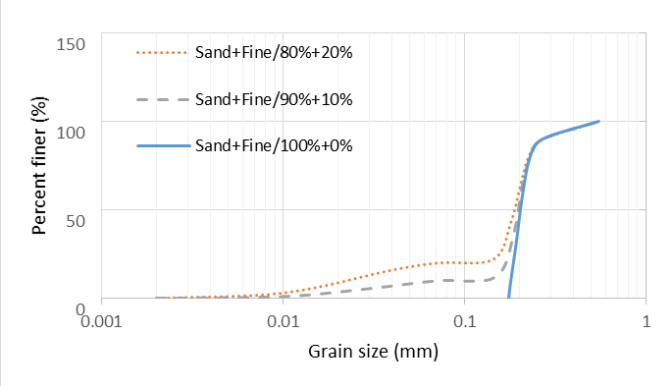

Figure1. Soil grain size characteristics

Eight cylindrical samples with a diameter of 40 cm and a height of 20 cm were prepared from each soil type. The EICP solution was sprayed in varying volumes onto cylindrical samples of prepared soil. After 21 days, the surface resistance of the improved samples was examined using a pocket penetrant test (Standard: ASTM D1558.D2573).

2.2. the measurement of treated soil's unconfined compressive strength

Three cylindrical samples were made for each soil in order to determine its unconfined compressive strength. The cylindrical samples were injected with EICP solution. The strength measurement test was carried out following the samples' drying.

3. Costs of production of 1 liter of crude soybean extract (containing urease enzyme)

The preparation of one liter of crude soybean extract for the EICP process costs about 17,000 rials.

4. Cost of preparing one liter of solution containing pure urease enzyme

According to the EICP study, 0.25 to 5 grams of enzyme are used in the EICP process to produce one liter of solution containing enzymes [7-13]. According to the prices reported by the sellers, the cost of the preparation of one gram of urease enzyme (Merck) is over twenty million Rials.

4. Discussion and analysis of results

In this study, soybean aerial part extract was used as a source of urease enzyme in the EICP process. It is also more cost-effective and easier to prepare than pure enzyme. Numerous studies have confirmed that spraying EICP solution increases soil surface resistance. These studies show a correlation between soil erodibility indicators and an increase in soil surface resistance. Additionally, soil erodibility parameters decrease as surface resistance rises [14-16]. The penetrometer's maximum resistance for SP soil in this investigation was approximately 360 kPa. The UCS test results show that the strength of the improved soil decreased as the percentage of fine-grained soil (less than 0.075 mm) increased and the percentage of sand soil decreased. The Tung Hoang et al. study found similar outcomes for varying soil grain sizes [17].

5. Suggestions

• To further investigate the effectiveness of using crude soybean extract to increase soil surface resistance, solutions with different concentrations of calcium chloride and urea should be used in the EICP process. The optimal concentration of materials in this process should be investigated.

• The process of surface erosion should be examined using wind tunnel testing.

6. Conclutions

The resistance measured by the surface penetrant test and the thickness of the layer that forms decrease with increasing silt content in sandy soil under the same conditions as when EICP solution is sprayed on it.

Increasing the spraying recurrence results in higher surface resistance of the soil and a thicker crust formation in the samples.

The experiments in this study demonstrate the effectiveness of crude soybean extract as a source of urease, which is easier and cheaper to prepare than other methods.

According to the results, this method can be used as an effective method to control surface soil erosion.

7. References

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