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The Compressive Strengh Of Cohesive Soil Stabilized With Microbial Induced Cementation

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Abstract. This research aims to evaluate the physical and mechanical characteristics of soil stablized with microbial induced cementation method. The variation of microbial induced by 4%, 6%, and 8%, while the age variations of bacterial culture of 2, 4, and, 6 days and a curing period of 3,7,14 and 28 days. The properties of the soil studied in this research are as optimum moisture content of 32.19%, dry volume weight (γd) 1.36 gr/cm^3, soil density 2.63 gr/cm^3, atterberg limit test liquid limit 46.89% plastic limit 31 ,94%, plasticity index 14.96% and shrinkage limit 7.49%. The compressive strength of the soil which was stabilized with 6% solution of Bacillus subtilis bacteria for 4 days found to be optimum 19.96 kg/cm^2 at 28 days or an increase of 6 times from the soil was not stabilized with microbial induced 3.02 kg/cm^2

Keywords: Soil, biocementation, Unconfined Compressive test

1. Introduction

Soil in one location has different characteristics from soil in other locations, this is what makes the bearing capacity of the soil as part of the highway construction system different from one location to another, basically not all types of soil can be used in road construction. or structural construction. Soil properties and behavior will be taken into consideration in the planning and implementation of a work, soil improvement has become a very important part and must be considered because of the scarcity of suitable soil is increasingly difficult to obtain and the rate of human population growth continues to increase. In terms of the need for road construction where material replacement and the use of chemicals for subgrade layers is inefficient, it is necessary to use other methods so that the existing soil quality is better for road construction purposes without having to replace the existing soil and damage the environment. There needs to be a new effort to utilize biological processes to modify soil properties and microbes capable of depositing calcium carbonate ($CaCO_3$) compounds called microbial induced calcite precipitation (MICP) by utilizing biological processes to modify soil properties [1] The use of micro-organisms is considered as an alternative in the midst of the proliferation of chemicals and synthetics in civil construction [2] Effective formation of CaCO3 will increase the strength and stiffness of the subgrade and embankment layers while maintaining the permeability characteristics [3] Bio-cementation is a method of soil improvement by utilizing the ability of bacteria that do live in the soil to produce the enzyme urease. The ex-mining land materialafter treated with MICP using Bacillus subtilis, it can be reused and qualifies as a road construction material [4]. The addition of bacteria to stabilize sandy loam using the bio-grouting

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method succeeded in increasing the carrying capacity of the soil [5] Tropical organic soil along with the addition of sand using a pre-mixing treatment method with a curing period of 3 days. The value of unconfined compressive strength (UCS) increased [6] According to the California Bearing Ratio (CBR) value range criteria (20% ≤CBR<40%) for subbase layer, the use of 3.5 to 6% bacteria can technically be functionally justified as a road material with the modulus of stabilized clay soil reaction value of 68 to 110 kN/m2/mm. The results of this study have technical. Implications for the significance of the use of Bacillus subtilis bacteria as the biotechnology stabilization material to increase the bearing capacity and modulus of soil reaction with high plasticity clay [7] Transformation in sand soil structure after bacterial stabilization for 14 days by varying the injection of bacteria [8]. The gap between this study and previous research is, this study tries to variation the percentages, 4%, 6% and 8% bacterial solution, which have the most optimum compressive strength values and the age of bacterial culture is 2, 4, and 6 days with a curing period of 3, 7, 14 and 28 days.

2. Materials and Testing Methods

2.1. Preparation of material

The material used in the research came from Makassar City, South Sulawesi province. Sampling by conventional excavation using a hoe and a shovel as shown in Figure 1, then the sample is placed in a sample sack and wrapped in plastic to maintain the condition of the moisture content, and labelled with the initials according to the location . The second is the preparation of a preliminary test of the sample that has been taken to determine the physical properties of the soil which includes testing the water content, testing the specific gravity of the soil, testing the limits of Atterberg, sieve analysis test, compaction test and mechanical test of unconfined compression test. The bacteria used in this research is Bacillus subtilis as shown in Figure 2. The reason for choosing Bacillus subtilis is it lives in the soil, forms endospores, which is a period of survival in extreme environmental conditions of temperature and produce calcite.

Figure 1. Sample of soil

Figure 2. Bacterical salution

2.2. Test of bacterial growth

The growth test was carried out to determine the growth characteristics of a type of bacteria through a growth curve marked by turbidity in liquid media with the help of a shaker and incubator. Microbiological culture is a method of multiplying microbes on culture media by controlled laboratory culture. Bacterial growth curves were made to determine the growth phases of bacteria, namely the lag, exponential, stationary, and death phases. Lag phase is the adjustment phase of bacteria to the new environment, the exponential or logarithmic phase is characterized by a period of fairly rapid growth. Each cell in the population divides into two, the stationary phase occurs when the rate of bacterial growth occurs, and the death phase is the phase where the death rate is greater as shown in Figure 3. Bacterial culturing process with a composition of 20 g Urea, 3 g Nutrient Brouth, 2.12 g $NaHCO_3$, 4.14 g CaCl, 10 g NH_4Cl then mixed with activated bacteria Bacillus subtilis.

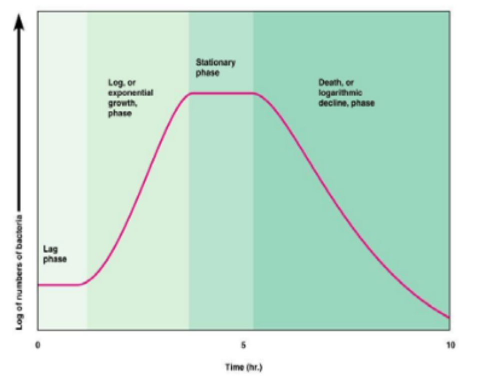

Figure 3. Curve of bacteria growth

2.3. Testing of physical and mechanical properties

Physical properties of the soil are properties related to the elements of the composition of the soil mass, while the mechanical properties of the soil are the behavioral properties of the soil mass structure when subjected to a force or pressure. Laboratory tests to determine physical properties include water content, Atterberg limit, sieve analysis, and specific gravity (specific gravity), while mechanical properties tests include compaction test, and Unconfined Compression Test (UCT) based ASTM D2166-06. Before material testing first measures and weighs the sample to be tested as shown in Figure 4, the surface of the sample looks whitish after curing for a few days as shown in Figure 5, Unconfined Compressive Strength test as shown in Figure 6. The tools that will be used in this research were previously checked for their conditions and capabilities and calibrated first. The procedure and the workings of the tool must be studied carefully, the ability, accuracy, and capacity of the tool must be well understood so that errors do not occur during the implementation of the testing. The Unconfined Compression Test (UCT) testing begins with mixing soil with a bacterial solution with a variation of 4, 6, and 8% solution, soil with bacterial culture 2, 4 and 6 days, UCT samples were made with a diameter of 5.5 cm and a height of 11 cm and then cured for 3, 7, 14 and 28 days, this curing aims to improve the chemical process between the soil and a solution of Bacillus subtilis which is expected to improve the compressive strength of the soil, Then the UCT test is carried out to get the value of axial strain ε (1), average cross-sectional area A (2) and value of compressive strength qu (3)

$$\varepsilon = \frac{\Delta L}{Lo} \text{ x } 100 \tag{1}$$

$$A = \frac{Ao}{1-\varepsilon} \tag{2}$$

$$qu = \frac{K \text{ x } R}{A} \tag{3}$$

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Figure 4 . Samples before UCT test	**Figure 5**. Surface of the sample is slightly whitish in color	**Figure 6**. Unconfined compression test

Result and Discussion

The results of the physical tests in the laboratory are shown in Table 1. The initial moisture content is 12.12%. The results of the standard Proctor compaction test obtained the optimum moisture content of 32.19% with dry volume weight (γd) 1.36 gr/cm3, soil density 2.63 gr/cm^3, Atterberg limit test liquid limit 46.89% plastic limit 31 ,94%, plasticity index 14.96% and shrinkage limit 7.49%, while the results of the analysis of sand filters are 21.60%, silt 38.32% and clay (clay) 36.88%. The results of the Unified Soil Classification System (USCS) are classified as fine-grained soils with the ML classification, namely silt with low plasticity, while based on AASHTO the soil samples classified into group A-7-5 are clay soils with moderate to poor ratings

Table 1. Result of Soil Properties Testing

Testing	Result
Water (W) % Content	12.92
Specific Gravity (Gs)	2.63
Liquid Limit (LL) %	46.89
Plastic Limit (PL) %	31.94
Plasticity Index (PI) %	14.96
Shrinkage Limit (SL) %	7.49
AASHTO	A-7-5
USCS	ML
Gravel (%)	3.2
Sand (%)	21.6
Silt (%)	38.32
Clay (%)	36.88
Optimum moisture content (Wc) %	32.19
Maximum dry density kg/cm^3	1.36
Sliding angle (ø) kg/cm^2 (°)	33
Cohesion (c) %	0.65

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USCS plasticity diagram to obtain a soil classification. Based on the liquid limit value, soils can be classified as high plasticity and low plasticity soils. Soils with high plasticity are characterized by the liquid limit value above 50%, while low plasticity if the liquid limit value is below 50 as shown in Figure 7.

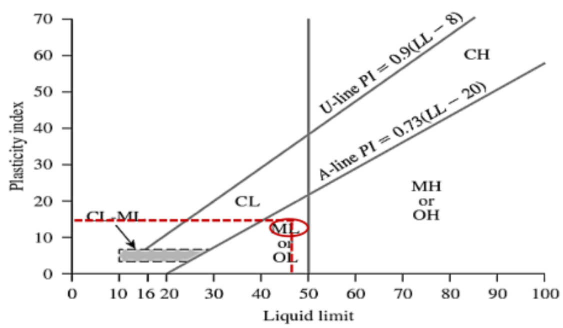

Figure 7. Unified soil classification system plasticity diagram

3.1. Result of Unconfined compression test

The results of the compressive test of stabilized soil with the addition of 4% solution of bacillus subtilis bacteria and treatment periods of 3, 7, 14, and 28. Figure 8, for 2-day culture shows an increase at 28 days of age with a compressive strength value of 17.54 kg/cm2, for 4 days culture at 28 days old showed a compressive strength value of 18.46 kg/cm2, 6-day bacterial culture at 28 days showed a decrease to 12.23 kg g/cm2, the compressive strength value of variation 6% of bacteria culture 4 days at 28 days showed the most optimum compressive strength value 19.96, for a variation of 8% bacteria culture 4 days aged 28 showed a UCT value of 17.44 kg/cm2 as shown in Figure 8,9,10. From the test results showed that the soil was not stabilized with bacteria has a compressive strength value of 3.02 kg/cm2. The age of 4 days of bacterial culture is the highest phase of bacteria because in this phase the bacteria are in a stationary phase, which means the level of calcite production increases compared to 6 days of culture which has decreased due to this phase the bacteria enter the death phase, the longer the curing time, the addition of a concentrated solution. The optimum bacteria is with the value of 6% and culture 4 days mixed into the soil, the greater the value of soil strength or an increase of 6 times the strength of the original soil

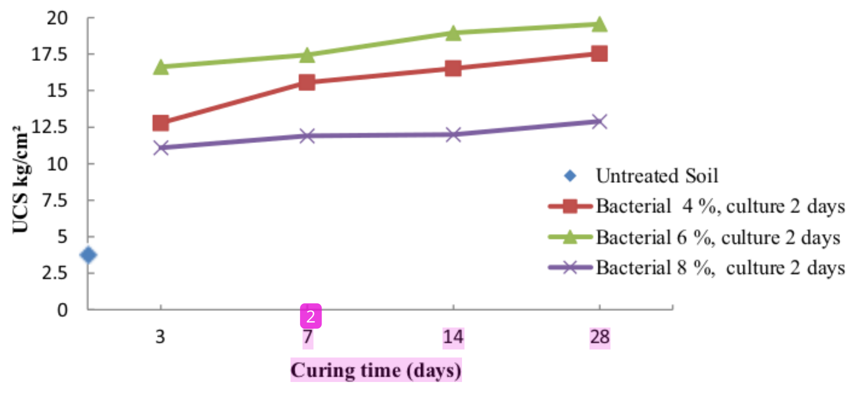

Figure 8. Variations in the solution of 4%, 6%, and 8% bacteria for 2-day culture

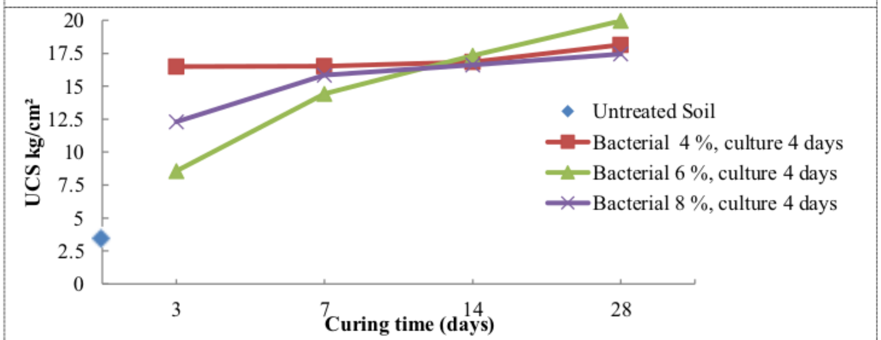

Figure 9. Variations in the solution of 4%, 6%, and 8% bacteria for 4-day culture

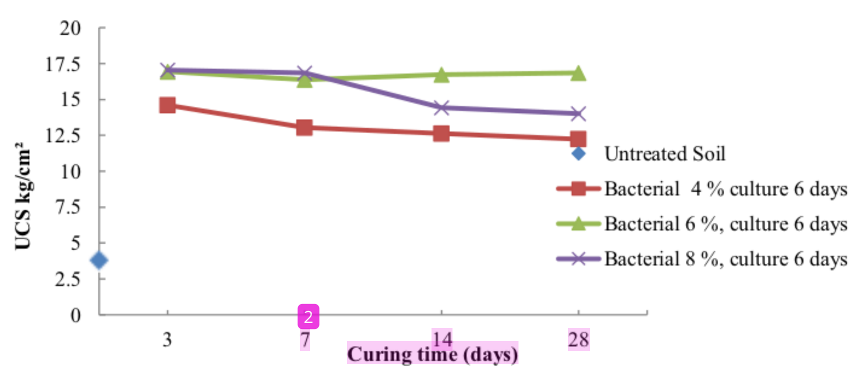

Figure 10. Variations in the solution of 4%, 6%, and 8% bacteria for 6-day culture

22 Conclusion

The compressive strength of the soil stabilized with the addition of 6% solution of bacillus subtilis bacteria and 4 days of culture had the optimum compressive strength value at 28 days with acompressive strength value of 19.96 kg/cm^2, or an increase of 6 times from soil that was not stabilized with bacteria only has a compressive strength value of 3.02 kg/cm$^{2.}$ The research was conducted on a laboratory scale, further development needs to be done by conducting field testing (full scale) to see how the behaviour of bacteria when the conditions are dynamic, such as in dry/hot and wet/rainy conditions

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