Mechanical Properties Improvement of Clays Using Silica Sand Waste and Dust Sand Foundry Waste

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Abstract. The increase of industrial waste and many road damages due to unstable subgrade invite the research on soil additives made from waste treatment as stabilizers to improve the mechanical value of clay. This study used California Bearing Ratio Test based on the ASTM standard for mechanical properties testing of clay. The soil stabilization method was carried out by mixing the clay with Silica Sand waste and Dust Sand Foundry waste in a predetermined composition. California Bearing Ratio value of 2.5 mm penetration showed a significant increase of 47.9% from the original clay in the composition of the waste 5% Silica Sand and 5% Dust Sand Foundry.

1. Introduction

A mineral factory in the Jababeka Industrial Estate, Cikarang, West Java, produces 50 tons of silica sand (SS) waste every month. Another factory, a metal mold manufacturing industry, produces the Dust Sand Foundry (DSF) waste. Both of these wastes contain compound elements that can be used as stabilizers or clay soil additives. These new materials are cheap and available for improving the subgrade. Some researchers have conducted research using waste or other additives, yet research by mixing two types of SS and DSF waste is still lacking. The CBR value showed an upward trend in stabilizing the soils using Ground Granulated Blast Furnace Slag (GGBS) industrial waste [1]. Another study utilized the recycled tiles and tires in stabilizing the soils which gave a good effect as a substitute for cement or sand [2]. The use of electric arc furnace dust (EAFD), an industrial by-product in lieu of cement or lime, showed a significant improvement in mechanical properties and durability of sand [3]. The stabilizing effect of powdered glass on clay soil showed an increase in CBR values in the soil with the addition of 5% glass powdered [4]. Addition of Saw Dust Ash to clayey soil, resulting in increased CBR and unconfined compressive strength [5]. Garnet waste as much as 40% mixed on the ground for road shoulder showed an improvement in the CBR value [6].

This research proposed an innovative combination of two different types of industrial waste, namely SS and DSF, as additives to replace cement or lime for clay soil stabilization. Improving the mechanical properties based on California Bearing Ratio (CBR) values in soil mixtures using SS and DSF wastes, and finding the optimal waste composition with maximum CBR values were the aim of this study. This study did not review the changes in soil chemical structure due to soil stabilization using waste as the limitation but only focused on mechanical changes in soil stabilized through CBR values. The research contributes to the report of a method of combining two different types of
industrial wastes, namely SS and DSF as clay soil stabilization additives in order to increase the CBR value and to find the composition/percentage of waste based on the highest increase in CBR value. Potential Impact of this research is the discovery of compositions and combinations of materials made from industrial waste that are useful as additives for improving the carrying capacity of clay in subgrade roads. In addition, this waste utilization will produce technical and economic benefits.

2. Materials and Methods
The material in this research was the clay gathered from the soil of Universitas Islam 45 Bekasi at a depth of 20-50 cm from the original ground surface (disturbed condition), Silica Sand (SS) waste, and Dust Sand Foundry (DSF) waste. Samples were prepared by mixing air-dried clay conditions with SS waste and DSF waste as additives or stabilizers, then left in a closed bag for seven days at room temperature. The composition of the waste was as follows: SS waste 2.5% and 5% of the soil dry weight, and DSF waste as much as 2.5% and 5% of the soil dry weight. The mechanical properties test of the un-soaked clay is California Bearing Ratio (CBR) with 2.5 mm penetration following the ASTM standard. This test was carried out under Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) conditions based on the results of the proctor standard compaction test. Variations in waste composition are shown in table 1.

| Varian Number | SS (%) | DSF (%) |
|---------------|--------|---------|
| 1             | 0      | 0       |
| 2             | 0      | 2.5     |
| 3             | 0      | 5       |
| 4             | 2.5    | 2.5     |
| 5             | 2.5    | 5       |
| 6             | 5      | 2.5     |
| 7             | 5      | 5       |

Table 1. Additives Composition

3. Result and Discussion
Clay gathered from Universitas Islam 45 Bekasi has a specific gravity value (Gs) of 2.510 [7]-[8] and is categorized as inorganic type clay [9]. CBR test results for all variants are shown in table 2. CBR values for all variants of additives composition showed an increase in the CBR value of the original clay, whereas the OMC value showed a decrease in the OMC value on the original clay. This is due to the very fine-grained waste filling the pore cavity of the soil, which in the original clay, the cavity is filled with water and air [10]. The water content in the soil decreases due to the presence of fine grains of waste that fill the pore cavity. An increase in the number of solid particles in the soil results in an increase in the weight of the dry volume compared to the original clay soil conditions.
Table 2. Mechanical Properties Value

| Variant Number | Additives Composition | OMC \(^c\) (%) | CBR \(^d\) (%) |
|----------------|----------------------|----------------|---------------|
|                | SS\(^a\) (%) | DSF\(^b\) (%) |                  |                  |
| 1              | 0       | 0       | 30.50          | 7.14          |
| 2              | 0       | 2.5     | 29.15          | 9.24          |
| 3              | 0       | 5       | 29.10          | 9.68          |
| 4              | 2.5     | 2.5     | 30.135         | 7.91          |
| 5              | 2.5     | 5       | 29.04          | 10.11         |
| 6              | 5       | 2.5     | 29.78          | 9.01          |
| 7              | 5       | 5       | 29.08          | 10.56         |

\(^a\)Silica Sand Waste
\(^b\)Dust Sand Foundry Waste
\(^c\)Optimum Moisture Content
\(^d\)California Bearing Ratio

Figure 1 shows the increase of the CBR value based on the increase the DSF waste percentage. Chemical reactions occur in the mixture of soil and waste during curing 7 days, thus forming new grains that were harder and stronger to withstand the load. Waste mixed with clay caused the cation exchange process from the soil to be replaced by cation from the waste so that the size of the clay granules increases (flocculation). In addition to the flocculation process that occurs in soil stabilization, there was also a hydration process.

Figure 2 shows that the CBR value tends to increase following the percentage of SS waste. It can be seen at the 0% DSF line, and the 5% DSF. In the other hand, the 2.5% DSF line shows the decrease of the CBR value when the percentage of SS waste is decreased.
4. Conclusions
Based on the CBR value, clay mixed with SS waste and DSF waste showed an increase in mechanical properties. The highest CBR value was shown in the clay mixture with an additives composition of 5% SS waste and 5% DSF that showed the increased of CBR value of 47.9% compared to of the original clay. Further research is needed on testing the chemical properties of stabilized clay soils using SS and DSF, as well as environmental feasibility testing.

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