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Mechanical properties improvement of clay soils using dry dust collector and silica sand wastes

A S S Gunarti¹, S Nuryati¹, F Primatama¹ and I Raharja²

¹ Department of Civil Engineering, Universitas Islam 45, Bekasi, Indonesia  
² Department of Accounting Information Systems, Universitas Bina Sarana Informatika, Karawang Barat, Indonesia

Corresponding e-mail: anita_ft@unismabekasi.ac.id

Abstract. Wastes from industrial parks increase rapidly; they are also difficult to manage. They should be carefully managed and used for other purposes, e.g., improving the infrastructure. The study did some laboratory experiments, e.g., California bearing ratio test, direct shear test, and triaxial (unconsolidated and undrained condition) test. Soil stabilization through chemical addition was done by mixing the original soil with some compositions of dry dust collector and silica sand wastes. California bearing ratio value of the 5mm penetration of soil with an additive composition of 7.5 % silica sand and 1.5 % dry dust collector was increased by 86 %. Internal friction angle value based on triaxial test showed that soil with an additive composition of 7.5 % silica sand (without dry dust collector) was increased by 2.5 %. The cohesion of soil having the additive composition of 7.5 % silica sand and 1.5 % dry dust collector increased by 60 % from the original soils.

1. Introduction

Industrial parks always create wastes from their factories in a production process, for example a coloring and compounding plastic resin in EJIP industrial park, located in Cikarang, West Java, Indonesia, which throws the dry dust collector (DDC) for about 3 tons monthly. Another example is a mineral factory in JABABEKA industrial park that creates silica sand wastes (SS) for about 50 tons monthly. DDC and SS wastes compound sand contents that actually can be utilized productively for soils stabilizer. Such kind of waste has not been managed optimally; the waste collection also depends on some collectors at a high price. This situation happens because of the lack of innovation in waste management. In addition, the factory owners strongly depend on the collector. A research in [1], entitled “direct shear strength improvement through soil stabilization using DDC and SS from industrial waste”, indicated the best friction angle for the mixed soil containing SS (5 %) and DDC and the increase of shear strength for about 32.26 % when 1.5 % of DDC and 5 % of SS were mixed in the soil. This study concluded that mechanical characteristic was improved when clay was mixed with DDC and SS. Therefore, new materials should be studied from waste processing to get cheaper additive materials for an optimum clay additive composition.

This study aims to know the mechanical properties change of the clay mixed with DDC and SS and to find an optimal composition for getting maximum shear strength. The studies on the uses of DDC and SS for additive are still lacking.

Another study [2] showed a different character based on the aggregate’s contribution. A sample with 10 % of diabase aggregate had higher compressive strength than a reference sample. A study [3] on the “utilization of drinking water treatment sludge for the manufacturing of ceramic products” showed that
the property of ceramic bodies—both physical and mechanical—varied depend on the amount of sludge added. Moreover, the additive was proved to be an effective coloring agent which makes the ceramic have a darker red color. A previous study [4] on clay soil stabilization using powdered glass concluded that the highest California bearing ratio (CBR) values of 14.9 % and 112.91 % were obtained at the content of 5 % glass powder and penetration of 5 mm for both unsoaked and soaked treated samples, respectively. In addition, the maximum cohesion and angle of internal friction values of 17.0 and 15.0 were obtained at 10 % of glass powder content.

Another study [5] of the experimental study showed that the addition of SDA resulted in a significant increase in CBR and unconfined compressive strength. The CBR values obtained are also within limits recommended by the Asphalt Institute for highway sub-base and sub-grade. Thus, the inexpensive industrial wastes may be used for the satisfactory stabilizing agents for the sub-base and base course in clayey fills, although their performances are often improved by combining waste to reduce the construction cost of road, particularly in the rural areas.

2. Methodology

This study used several materials which were clay soils [6]-[8], from Bekasi – Indonesia, gathered from 20 to 50 cm deep from original soil (disturbed condition), water, SS, and DDC. SS and DDC were used as the additive. Figure 1 shows the research flowchart. Sample preparation was done by mixing the soil with DDC and SS wastes at a predetermined composition. While the curing was carried out for seven days up to be a homogeneous mixture and ready to test. For the composition of additives, SS is 7.5% of the dry weight of soil and DDC is 1.5% of the dry weight of soil. The variations of the soil mixture, which uses waste as the additive, are given in table 1. A compaction test was applied to the original soil and the stabilized soil to get the optimum moisture content (OMC). Then, the mechanical properties of the original soil and the stabilized soil (OMC conditions) were tested using the CBR test and the triaxial unconsolidated undrained test based on the ASTM standard.

Table 1. Mix Variation.

| No  | Additive composition         |
|-----|------------------------------|
| 1   | Original soil                |
| 2   | Original soil + 7.5 % SS     |
| 3   | Original soil + 7.5 % SS + 1.5 % DDC |

3. Results and discussion

3.1. Compaction

Compaction test results are given in table 2. The maximum dry density (γdmax) of stabilized soil, which has 7.5% of SS additive % and has no DDC, decreased to about 3.71 % of γdmax of original soil. The γdmax of stabilized soil, having the additive composition of 1.5% DDC and 7.5% SS, increased for about 7.43%, compared to the original soil.

Table 2. Compaction Test Result.

| Mix Variation                  | Optimum Moisture Content (%) | Maximum Dry Density (γdmax) (gram/cm³) |
|-------------------------------|-----------------------------|---------------------------------------|
| Original soil                 | 33.00                       | 1.345                                 |
| Original soil + 7.5% SS       | 32.00                       | 1.340                                 |
| Original soil + 7.5% SS + 1.5 % DDC | 31.55                      | 1.355                                 |
Stabilized soil with an additive composition of 7.5 % SS (without DDC) showed that OMC was decreased by 3.03 %, compared to the original soil. The OMC value of the soil with an additive composition of 1.5 % DDC and 7.5 % SS showed that the OMC was decreased by 4.39 % compared to the original soil. Figure 2 shows the change in the OMC value.

*Figure 1. Research flowchart.*
3.2. Mechanical properties

The test results of the mechanical properties of the soil are given in table 3.

| Type of Test | Original Soil | Soil + 7.5% SS | Soil + 1.5% DDC + 7.5% SS |
|--------------|---------------|----------------|--------------------------|
| CBR          | 2.5 mm 3.20   | 3.93           | 5.09                     |
|              | 5 mm 2.77     | 3.91           | 5.15                     |
| Triaxial     | C (kPa) 69.56 | 61.57          | 69.28                    |
|              | $\phi$ (°) 26.67 | 27.34         | 10.58                    |
| Direct Shear | C (kg/cm²) 0.025 | 0.028         | 0.040                    |

3.2.1. California bearing ratio. The CBR value (2.5 mm penetration) in stabilized soils increases compared to the CBR value (2.5mm penetration) in the original soil. The CBR value (5mm penetration) increased by 41 %, compared to the CBR of original soil. For the stabilized soil with the additive composition of 1.5% DDC and 7.5% SS, the CBR increases significantly by 86%, compared to the CBR of original soil. The CBR value of the soil, which was stabilized using SS and DDC, improves. Figure 3 shows the change in 5 mm penetration - CBR value.

3.2.2. Triaxial UU. The triaxial test result (figure 4) showed a cohesion value of 61.57 kPa for stabilized soil with SS composition of 7.5% (without DDC). This cohesion value decreased by 11 % compared to the original soil. Stabilized soil with the additive composition of 1.5 % DDC and 7.5 % SS had a cohesion value of 69.28 kPa or decreased 4.02 %, compared to the cohesion value of original soil.

Internal friction angle value ($\phi$) from the triaxial test of a stabilized clay with the additive composition of 7.5 % SS (without DDC) was 27.34°. This value showed the increment of $\phi$ by 2.5 %, compared to the $\phi$ value of original soil. The $\phi$ value of soil using additive DDC decreases against the value of the original clay. Figure 5 shows the change of the internal friction angle based on the triaxial test result.
Figure 3. CBR’s (penetration 5 mm) value chart.

Figure 4. Cohesion value chart.

Figure 5. Shear angle value chart.
3.2.3. Direct shear. There was no significant change in internal friction angle ($\phi$) based on a direct shear test for stabilized soil with the additive composition of 7.5% SS (without DDC). Figure 6 shows the change in the internal friction angle. On the other hand, for stabilized soil with the additive composition of 1.5% DDC and 7.5% SS, the value of $\phi$ obtained from a direct shear test decreased by 8.84%, compared to the original.

![Figure 6. Internal friction angle ($\phi$) chart.](chart)

For stabilized soil with an additive composition of 7.5% SS (without DDC), from the direct shear test, the cohesion value was 0.028 kg/cm² or increased by 12%, compared to original soil. For stabilized soil with the additive composition of 1.5% DDC and 7.5% SS, the cohesion value increased by 60%, as shown in figure 7.

![Figure 7. Cohesion value chart.](chart)

4. Conclusion
The result indicated that mechanical properties were improved based on the soil test. CBR value of stabilized soil with the additive composition of 7.5% SS and 1.5% DDC was increased by 86%, compared to the CBR value of original soil. Triaxial test in this study, which was in unconsolidated and undrained condition, indicated that for stabilized soil with the additive composition of 7.5% SS (without DDC), the internal friction angle value increased by 2.5%, compared to original soil’s internal friction
angle. Based on the direct shear test of stabilized soil with the additive composition of 1.5 % DDC and 7.5 % SS, there was an increment of cohesion value up to 60 %, compared to original soil’s cohesion.

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