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The Characteristic of Sandy Soil's Shear Strength with Lime and Coal Fly Ash Mixture

Ibnu Toto Husodo
Doctoral Program of Civil Engineering
Islamic University of Sultan Agung Semarang
Jl. Raya Kaligawe Km 04, Semarang, Central Java, Indonesia
ibnutotohusodork@gmail.com

Abstract- Sandy soil in solid conditions tends to have good characteristics. However, sand in the even and loose and water-saturated conditions has low shear strength when cyclic load occurs (such as earthquake). This paper presents the results of research on the improvement of sandy soil with a mixture of lime and coal fly ash. Two mixing techniques on the sandy soil were done in column (method A) and mixed (method B). Coal fly ash - lime mixture was done with a ratio of 1: 1 (in weight ratio). An unconsolidated undrained triaxial test was performed for both methods at the test of 1 day, 3 days, 7 days and 14 days. The size of the triaxial test specimen was diameter = 36 mm and height = 72 mm. For method A, the column was made as high as the test specimen with a diameter size of 12 mm. The shear strength value of unstable sand was 35.4 kPa. Overall, it can be concluded that stabilization techniques affect the shear strength of sandy soil. The soil improvement technique with method B gives a larger shear strength value than method A does. However, sand soil behavior with improved technique of method B is more brittle than method A.

Keywords*: strong shear, sand, coal, lime, triaxial*

1. Background

Sandy soil in solid conditions tends to has good characteristics. However under the certain condition, such as when in a loose and water-saturated condition, it may have low shear strength when there is a cyclic load such as earthquakes. In this state, the sand layer loses or decreases its shear strength. In general, the shear strength of sandy soil is contributed by the internal friction angle values. In order to increase the shear strength, sandy soil improvement is often accomplished by fiber inclusions or cement mixtures (Consoli, et al, 1998). Fly ash of coal and lime as stabilization materials of clay soil have been widely studied, but their use for sandy soil has not been studied. Hence, this research will study the influence of coal and lime mixture to the shear strength of sandy soil.

In most studies, the ground improvement techniques often used are stone-column or stone-piers techniques. These techniques are able to reduce the risk of structure damage due to liquefaction (Mitchell et al, 1995). However, other soil improvement techniques such as column techniques with lime or cement can be used as an alternative to reduce liquefaction risk (Seed et al., 2001). In addition, this column technique can also be used as a foundation for building structures (Kempfert, 2003). In its development, the material for columns may be colloidal-silica, i.e. silica in the form of gels or liquids (Gallagher et al., 2007; Liao et al, 2004). On the other hand, coal Fly ash mainly consists of silicate glass compounds containing silica (Si), alumina (Al), ferrum (fe), and calcium (Ca). Other small compounds contained in fly ash are magnesium (Mg), sulfur (S), sodium (Na), potassium (P), and carbon (C). The contents of hazardous materialsin fly ash include: arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, selenium, strontium, thallium, vanadium, also contain dioxins and PAH (polycyclic aromatic hydrocarbon) compounds. Hence, its use with lime for liquefaction mitigation is an alternative material utilization.

2. Research Methods

2.1 Sand, lime and coal fly ash

The sand used was the sand that originated from the Merapi volcano deposit which has a particle size distribution of soil as shown in Figure 1. The sand samples tested had relatively even gradations between fair to fine with average diameters or d50 = 0.4 mm. Based on the examination of physical characteristics, it was found the volume weigh of sand = 16.5 kN / m3, specific gravity (Gs) of sand in the state of surface dry = 2.29, and water content = 2.99%.

The lime used came from Tanggungharjo Purwodadi which is hydrated lime in the form of powder. In order to reduce the hardening process, the lime was stored in an airtight place. Based on X-ray diffraction test results showed that the main compiler minerals used was calcium hydrate Ca (OH) 2.

Coal Fly ash used was taken from the rest of the burning of the sango plant in Semarang where the coal ash was formed aggregate (bottom ash) which is generally stacked in the industrial area. This bottom ash stacking creates problems for the environment. Various studies on bottom ash utilization were done to improve its economic value and reduce its adverse impact on the environment.

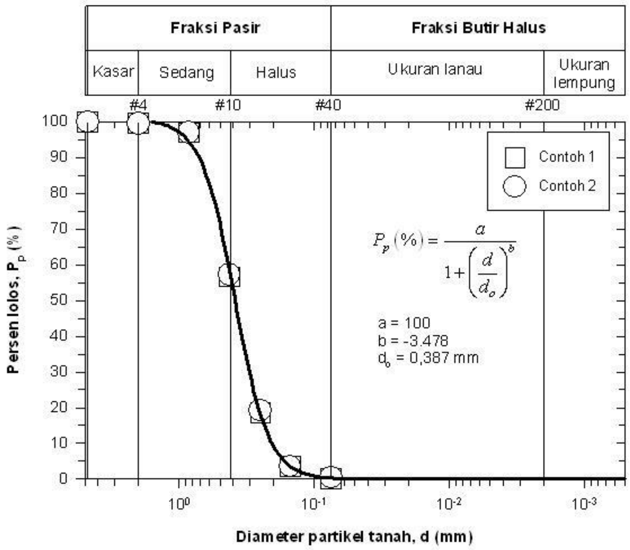

Figure 1. The particle size soil distribution curve for the sand used

2.2 The Manufacture of the test specimens

The size of the triaxial test specimen of this UU was a diameter d = 38 mm and a height of h = 76 cm in amount of 3 pieces for each specimen.

The test specimen for Method A was prepared by solidifying the sand according to the solidification standard test of standard Proctor ASTM D698. Sand was mixed with water with a content of 24% by weight of sand. After the solidification, the mold of the triaxial specimen was inserted into the solidification cylinder. To model the column system of lime - coal fly ash, in the middle of the sand test specimen was given a hole with diameter of 12 mm and length of 76 mm. This column was made by inserting a 12 mm diameter tube into the sand test specimen in the mold. Then, some sand in the tube was removed and filled with a mixture of lime – coal fly ash. The ratio of lime and coal fly ash was 1: 1 to the weight. The ratio of water used to form the column was 0.50.¬ For the test specimen with Method B, sand was mixed with lime-coal fly ash with a weight ratio of 1: 2.75. Meanwhile, the ratio of lime and coal fly ash is 1: 1 with the weight of water used was 24% of the weight of sand.

2.3 Test Tools and Test Procedures

The triaxial test tools were used to determine the shear strength parameter and the soil's mechanical behavior of cohesion, internal friction angle, and modulus of elasticity in non-undrained unconsolidated conditions. The strength of the lime - coal fly ash mixed material was tested by a compressor to determine the axial compressive strength. The triaxial test was performed to determine the soil shear strength parameters and mechanical behavior. In this study, triaxial test was performed under unconsolidated-undrained (UU) conditions. The given circumference voltages were 9821 kPa, 196.2 kPa and 294.3 kPa. The axial voltage was provided through a deviator voltage with a loading speed of 1 mm/min until the test specimen collapsed. The changes of the test specimens during the application of the deviator voltage were recorded. This triaxial test procedure followed the ASTM D-2580 standard. This UU triaxial test results can provide undrained Eu soil elasticity modulus data which was the slope of the stress-strain curve on the linear part.

3. The Results Discussion

One of the most important things to examine the shear strength characteristics is the stress and strain relationship curve. Figure 3 gives a typical stress-strain relationship curve of triaxial test results at cell voltage σ_3 = 98.1kPa. The axial strain during collapse tends to decrease as the age of the test specimen increases which depends on the applied cell pressure. Overall, the axial strain collapsed from the test specimens ranging from 1.24% - 3.2% for the test specimen of Method A. As for the test specimen of Method B, the collapse occurred in relatively small strains ranging from 0.81% - 2.38% of the height. The value of this collapse strain varies by the age of the test specimen and the cell pressure. Based on this characteristic, the test specimen with the mixed repair system (Method B) resulted in brittle sand behavior compared to the improvement of the column method (Method A). However, at higher cell pressures, the test specimen by improving technique of Method B gave a higher deviatoric voltage value than Method A did.

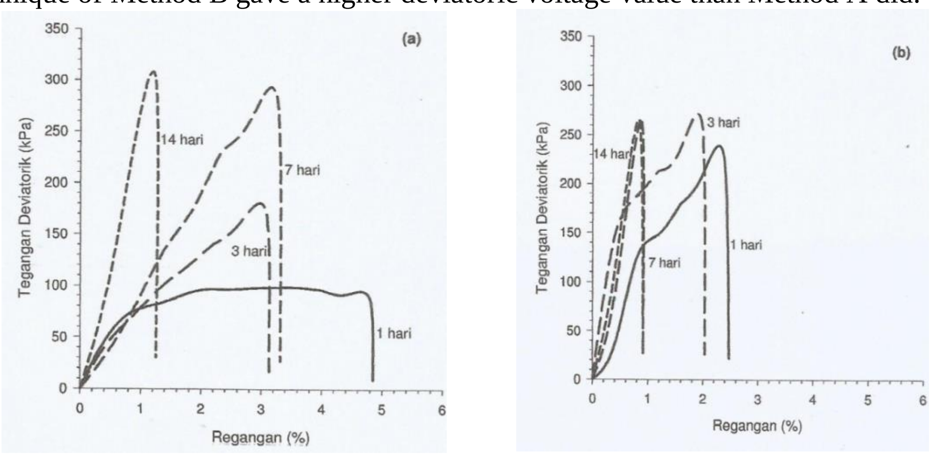

Figure 2. Typical relationship of stress-strain (a) Method A, (b) Method B (σ_3 = 98.1 kPa)

Shear strength soil is the ability of the soil to withstand a load or force that works. This soil shear strength according to Mohr and Coulomb is contributed by two important parameters of cohesion (c) and internal friction angle (φ). The two values of this soil shear strength parameters vary depending on the degree of cementation determined by the age of the specimen.

FIGS. 4a and 4b illustrate the Mohr circle combined with the age of the test specimen for both methods of improvement; Method A and Method B. Referring to FIG. 4, the collapsed sheath from the sand stabilized by lime-ash rice husk is a non- linear curve. This result is also shown by Ashgari et al (2004), which the cemented sand collapse is a non-linear curve.

Figures 5 and 6 respectively show changes in the internal friction angle and cohesion values (intercept cohesion) of the age of the specimen. The value of internal sand friction angles that have been stabilized relatively low ranging from 1o to 6o. At the early age of the stabilization process, the method of sandy soil improvement by Method B provides a larger internal friction angle than Method A

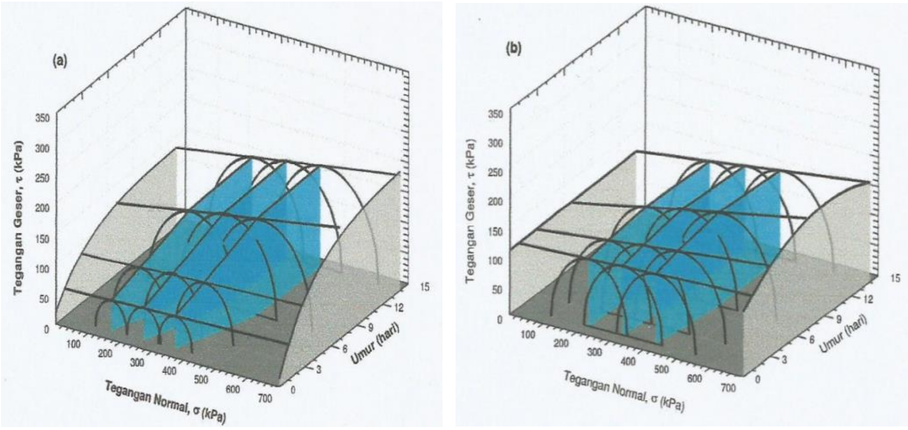

Figure 3. Mohr circle and shear strength sheath (a) Method A, (b) Method B

Similar to the value of cohesion, at the age of the test specimen is less than 7 days, the soil improvement technique with Method B results in a higher cohesion value than Method B. After the age of 7 days, the opposite condition occurs. It indicates that at the beginning of column installation (Method A), additive materials (lime – coal fly ash) have not undergone extensive migration with surrounding sand. As the columns age, lime - coal fly ash particles migrate more and react with sand around the column, thereby increasing the shear strength.

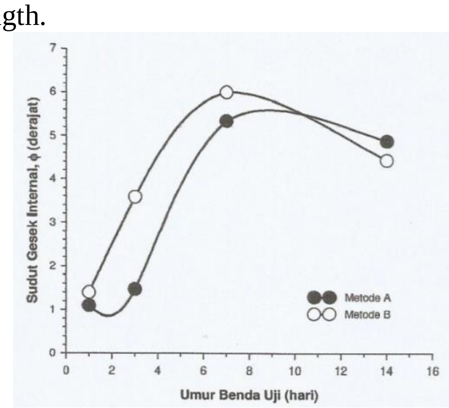

Figure 4. Variation of the internal friction angle value to the life of the specimen

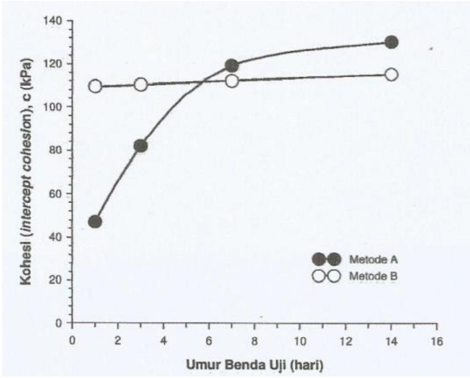

Figure 5. Variation of cohesion values on the age of the specimen

4. Conclusions

Based on the results and discussions previously described, it can be concluded that stabilization techniques influence the shear strength of the sandy soil. The soil improvement technique by method B gives a larger shear strength value than method A at the beginning of mixing age. However, the sandy soil's behavior with improving technique of method B is more brittle than method A.

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