The Influence of Sand Addition on Clay Soil From Deket Kulon, Deket Subdistrict, Lamongan Viewed From The Physical and Shear Strength Characteristics Changes

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Abstract- **One of the problems often found in constructing road is the deposit of expansive soil. According to data from Federal Emergency Agency (FEMA) in 1982, the lost caused by expansive soil in 1970 reached 798.1 million USD. In Java, the expansive soil problem can be found on the road to Surabaya. In five years, road damage in Lamongan Regency reached more than 73%, caused by an extreme soil shrinkage–swelling. Those soil problems can be solved by using soil stabilization techniques. Grain size improvement is one of the most widely used methods for fine-grained soil with low bearing capacity index.**

This research aimed to identify the physical and mechanical characteristics of clay soil by using sand as stabilization material containing: (1) Consistency limits characteristic of clay soil after being stabilized using selected sand, (2) Shear strength parameter of clay soil after being stabilised using sand, (3) Bearing parameter after stabilization using sand. This research was an experimental method. Research data were analysed using the descriptive method. Different amounts of sand were used as stabilization, namely 0%, 10%, 20%, and 30% of total weight of soil sample. There were 72 specimens utilised in the experiments. Tested parameter contained Liquid Limit, Plastic Limit, Shrinkage Limit and shear strength parameter using Direct Shear Test method.

The results of the research showed that the best amount of sand as an addition was 30%; this amount contributed Liquid Limit from 75 % to 50 % and Plasticity Index from 29.51% to 20.69%. In other words, the more the sand added to clay soil, the less the LL and PL. Direct shear test result from the addition of 30% sand on clay soil from Deket Mojokerto contributed to the improvement of the inner shear angle from 59.27o to 65.23o. The soil cleeveness index decreased from 0.596 kg/cm2 to 0.431 kg/cm2. This result indicated that sand stabilization contributed to the improvement of clay soil shear parameter for bearing strength increment.

***Keywords:** Clay, sand stabilization, shear parameter for bearing strength increment*

I. INTRODUCTION

One of the problems most frequently encountered in the construction of highways is expansive soils. Jones & Holtz concluded that expansive soils in the United States caused more serious losses than any other disasters such as tornado and earthquake [17]. The Federal Emergency Agency (FEMA) argued that the losses due to the expansive soils in 1970 reached 798.1 million dollars and were estimated to continue to rise to 997.1 million dollars in 2000 [13].

Mochtar stated expansive soils are scattered from North Sumatra to Irian Jaya. Regarding losses caused by expansive soils, there has been no accurate report. According to the survey results released by Bina Marga (Directorate General of Highway) and the Research and Development Center for Road of the Ministry of Public Works, expansive soils have caused damage to Semarang-Demak-Kudus-Yogyakarta-Wates road, Surabaya-Gresik road and Jakarta-Cikampek, Dempet Godong, and Ngawi-Caruban toll roads (Majalah Konstruksi, 1997: 242). Not only that, in East Java the problem of expansive soils can be found along Pantai Utara, from Bojonegero to West Surabaya.

Subgrade is an important part of road construction since it can determine the strength of the pavement design. The nature of subgrade affects the resistance of the upper layers and the overall quality of the road [1]. The strength and durability of pavement structure are determined by the bearing capacity of the subgrade [11]. Subgrade in the form of clay soil with a shrink-swell potential is called expansive soil. Not only such clay soil has low bearing capacity but also causes severe damage to roads.

Melisyanah stated that in the last few years, road damage in Lamongan Regency had reached 73.27%[7]. The parameter used to determine the bearing capacity of the subgrade is the value of the California Bearing Ratio (CBR). The CBR value in the subgrade in Lamongan Regency was 1.44%, far below the standard established by Bina Marga namely 10% [10]. Another factor sufficient to prove that the soil in Lamongan is problematic was its Plasticity Index (PI), i.e [3]. greater than 25%. Moreover, Hayu found that the clay soil of Deket Kulon Village, Lamongan had a Liquid Limit (LL) value of 74%, Plastic Limit (PL) value of 40.74%, and IP of 33.26% (maximum IP= 25%). This sort of soil is not suitable for subgrade, as it can decrease the resistance of pavement construction.

Subgrade is more likely to swell during the rainy season as it gets wet and shrinks during the drought. Soil swelling and shrinkage with a large deviation cause significant damage to the pavement. Moreover, if the shrinkage is not extensive but occurs only in one place—called settlement differentiation, the soil cannot be used for road subgrades. One of the common ways to cope with this situation is stabilization. This is done when replacing subgrades with huge costs.

Soil stabilization is a method used to improve soil quality. Stabilization can improve the bearing capacity of subgrade so as to reduce the thickness of pavement. Soil stability can be distinguished by the type of stabilized soil. Mechanical stabilization is used for coarse-grained soils with the help of several tools including roller machine, explosive, static pressure, freezing, and so on. Stabilization of fine-grained soils involves mixed materials, gradation improvement, sand columns, surface repair methods, displacement methods and others[8].

This research used stabilization with gradation improvement to overcome soils with low bearing capacity due to its smooth gradation. Stabilization by improving gradation and with the addition of sand aims to improve the gradation of the subgrade. Bina Marga stated that clay soil has an average CBR value of 3.5%, while coarse-grained soil can be up to 8%. It means that the value of CBR can also be determined from the soil gradation (grain size distribution). Stabilization through improving gradation aims to increase the soil mechanical strength or long-term stability [9]. Clay soils mixed with sand could reduce the plasticity of the soil and its cohesion [4]. The addition of coarse-grained sand to clay may change the mechanism of soil development and increase the bearing capacity of the soil [38]. 50% sand to clay could increase the CBR value by 2.10% [8].

This study focused on stabilization of clay soil by looking at changes in physical and mechanical characteristics of the soil, in the form of bearing capacity of clay soil after stabilized with sand. Based on the background described above, this paper aims (1) to investigate the changes in physical characteristics of Deket Village clay soil stabilized with different amount of sand (0%, 10%, 20%, and 30%) due to changes in water content, and (2) to identify the mechanical parameters of Deket Village clay soil stabilized with sand, ranging from 0%, 10%, 20%, and 30% by volume.

II. METHOD

This study utilized a quantitative method with experimental research design. The independent variable was the percentage of the various amounts of sand added to clay soil. The dependent variable was the carrying capacity of the soil reflected in the cohesion (c) and angle of internal friction (φ) parameters. The control variable was the clay soil sampled at Deket Village of Lamongan Regency without being mixed with sand.

The samples of clay soil were taken from Deket Kulon Village, Deket Subdistrict, Lamongan Regency. The clay soil, ± 150 kg, was obtained manually from a paddy field at a depth of 0.5-1 meter. In order to understand the changes in soil characteristics due to the addition of sand as a stabilization material, the clay soil was sampled at the same location. The soil sample was then added with different concentrations of sand, ranging from 0%, 10%, 20% and 30%.

In this research, there were 72 specimens in total with the detail shown in Table 1.

Table 1. Details of Specimens

Code	Sand (%)	Total Specimen LL	Total Specimen PL	Total Specimen SL	Direct Shear
P1	0	5	5	5	3
P2	10	5	5	5	3
P3	20	5	5	5	3
P4	30	5	5	5	3
		20	20	20	12
Total					**72**

Data were collected from the results of filter analysis, LL, PL, SL, and direct shear tests. They were analyzed using the descriptive, experimental analysis. Data processing was based on the tendency of the test results presented in tables and graphs.

III. RESULTS AND DISCUSSION

A. *Results of Consistency Limit Tests*

Consistency limit tests determine Liquid Limit (LL), Plastic Limit (PL), and Shelf Limit (SL). The values obtained from LL and PL are used to determine the value of PI=LL-PL. In this research, the Atteberg Limit testing was performed with 4 (four) variations of sand addition, i.e. 0%, 10%, 20%, and 30%. Test results are presented in Table 2.

TABLE 2. RESULTS OF CONSISTENCY LIMIT TESTING

No.	% Addition of Sand	LL (%)	PL (%)	SL (%)
1.	Addition of 0% Sand	74.16	44.49	3.93
2.	Addition of 10% Sand	64.60	41.54	4.09
3.	Addition of 20% Sand	57.07	35.61	4.50
4.	Addition of 30% Sand	51.11	29.31	5.69

B. *Results of Direct Shear Testing*

The results of the shear tests determining the parameters of the cohesion (c) and the internal friction angle (φ) for the addition of 0%, 10%, 20% and 30% sand are presented in Table 3.

TABLE 3. DIRECT SHEAR TESTING RESULT

No.	% Addition of Sand	Cohesion ($c = kg/cm^2$)	Internal Friction Angle (Degree)
1.	Addition of 0% Sand	0.596	59.27
2.	Addition of 10% Sand	0.544	60.20
3.	Addition of 20% Sand	0.478	62.54
4.	Addition of 30% Sand	0.431	65.23

The physical characteristics of clay soil could be identified based on the results of filter analysis, LL, PL and SL tests of samples mixed with 0%, 10%, 20%, and 30% sand. Changes in LL, PL and PI values are illustrated in Figure 2.

Figure 2 shows that the addition of sand could decrease the value of LL, PL and PI. In fact, the PI of soils has a strong effect on soil swelling-shrinkage. High PI values indicate that the soil has a high swell-shrink capacity, meaning that the soil tends to be less stable when subjected to loading. It is more likely to swell as it absorbs a lot of water and to shrink when it dries out.

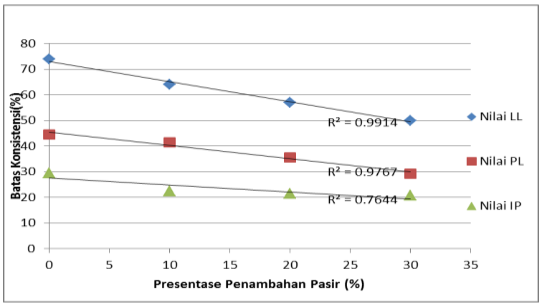

Fig 2. Correlation between the Addition of Sand and the Value of LL, LP and PI

As shown in Figure 2, the clay soil with 0% sand had a PI of 29.51%, while that added with 20% sand had a lower PI, i.e. 20.69%. The effect of the addition of sand occurred because sand is nonplastic, meaning that sand has a low swelling/shrinkage because it is not easily deformed when reacting with water. Therefore, the combination of clay and sand is more likely to increase the bearing capacity and decrease the swell-shrink potential of clay soil.

The results of this study concur well with Seta stating that the addition of sand to clay soil as much as 20% could decrease PI value to 19% [8]. This research is also supported by Utami (2015) arguing that the addition of 20% sand to clay could lower PI value by 7.35%.

C. *Bearing Capacity of Clay Soils Mixed with Sand*

Soil shear strength is the resistance of the soil to loading based on the cohesion and the friction angle of the soil grain size. Clay soil has a high swell-shrink capacity which can be seen from its cohesive properties. Sand tends not to be cohesive because it has large grains, resulting in water not easily trapped in the sand grains. The addition of sand to the clay soil is expected to decrease the soil cohesive properties and hence lower water-holding capacity. Figure 3 and Figure 4 illustrate the correlation between soil cohesion value and the amount of sand added to clay soil.

Figure 3 shows that the addition of 30% sand could decrease the soil cohesion value from 0.596 kg/cm2 to 0.431 kg/cm2. This means that the soil cohesive properties decrease with the addition of sand. Figure 4 demonstrates that the addition of 30% sand could increase the friction angle value of the clay soil, i.e. from 59.27° to 65.23°. This effect of sand addition is associated with the non-cohesive properties of sand.

The results of this study are in line with Jalil and Adi (2014) stating that the amount of sand added to clay soil could raise the friction angle and decrease the cohesion value of soil. Increased friction angle affects the shear strength of the soil, and hence increased bearing capacity. See the following calculation:

c = 0.596, ϴ = 59.22o and σ= 0.169 kg/cm2 (original soil)
Shear strength, τ = c + σtg ϴ = 0.596 + 0.169 x tg 59.22o

The addition of sand to the clay soil exerted a significant effect on the shear strength of the soil due to the non-cohesive sand properties. Its non-cohesiveness could
improve the empty pores of the clay soil so that its ability to absorb water is hindered. This can boost the bearing capacity of the soil because its cavities are smaller.

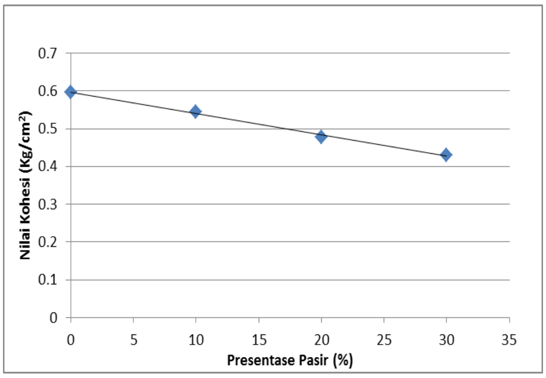

Fig 3. Correlation between Sand Addition and Cohesion Value

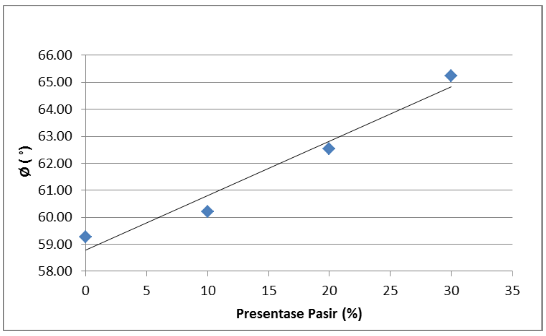

Fig 4. Correlation between Sand Addition and Soil Friction Angle

The bearing capacity of the soil increases as a result of a decrease in soil swelling/shrinkage and hence good for construction.

IV. CONCLUSION

Taken together, the findings of this research on changes in physical and mechanical characteristics of clay soils sampled at Deket Village, Lamongan and stabilized with different amounts of sand (0%, 10%, 20%, and 30% of total weight of soil sample) suggest the following conclusions.

A. *Physical Characteristics of Clay Soil*

1. There was a significant change in the liquid limit (LL) of soil, which was originally 74% (with 0% sand) and dropped to 64% (with 10% sand), 57% (with 20% sand), and 50% (with 30% sand).
2. There was a significant change in the plastic limit (PL), originated from 44.45% (with 0% sand) and fell to 41.54% (with 10% sand), 35.61% (with 20% sand), and 29.31% (with 30% sand).
3. There was a significant change in the shrinkage limit (SL), i.e. 3.93% (with 0% sand), 4.09% (with 10% sand), 4.5% (with 20% sand), and 5.69% (with 30% sand)

B. *Mechanical Characteristics of Clay Soil*

1. The cohesion (c) value of each sample was: 0.596 kg/cm2 (with 0% sand), 0.544 kg/cm2 (with 10% sand), 0.478 kg/cm2 (with 20% sand), and 0.431 kg/cm2 (with 30% sand).
2. The friction angle (φ) of each sample was 59.22o (with 0% sand), 60.20o (with 10% sand), 62.84o (with 20% sand), and 65.23o (with 30% sand).

V. SUGGESTION

If the bearing capacity of the soil is caused by various factors, it is, therefore, insufficient to limit the research on the Consistency Limit and Direct Shear Testing.

For road works, in particular, CBR testing should be performed as well so that the findings will be more convincing and yield more significant contributions to this field of study.

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