The Effect of Adding Bledug Kuwu Mud and Vermiculite on CBR Values of Expansive Soils

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ABSTRACT
Expansive soil is soil containing very high mineral montmorillonite which is sensitive to water, high shrinkage, and low bearing capacity. Therefore, an effort is needed to solve this problem by performing soil stabilization to increase the soil in terms of bearing capacity, increased stability, and reduced settlement so that it can be used as subgrade in a construction. Soil from Gedebage, a region in Bandung, became the test subject in this research. From the results of physical testing, the soil from Gedebage is an expansive soil with a plasticity index value of approximately 48%. The stabilization method was carried out in this research by mixing additives in the form of bledug kuwu mud and vermiculite to investigate their effects on strength and swelling. In this research, a preliminary test was carried out by mixing the content of bledug kuwu of 5%, 10%, 15%%, and the vermiculite content of 4% was used for all tests. Furthermore, the treatment was conducted by curing the samples that had been made for 0 days, 3 days, and 7 days. The results showed that the addition of mixed materials consisting of bledug kuwu mud and vermiculite contents of 15% bledug kuwu mud, and 4% vermiculite, respectively can increase the bearing capacity of expansive soil and reduce its swelling.

Keywords: *Expansive Soil, Stabilization, CBR, Curing, Vermiculite, Bledug Kuwu Mud*.

1. INTRODUCTION

Soil is the most important part of the highway construction system. The strength and stability of the soil are foremost to support the load of the highway construction. If the characteristics of the soil with soil mineral content are not strong enough to support the load on it, it will cause damage to the construction it supports. Soil damage as part of the highway construction system can be repaired by strengthening the road pavement through soil stabilization to improve the soft soil properties like adding a certain material that causes changes in the soft soil properties. In addition, soil stabilization is needed to fix soil properties that have a low bearing capacity, high plasticity index, high development, and poor soil gradation improvement for road construction. The soil condition in Gedebage, a region in Bandung City, West Java Province, is an expansive soil type that has a high montmorillonite content so that it is very sensitive to water. This expansive soil is easy to expand and often causes problems in construction [1] Based on the research that has been done to get more stable soil characteristics on expansive soils, industrial materials such as lime [2] cement [3], and gypsum [4] can be used. Moreover, additives, as waste from a production process such as coal fly ash [5], coal bottom ash [6], steel fly ash [7], rice husk fly ash (rice husk ash) [8] can be used. The materials used in this study were bledug kuwu mud and vermiculite. Bledug kuwu mud contains SiO2, Al2O3, CaO which has the same chemical content as fly ash and lime while the properties of vermiculite can absorb water. Therefore, this research discusses the effect of adding vermiculite and bledug kuwu mud as soil stabilization material to determine the effect on the bearing capacity and swelling values of expansive soils.

2. LITERATURE REVIEW

2.1. Expansive Soil

Expansive soil is soil that experiences significant volume changes associated with the changes in water contents. These volume changes can be either in the form of swell or in the form of shrinkage. Expansive soil can be found in moist places where expansive problems occur in soils with high plasticity index which can cause significant damage [9].

2.2. Soil Stabilization

Soil stabilization is a process used to improve the engineering properties of the soil and make the soil more stable. Soil stabilization is required when the existing soil in the construction is not suitable for the implementation of a particular structure. What is meant here is such as soil compaction, pre-consolidation, permeability, and various other similar processes [10].

2.3. California Bearing Ratio (CBR)

California Bearing Ratio (CBR) is defined as a comparison between the load on the experiment (test load) with the standard load at the same penetration and expressed in percent. The test results can be obtained by measuring the magnitude of the load on certain penetration. The CBR experiment is carried out using a mechanical jack while a penetration piston is pressed into the ground at a speed of 0.05 inches/min. The area of the piston is 3 inches^2 [11]. The CBR value is one of the parameters to determine the bearing strength of the subgrade in the pavement structure. The CBR test is used to determine the CBR value of soil carried out in the laboratory. CBR value which states the quality of the subgrade will be compared with standard material in the form of crushed stone which has a CBR value of 100% in traffic loads. CBR testing is carried out on soil samples compacted with standard compaction [12].

2.4. Additive Materials

2.4.1 Vermiculite

Vermiculite is a sterile inorganic medium produced by heating mica chips and contains potassium and calcium. Based on its properties, vermiculite has a high cation exchange capacity, especially in the solid-state and in the wet-state. Vermiculite can reduce specific gravity and increase water absorption so that it can dry easily [13].

2.4.2 Bledug Kuwu Mud

Bledug Kuwu is a mud volcano phenomenon located in Kuwu Village, Kradenan District, Grobogan Regency, Central Java. The salinity in the chemical content of the Bledug Kuwu mud causes plants and animals to be unable to live in this area [14]. Bledug Kuwu is a mud volcano that comes out together with a gas explosion from the ground containing sulfur which has an average temperature of 32^{o}C, pH of 7.5, and sulfur concentration of 62.883x102 mg/Kg [15].

Based on previous research, mixing additives in expansive clay can improve the quality of the soil. [16] conducted stabilization method of cement and vermiculite by mixing 8% cement with variations in the addition of vermiculite of 2%, 4%, 6%, 8%, 10%. The results showed that there was an effect of 4% addition of vermiculite which indicated the maximum value in the unconfined compression test during 7 days of curing. The obtained value of Qu = 32.02 Kg/cm^2 in dry conditions and wet conditions Qu = 1.25 kg/cm^2.

The next research found how to increase the plasticity index in expansive soils using bledug kuwu mud and vermiculite with a percentage of 5%, 10%, 15% as a substitute for cement [17]. The results showed that there was a decrease in the value of the soft soil plasticity index that had been mixed with bledug kuwu mud and vermiculite by 61.73%. This means that the addition of bledug kuwu mud and vermiculite material to the soil can reduce the plastic properties and swelling.

Another research investigated stabilization of expansive clay using vermiculite and bledug kuwu mud on the value of unconfined compressive strength [18]. From the test results, the highest increase in soil compressive strength in this research was a mixture of 4% vermiculite and 15% bledug kuwu mud where the compressive strength of the soil was 12.87 kg/cm^2 with the previous compressive strength of the soil 7.547 kg/cm^2. The unconfined compressive strength test concluded that the higher the proportion of bledug kuwu mud mixture, the higher the increase in soil compressive strength. The compressive strength of the soil also increases with increasing curing time.

3. METHODOLOGY

The flow chart of the research can be observed in Figure 1 and the standards used for the experiments can be seen in Table 1.

The first stage of this research was soil sampling in Gedebage region, Bandung City, West Java Province, then testing the Index Properties of the soft soil and the mixed soil (disturbed). This test was carried out to obtain the optimum water content (OMC) of the soil. The optimum moisture content (OMC) values obtained were used for CBR and swelling tests, then the curing process was carried out before testing CBR and swelling. Variations in curing time were 0 days, 3 days, and 7 days on each of the soft soil and soil that had been mixed with bledug kuwu mud and vermiculite.

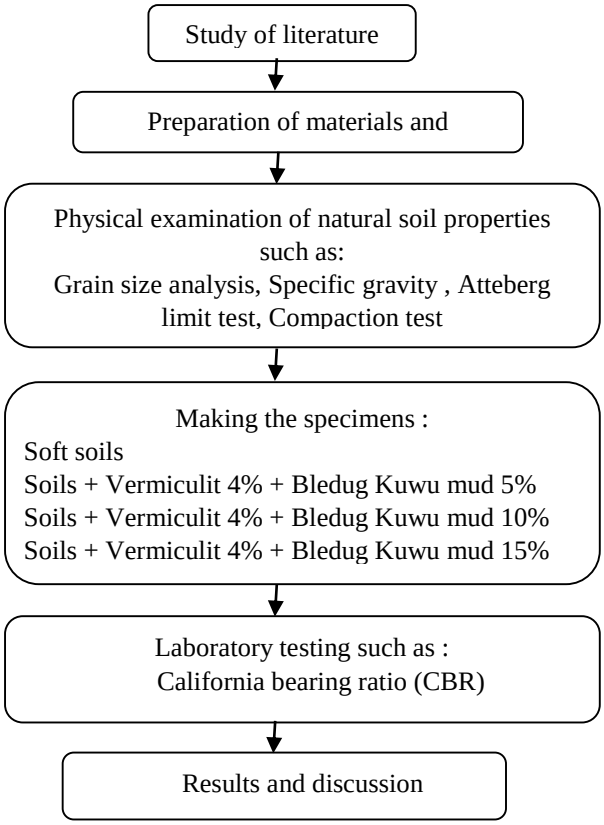

Figure 1 Research Flowchart

The testing standard of the testing items can be seen in Table 1.

Table 1. Laboratory Testing

Num.	Testing Item	Testing Standard
1.	Specific Gravity	ASTM D854-91
2.	Grain Size Analysis	ASTM D421-58
3.	Atteberg Limit Test	ASTM D4318
4.	Compaction test (standard)	ASTM D-698 (Method B)
5.	California bearing ratio test (CBR)	ASTM D-1883

4. RESULT AND DISCUSSION

4.1. Specific Gravity

The result of the Specific gravity test can be seen in Table 2. Based on this test, adding a mixture of bledug kuwu and vermiculite to the soft soil can increase the specific gravity value. It is because the soft soil mixed with additives that also have different specific gravity values. Soil mixed with bledug kuwu mud and vermiculite has a higher specific gravity value than soft soil. As a result, when the two materials are mixed, it will have a higher specific gravity value.

Table 2. Specific Gravity Test Results

Composition	Soft soil	BK 5%	BK 10%	BK 15%
Average of Gs	2,54	2,59	2,65	2,72

4.2. Grain size analysis

The grain size analysis aims to determine the distribution of grains (gradation) of fine aggregate and coarse aggregate by using a sieve. The hydrometer analysis test is used to determine the distribution of grains in the soil that passes the number sieve 200.

The results of the filter analysis and hydrometer test results are shown in Figure 2.

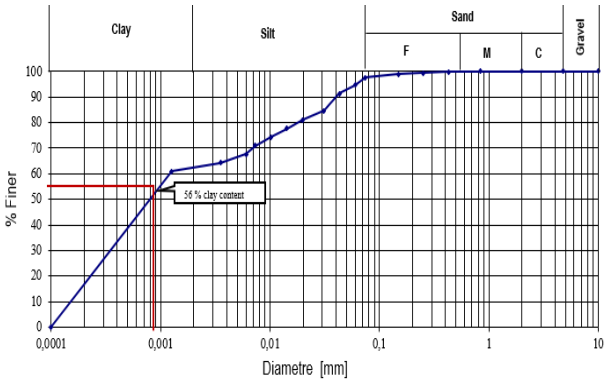

Figure 2 Distribution of Grain Size Sieve Analysis

From the results of grain analysis, the soil from Gedebage has a distribution percentage that passes the sieve number 200 with a value of 97, 52%.

Based on the USCS soil classification system (unified soil classification system), this soil is classified as a fine-grained soil type (Fine-Grained Soils).

4.3. Atteberg Limit Test

Table 3 shows that the plasticity index (PI) value of the expansive clay after stabilization with bledug kuwu mud and vermiculite obtained a smaller plasticity index (PI) value along with the increase in the percentage of bledug kuwu mud. This means that the soft soil after being mixed with bledug kuwu mud material and vermiculite in a plastic condition is getting denser and more stable.

Table 3. Atteberg Limit Test Results

Index Properties	Soft soil	Variations		
		1	2	3
Plastic Limit (PL)	37,00%	36,57%	29,61%	24,31%
Liquid Limit (LL)	85,00%	78,21%	53,71%	42,72%
Plasticity Index (PI)	48,00%	41,64%	24,11%	18,40%
Remarks : Variations 1 = 5% Bledug Kuwu Mud + 4% Vermiculite Variations 2 = 10% Bledug Kuwu Mud + 4% Vermiculite Variations 3 = 15% Bledug Kuwu Mud + 4% Vermiculite				

4.4. Compaction Test (Standard)

The results of the standard compaction test on the soft soil and soil mixed with vermiculite and bledug kuwu mud with the percentage variation of bledug kuwu mud are shown in table 4.

The effect of vermiculite and bledug kuwu mud on the behavior of soil density showed a greater value as the percentage of variation of bledug kuwu mud increased. The dry density of the soil increases and the optimum moisture content of the soil decreases because the bledug kuwu mud particles fill the soil pores, where in the soft soil conditions the pore cavities are filled with water and air. With the presence of bledug kuwu mud and vermiculite in the soil pores, the percentage of water contained in the soil is reduced.

Table 4. Compaction Test Results

Sample	OMC (%)	γd maks (gr/cm^3)
Soft soil	27,50	1,215
Soil + 5% Bledug Kuwu mud + 4% vermiculite	27,00	1,24
Soil + 10% Bledug Kuwu mud + 4% vermiculite	26,30	1,254
Soil + 15% Bledug Kuwu mud + 4% vermiculite	25,20	1,31

4.5. California bearing ratio test (CBR)

CBR test is divided into 2, namely Unsoaked CBR and Soaked CBR. The results of the CBR test are shown in Table 5 and Table 6.

Expansive soil showed an increase in the CBR value of the soil along with the increase in curing time and the addition of bledug kuwu mud content.

There was a relatively small difference between the unsoaked CBR and the soaked CBR because the sample treatment of the soaked CBR was soaked in water which caused the soil surface to tend to be soft. However, the increase in the CBR value of the soil mixed with vermiculite and bledug kuwu mud shows a relatively small CBR value.

Table 5. Unsoaked CBR testing with variations in curing time

Index Properties	Soft soil	Variations		
		1	2	3
CBR unsoaked (0 days cured)	3,0%	3,1%	3,3%	3,8%
CBR unsoaked (3 days cured)		3,2%	3,9%	4,1%
CBR unsoaked (7 days cured)		3,6%	4,1%	4,8%
Remarks : Variations 1 = 5% Bledug Kuwu Mud + 4% Vermiculite Variations 2 = 10% Bledug Kuwu Mud + 4% Vermiculite Variations 3 = 15% Bledug Kuwu Mud + 4% Vermiculite				

Table 6. Soaked CBR testing with variations in curing time

Index Properties	Soft soil	Variations		
		1	2	3
CBR soaked (0 days cured)	0,7%	1,1%	1,4%	1,9%
CBR soaked (3 days cured)		1,6%	1,9%	2,4%
CBR soaked (7 days cured)		2,0%	2,6%	3,7%
Remarks : Variations 1 = 5% Bledug Kuwu Mud + 4% Vermiculite Variations 2 = 10% Bledug Kuwu Mud + 4% Vermiculite Variations 3 = 15% Bledug Kuwu Mud + 4% Vermiculite				

5. CONCLUSION

Based on the data from research conducted in the laboratory to data analysis and discussion, the research concludes as follows.

- The effect of adding bledug kuwu mud and vermiculite to the compacted expansive soil on stability (CBR) gives a relatively increased value especially in the addition of 15% bledug kuwu mud.
- From the results of the CBR test, there was an increase in the value of unsoaked CBR and soaked CBR along with the addition of bledug kuwu mud, where the CBR value of the original (soaked) soil was 0.70% increased to 3,70% in a mixture of 15% bledug kuwu mud and the CBR value of the original (unsoaked) soil was 0.30% increased to 4.80% in a mixture of 15% mud bledug kuwu.
- From the results of the CBR test, it is necessary to carry out further testing by adding a higher percentage variation of bledug kuwu mud and increasing the variation of curing time so that it can provide optimal CBR value.

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