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Expansion Potential and Plasticity Index Value of Expansive Soil Stabilization with Vermiculite and Bledug Kuwu Mud

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ABSTRACT
The construction and operation of road infrastructure in Indonesia are facing the damage of flexible pavement. One of the causes of the damage is the failure of the subgrade bearing capacity. The pavement structure requires a large amount of material, especially natural materials namely aggregate and asphalt which are included in the available non-renewable material category which quantity is limited in nature. One type of soil that is widely found in Indonesia is expansive clay. This type of soil often causes problems in the performance of the pavement structure. Expansive soil has large swelling and shrinkage properties and its behavior is greatly influenced by water; thus, when the soil is swelling, irregular waves appear on the expanded road surface above the ground. Previous research showed that mixing additives into expansive soil (cement, lime, fly ash) increased the shear strength of the soil and reducing the potential for soil shrinkage. Vermiculite can absorb water and Bledug Kuwu mud contains almost the same chemicals as fly ash and also contains Calcium Oxide such as lime. Therefore, it is necessary to conduct research to determine the effect of adding vermiculite and Bledug Kuwu mud on the plasticity behavior and shrinkage of the soil mixture. The vermiculite mixture used was 4% for all test items and variations of the percentage of Bledug Kuwu mud were by 5%, 10%, and 15%. The research results indicate that the soil in Gedebage is expansive soil that has very high swelling properties with a Plasticity Index (PI) value of 48.09%. The addition of mixed material in the form of Bledug Kuwu mud with a percentage of 5%, 10% and 15% and vermiculite of 4% for all variants reduced the PI value. The variant of 15% Bledug Kuwu mud + 4% vermiculite had the largest decrease of PI value which was 61.66%.

Keywords: *Expansive clay, stabilization, plasticity index, vermiculite, Bledug Kuwu mud*

1. INTRODUCTION

The subgrade layer of road pavement construction presents several challenges, such as low bearing capacity and high swelling potential which are often found in expansive soil [1] [2]. Expansive soil is clay whose behavior is greatly influenced by water. Clay soil that contains expansive minerals is very likely to expand and shrink. If road construction is built over expansive soil, the damage will occur on the pavement, such as cracks and settlement. Therefore, soil is an important factor that needs to be considered in planning due to its influence on the construction. One of the methods used to overcome this problem is to stabilize the soil to increase the bearing capacity and decrease the swelling potential of expansive soil. One way to stabilize expansive soil effectively is to add certain chemicals. The addition of chemicals can bind mineral clay to solid, thereby reducing swell-shrink potential and increase its strength [3]. Research has been done to find alternatives to improve expansive soil characteristics, such as by mixing with lime [4], Portland cement and clean set [5], geosta chemicals [6], micro-organism road tech [7], and waste materials (fly ash, husk ash, bottom ash, etc.). Vermiculite and Bledug Kuwu mud can be used as additives for soil stabilization mixtures. Bledug Kuwu Mud has a chemical content similar to fly ash and also contains Calcium Oxide similar to lime. Hence, this research investigates expansive soil stabilization by adding vermiculite and Bledug Kuwu mud to decrease the plasticity index of expansive clay.

2. LITERATURE REVIEW

2.1. Expansive Soil

Clay minerals consist of three components namely montmorillonite, illite, and kaolinite [8]. Montmorillonite minerals have a larger surface area and can easily absorb water compared to other minerals. Soil with montmorillonite is sensitive to the effects of water and easily expands, and it often creates problems in buildings [9]. The effective stabilization of expansive soil is to add certain chemicals so that it can bind clay minerals to solids to reduce shrinkage of expansive clay [10].

2.2 Additive Materials

2.2.1 Vermiculite

Vermiculite is a layer of silica minerals that has undergone a heating process at high temperatures. With this high heating, the minerals develop much like corn. The result is a sterile material with high porosity which can absorb large amounts of water and dry quickly. Vermiculite is made in various gradations, from a small, medium, to large. Its properties include lightweight, non-flammable, compressible, high absorption, non-reactive, and odorless.

This research was carried out by mixing Bledug Kuwu mud with a fixed percentage of 8% by weight into the soil and then adding vermiculite with variations of 2%, 4%, 6%, 8%, and 10%. Unconfined compression strength test during curing for 7 days was done and the test results showed that the addition of 4% vermiculite content obtained the maximum value of q_u = 32.02 kg /cm^2 in dry conditions and q_u = 1.25 kg / cm^2 in wet conditions [11].

Table 1 Index Properties of Vermiculite

1.	Specific Gravity	2.5
2.	Density	0.55 – 0.75 t/m^3
3.	Surface moisture content	< 6%
4.	Water absorption capacity	337 % from testing sample weight

2.2.2 Bledug Kuwu Mud

Bledug Kuwu is a mud volcano, from which the mud is accompanied by gas explosions from the ground. It is located in Kuwu Village, Kradenan District, Grobogan Regency, Central Java Province. Bledug Kuwu mud has an average temperature of 32ºC, pH of 7.5 and sulfur concentration of 62.883x102 mg/Kg [12].

3. METHODOLOGY

In this research, the original soil tested came from the Gedebage area, Bandung, the vermiculite was obtained from PT. IPI Sunijaya, Jakarta, and the Bledug Kuwu mud were obtained from Kuwu Village, Kradenan District, Grobogan Regency, Central Java. The general research flow chart is presented in Figure 1 and the test standard used can be seen in Table 2.

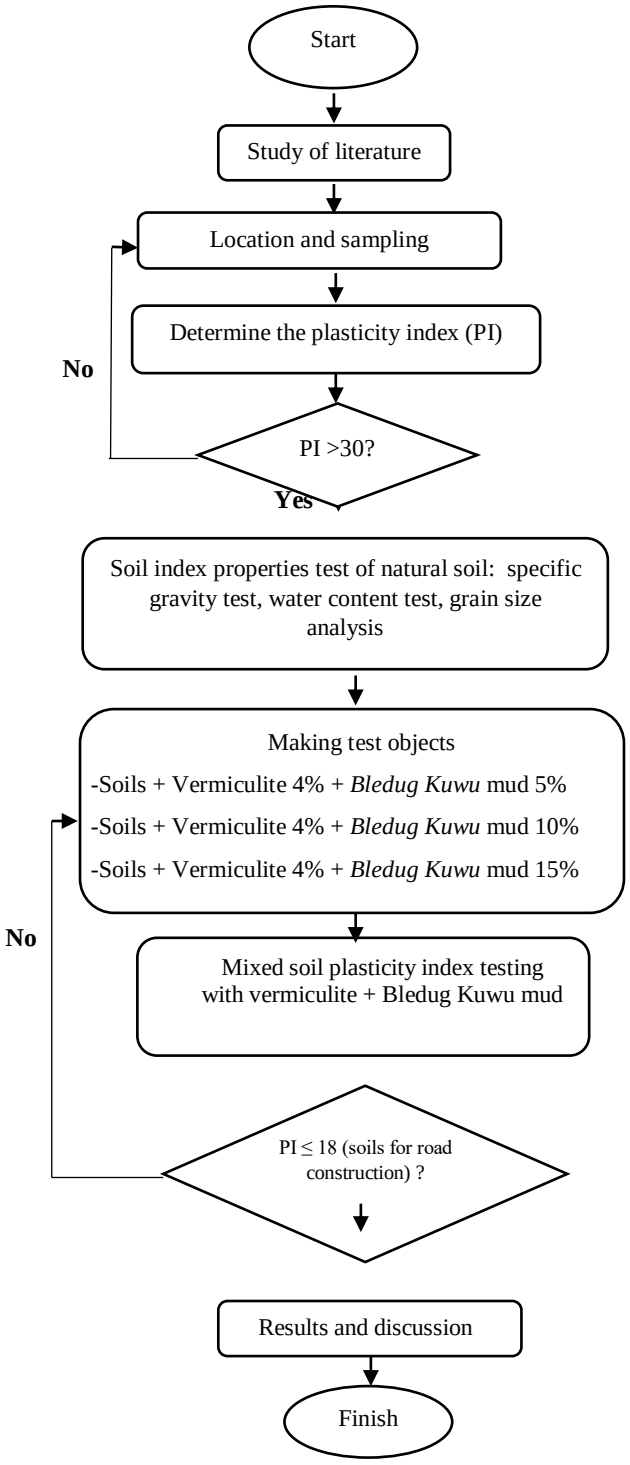

Figure 1 Research Flow Chart

Table 2 Requirement of testing [13]

No.	Testing Name	Testing Standard
1.	Specific Gravity Test	ASTM D854
2.	Water Content Test	ASTM D2216
3.	Grain Size Analysis	ASTM D421-58
4.	Atterberg Limit Test	ASTM D4318

Source: American Society for Testing and Materials (ASTM)

4. RESULT AND DISCUSSION

4.1. Chemical content test of Bledug Kuwu mud mineral

Material tests of the stabilization mixture were done to determine the content of the materials and their effect on soil properties. The test results can be seen in Table 3.

Table 3 Chemical Content of Bledug Kuwu mud

Num.	Chemical content	Percentage (%)
1.	SiO_2	45.02%
2.	Al_2O_3	12.58%
3.	Fe_2O_3	4.58%
4.	K_2O	0.82%
5.	Na_2O	3.25%
6.	CaO	11.06%
7.	MgO	1.55%
8.	TiO_2	0.50%
9.	LOI	20.02%

4.2. Experiment of Soil Index Properties

The following table presents the results of the experiment of the physical properties of the soft soil.

Table 4 Original Soil Test Result

Num.	Testing name	Unit	Result
1.	Water content (w)	%	50.89
2.	Specific gravity (Gs)	-	2.54
3.	Atterberg limit		
	Liquid limit (LL)	%	85.41
	Plastic limit (PL)	%	37.32
	Plasticity Index (PI)	%	48.09
4.	Grain size		
	Gravel	%	0.00
	Sand	%	4.62
	Silt	%	39.38
	Clay	%	56.00
5.	Soil classification		
	AASHTO method	-	A-7-5

4.2.1. Liquid limit (LL)

From the flow curve in the relation graph between the number of blows and water content, the obtained value of Liquid Limit (LL) is 85.41%.

4.2.2. Plastic limit (PL)

From the Plastic Limit test, the obtained value of Plastic Limit (PL) is 37.32%.

4.2.3. Plasticity index (PI)

Plasticity Index (PI) is obtained from the difference between the value of Liquid Limit and Plastic Limit, with the formula of PI=LL-PL, the obtained value of the Plasticity Index (PI) is 48.09%.

4.2.4. Grain size analysis

This grain size analysis refers to ASTM D421-85. The results of the sieve analysis can be seen in Table 5 and Figure 2.

Table 5 Grain Size Analysis Test Result

Sieve num.	Wt. Retained (gram)	Percentage (%)	
		Retained	Passing
4	0.00	0.00	100.00
10	0.00	0.00	100.00
20	0.04	0.04	99.96
40	0.10	0.10	99.86
60	0.39	0.39	99.47
100	0.54	0.54	98.93
200	1.24	1.24	97.69
pan	2.31		

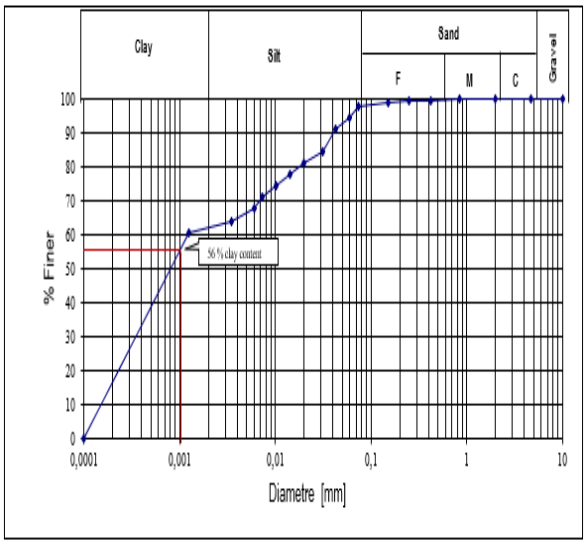

Figure 2 Distribution of Grain Size Sieve Analysis

4.2.5. Soil classification

4.2.5.1. AASHTO method

The analysis results showed that the original soil belongs to the classification group of A-7-5, according to the remark PI>(LL-30), where PI (48)<(85–30). The usability level as a subgrade is fair to poor. Figure 3 shows the soil classification using the AASHTO chart, which compares the value of Plasticity Index (PI) with the Liquid Limit (LL).

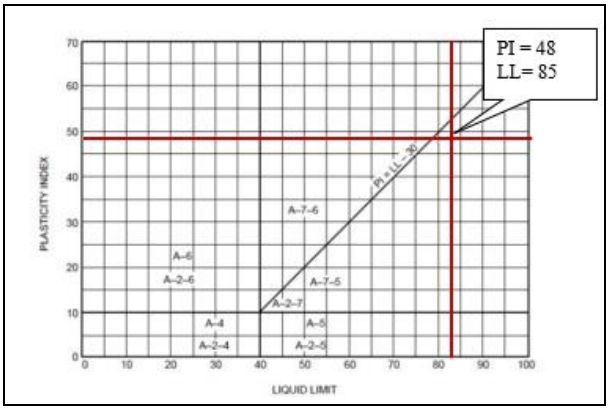

Figure 3 Correlation Plasticity Index and Liquid Limit for Soils Classification Using AASHTO Method

4.2.5.2. USCS method

From the results of the sieve analysis, the soil passed more than 50%, thus the soil was included in the fine-grained soil classification. LL is 85.00% and PI value is 48.00%, thus the soil is classified as Fat Clay with the symbol of CH (High Plasticity Clay).

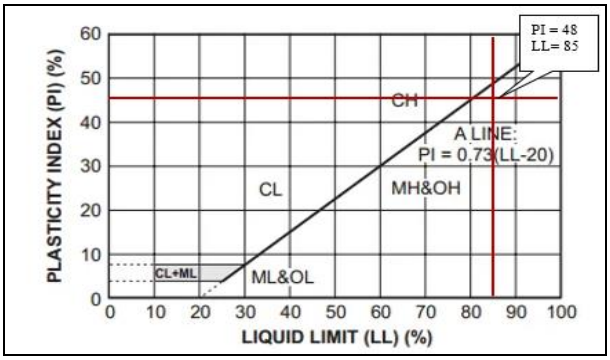

Figure 4 Correlation Plasticity Index and Liquid Limit for Soils Classification Using Unified Method

4.3. Test results of soil mixture with vermiculite and Bledug Kuwu Mud

The results of the plasticity test of clay soil stabilized with vermiculite and Bledug Kuwu mud can be seen in Table 6.

Table 6. Soil Mixture Test Result

Num	Index Properties	Unit	Test Result		
			1	2	3
1.	Atterberg Limit				
1.1.	Plastic Limit	%	36.57	29.61	24.31
1.2.	Liquid Limit	%	78.21	53.71	42.72
1.3.	Plasticity Index	%	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

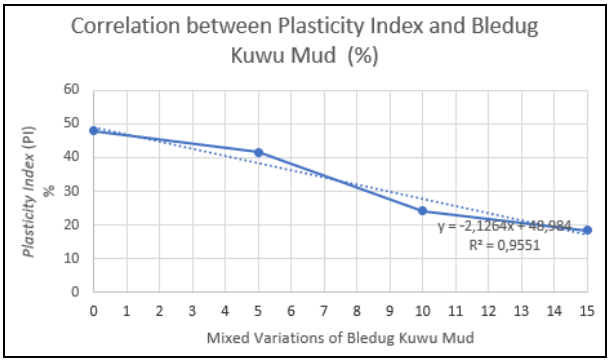

Figure 5 Graph of the Correlation between Plasticity Index and Bledug Kuwu Mud (%)

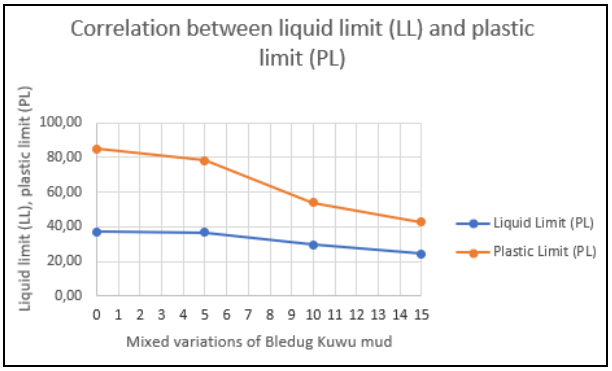

Figure 6 Graph of the Correlation between Liquid Limit (LL), Plastic Limit (PL) and Bledug Kuwu Mud (%)

Figure 5 and Figure 6 show that the physical properties of PI value of the expansive clay after being stabilized with variations in the mixture of vermiculite and Bledug Kuwu mud obtained a decreasing tendency for its physical properties, namely the pore number (e) and porosity (n) so that the percentage of the water content (w) it contains is smaller and makes the expansive clay soil denser.

Based on the research results, it can be concluded that the greater the percentage of the addition of the Bledug Kuwu mud, the smaller the range of PI values. In other words, the smaller the range of PI) values, the less likely it is to be in a plastic condition which resulting the clay soil to be solid and more stable.

5. CONCLUSION

Based on the data analysis and discussion, the following are the conclusions of the research.

- From the results of tests and data analysis, it was found that vermiculite and Bledug Kuwu mud on clay can change the index properties of the soil.
- From the test results, the characteristics of clay soil in the laboratory, the type of clay used was a type of expansive clay with high plasticity with a moisture content of 50.89%,

a specific gravity of 2.54, LL=85.41%, PL=37.32% and PI=48.09%.

- The test results show that the addition of vermiculite and Bledug Kuwu mud can significantly reduce the PI value. For the 5% Bledug Kuwu mud, the PI value decreased to 41.64% with a decrease percentage of 13.26%. For the 10% Bledug Kuwu mud, the PI value decreased to 24.11% with a decrease percentage of 49.78%. For the 15% Bledug Kuwu mud, the PI value decreased to 18.40% with a decrease percentage of 61.66%. Hence, the largest decrease of PI occurred in the third mixture variant (15% Bledug Kuwu mud + 4% vermiculite).

6. RECOMMENDATION

The following are the recommendation given based on the conclusions.

- There is a need for extensive use of vermiculite and Bledug Kuwu mud as soil stabilization material because in addition to changing the physical properties of the soil, it can also reduce the value of the plasticity index.
- It is necessary to conduct further research with the addition of the percentage of the vermiculite mixture and the Bledug Kuwu mud to obtain the optimum value of the added material mixture.
- Further research needs to determine soil mechanical properties such as shear strength, compressive strength (q_u), swelling potential, and coefficient of consolidation for soil subjects that have been mixed with vermiculite and Bledug Kuwu mud.

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