Soil Stabilization with *Bledug Kuwu* Mud and Phosphoric Acid on the Plasticity Index Value

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ABSTRACT
Soil condition in construction has an essential role because it can trigger a construction failure. Generally, before construction is carried out, a soil investigation process is conducted to gain the soil data in the form of parameters needed to design construction; one of them is the plasticity index (PI). In this research, soil parameters were repaired by using the stabilization method with the mixture material of *Bledug Kuwu* mud and phosphoric acid chemical solution. According to the test from the Public Service Agency of Mineral and Coal Technology Laboratory (TEKMIRA) in 2020, *Bledug Kuwu* mud has the same content as fly ash and volcanic ash. Those two materials can be used to be the mixture material of soil stabilization because it has high silica content and has the pozzolan character like cement. Meanwhile, a phosphoric acid solution has a function as a soil fastener with *Bledug Kuwu* mud material because its character that is easy to react with cation in soil minerals. The soil in the form of soft soil was mixed with *Bledug Kuwu* mud with the percentage variant of 5%, 10%, 15%, while the phosphoric acid chemical solution was 10% for all mixtures. This research is aimed to determine the optimum stabilization mixture variant in soil. The result of this research indicated that *Bledug Kuwu* mud waste and phosphoric acid could decrease the plasticity index. The optimum plasticity index degradation reached 73.91%, and its activity (A) was 0.26, which meant the soil had an inactive character (A < 0.75). From the result, it can be stated that the mixture of *Bledug Kuwu* mud waste and phosphoric acid is effective as a soil stabilization material.

Keywords: *Plasticity Index, Stabilization, Bledug Kuwu Mud, Phosphoric Acid, Soft Soil.*

1. INTRODUCTION

As the technology developed in the construction world, the infrastructure quality is also increased. For example, a street that is earlier made by compacted soil then it transforms into the complete pavement layer [1]. For joining the development era, innovation and nature waste utilization in the construction world need to be improved. One of the new materials used is *Bledug Kuwu* mud. *Bledug Kuwu* mud is a natural phenomenon in the form of hot mud at Desa Kuwu, Kecamatan Kradena, Kabupaten Grobogan [2]. The material will be used as soil stabilization mixture material because it has high silica content and has the pozzolan character as cement. Soil stabilization is soil character repair by mixing the additional material that can increase soil strength [3][4]. The other mixture material is phosphoric acid. Phosphoric acid has an easy-to-reach character with cation in the soil minerals [5]. The mixture variant percentage used in this research referred to the prior research. Those were 5%, 10%, 15% [6] for Bledug Kuwu mud, and the phosphoric acid was 10% [7] to determine the optimum stabilization mixture variant in soft soil. The result of this research showed that *Bledug Kuwu* mud mixture could decrease the plasticity index value.

2. LITERATURE REVIEW

2.1 Soft Soil

Soft soil is a soil that has very soft particle as clay or silt. This kind of soil involves cohesive soil which has a low-support power character. In a construction building, the basic soil or foundation must be strong and can resist its burden [8].

2.2 Bledug Kuwu Mud

Soil stabilization uses the additional material of *Bledug Kuwu* mud as 5%, 10%, 15%, and 4% vermiculite

can decrease the plasticity index (PI) by 61.66% from the plasticity index value of the soil [6]. According to the Public Service Agency of Mineral and Coal Technology Laboratory (TEKMIRA) in 2020, the chemical elements contained in *Bledug Kuwu* are like fly ash and volcanic ash. Those two materials are often used as the stabilization mixture material. The following table indicates the comparison of chemical elements content from the material of *Bledug Kuwu* mud with fly ash [9], and volcanic ash [10].

Table 1. Comparison of chemical elements content from the material of Bledug Kuwu mud with fly ash and volcanic ash

Chemical Elements	Bledug Kuwu Mud (%)	Fly Ash (%)	Volcanic Ash (%)
SiO_2	45.02	34.29	52.52
Al_2O_3	12.58	16.62	18.69
Fe_2O_3	4.58	15.38	9.17
K_2O	0.82	1.35	2.10
CaO	11.06	18.18	8.96
MgO	1.55	7.52	2.89
TiO_2	0.50	0.73	1.45
Na_2O	3.25	-	0.29
LOI	20.02	0.36	-

2.3 Phosphoric Acid Chemical Solution

The phosphoric acid chemical solution is a liquid in a cloudy white colored with a thick texture. The solution is used as a soil stabilization mixture material so it will have an easy-to-reach character with cation in the soil minerals [5]. In the prior research, the soil stabilization was conducted with three variants of volcanic ash such as 6%, 8%, 10%, and phosphoric acid mixture in 10%.

2.4 Plasticity Index (PI)

Plasticity index is the soil ability to experience shape change without volume and crack changes. This parameter can show the soil plasticity character if it is clay, so it has a high PI value. Meanwhile, if the soil is a little bit silt, it has a low PI value [11]; therefore, it can be conducted a soil repair by the stabilization method.

3. METHODOLOGY

In this research, the soil was taken from Gedebage, Bandung area. Soil stabilization uses the mixture percentage of *Bledug Kuwu* Mud Waste (*LLBK*) in 5%, 10%, and 15% and phosphoric acid of 10% for each mixture. It was expected to reach the optimum mixture. The soil repair used was the stabilization. The flowchart for this research be seen in **Figure 1** and the properties index test can be seen in **Table 2**.

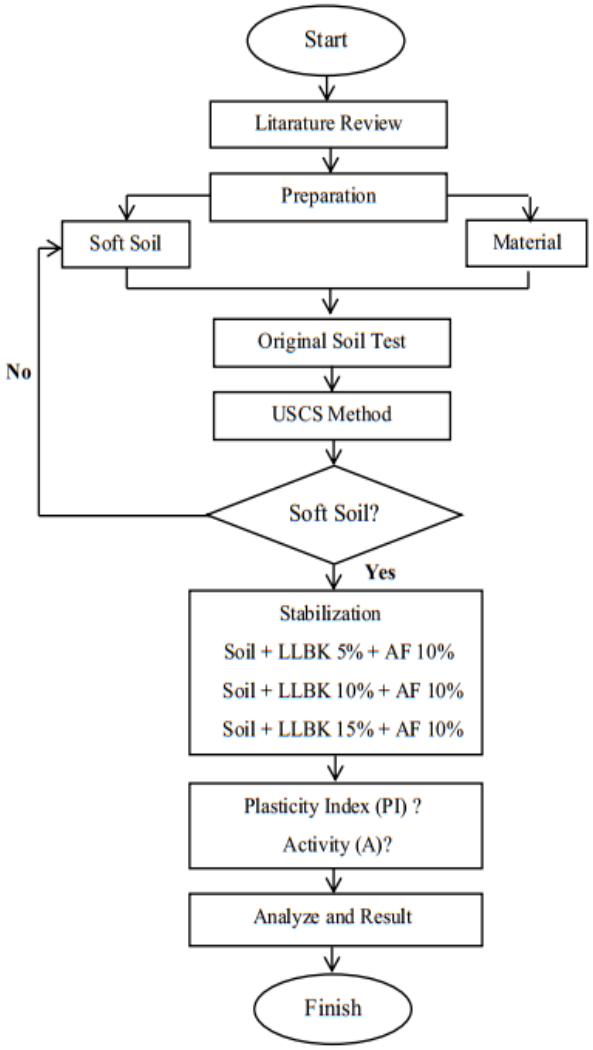

Figure 1 Research flowchart

Table 2. Index Properties Test

No	Test Name	Standard	Total Sample
1	Atterberg Limits	ASTM D4318	16
2	Specific of Gravity	SNI 1964-2008	11
3	Grain Size	SNI 3423-2008	1

4. RESULT

4.1 Grain Size of Soft Soil

The grain Size test in this research referred to SNI 3423-2008 regulation. Based on the graphic above, the content from each particle was 56% clay, 40% silt, 4% sand, and 0% gravel. The following is the grain size test of the original soft soil.

Table 3. Result of Grain Size Test of The Soft Soil

Sieve No.	Wt. Retained (gr)	Percentage (%)	
		Retained	Passing
4	0.00	0.00	100.00
10	0.00	0.00	100.00
20	0.08	0.08	99.92
40	0.25	0.25	99.67
60	0.84	0.84	98.83
100	1.27	1.27	97.56
200	2.55	2.55	95.01
pan	4.99		

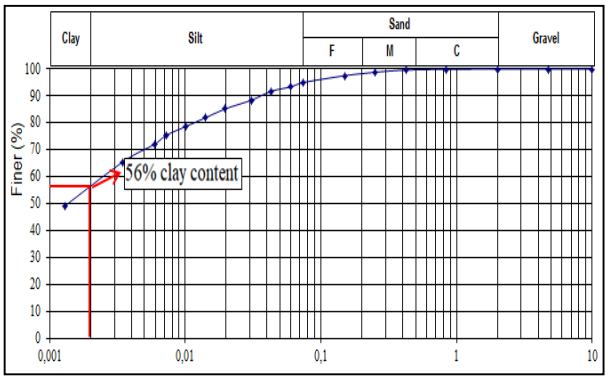

Figure 2 Grain Size Test Graphic

4.2 Specific of Gravity and Atterberg Limits of Soft Soil

Table 4. Result of Specific of Gravity dan Atterberg Limits test on The Soft Soil

No	Test Name	Result
1	Specific of Gravity (Gs)	2.490
2	Atterberg Limits	
	Liquid Limit (LL)	82%
	Plastic Limit (PL)	36%
	Plasticity Index (PI)	46%
	Activity (A)	0.99

The result of the Specific of Gravity (Gs) test was 2.580, the plasticity index of the soil was 46%, and had the normal soil activity of 0.99 (Based on the requirement, normal: 0.75 < A < 1.25). [12]

4.3 USCS Method Soil Classification

According to the grain size test result, the soil which passed the filter number 200 was 95.01% which meant it was involved as the soft particle soil (Fine-Grained Soils). The soil classification used the UCSC method (Unified Soil Classification System) and the soil in this research involved fat clay soft soil (CH) with high plasticity.

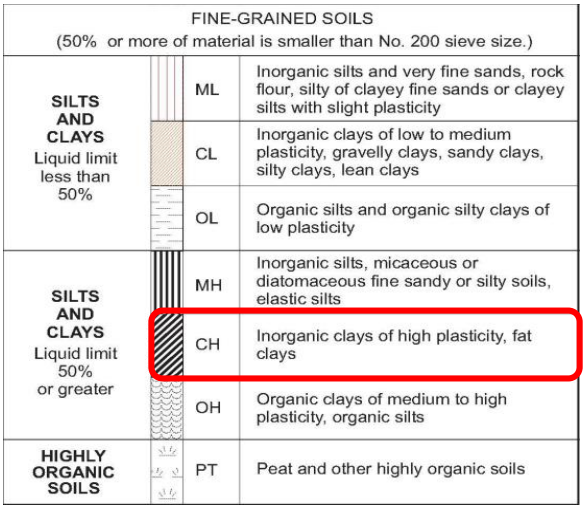

Figure 3 USCS Method Soil Classification

4.4 Specific of Gravity from Stabilization Soil

The result of specific gravity from the stabilization soil can be seen in the following table.

Table 5. Result of The Specific of Gravity from The Soil Stabilization

Variant	Percentage Sample	Gs
1	5% LLBK + 10% AF	2.580
2	10% LLBK + 10% AF	2.608
3	15% LLBK + 10% AF	2.625

4.5 Atterberg Limits of Stabilization Soil

Based on the Atterberg Limits of soil stabilization with three variants, it was obtained the optimum plasticity index reached 12.00% on the third variant (15% *LLBK* + 10% AF). If it was compared with the soil's PI, so its degradation reached 73.91% with the soil activity level (A) is inactive by 0.26% (Based on the requirement, inactive: A < 0.75). [12].

Table 6. Result of Atterberg Limits test on The Soil Stabilization

Test Name	Variant (%)		
	1	2	3
Liquid Limit (LL)	57.04	51.00	44.57
Plastic Limit (PL)	35.06	34.75	32.57
Plasticity Index (PI)	21.98	16.25	12.00
Activity (A)	0.48	0.35	0.26

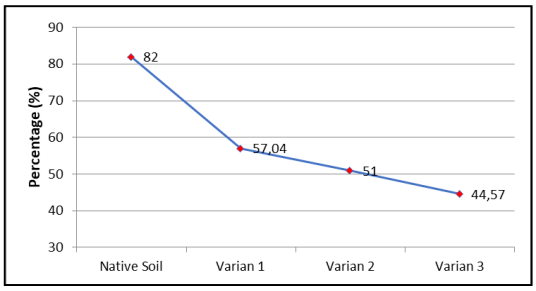

Figure 4 Liquid Limits Comparison Graphic (LL)

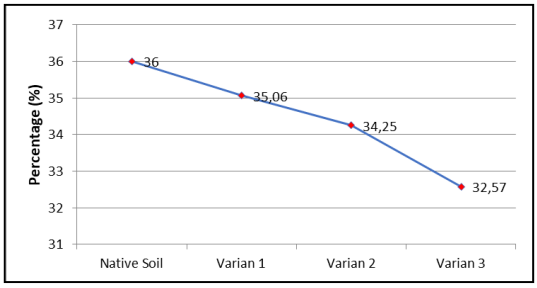

Figure 5 Plastic Limits Comparison Graphic (PL)

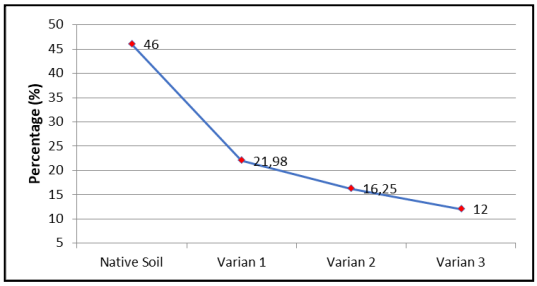

Figure 6 Plasticity Index Comparison Graphic (PI)

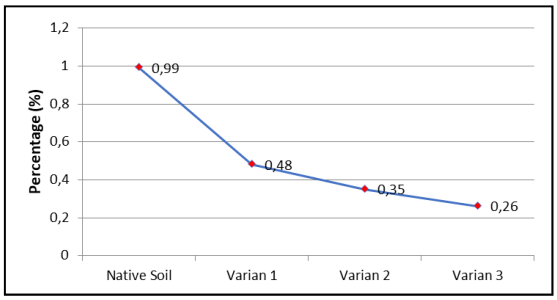

Figure 7 Soils Activity Comparison Graphic (A)

5. CONCLUSION

According to the Atterberg Limits test, the plasticity index in the soil was 46% with the normal category of soil activity (A) by 0.99. In the soil classification using USCS, the kind of soil in this research includes fat clay soil (CH) that had a very high plasticity. The soil was stabilized using the additional material *Bledug Kuwu* mud waste with a percentage of 5%10%, 15%, and phosphoric acid of 10%. From the Atterberg Limits test using the stabilized soil, it could decrease its Plasticity Index reached 73.91% in the optimum mixture that was the third variant (15% LLBK + 10% AF) with the plasticity index of 12% and its soil activity category (A) inactive in 0.26. From the result, it can be stated that the mixture of *Bledug Kuwu* mud waste and phosphoric acid is effective as the soil stabilization material.

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