Study of Soft Soil Stabilization on Slope Using Volcanic Ash and Phosphoric Acid Concerning of Plasticity Index

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ABSTRACT
The Roads and slopes are construction that's directly related to the land. Many cases that occur in the construction are about landslides due to an overload. One way that is often used to strengthen the soil on the slope is stabilization. Volcanic ash has pozzolanic properties, large silica content and has a very fine grain size (resembling cement) so that it can be close to cavities found in the soil. Phosphoric acid is a chemical that will react with cations from soil minerals, so that they can bind to each other and form new compounds. The purpose of this research was to determine the effect of volcanic ash and phosphoric acid which was stabilized for soft soil on a slope using the USCS (Unified Soil Classification System) method. The test will be done in the form of testing the properties index of soil and also the engineering properties. In this research will be comparing the results of the Plasticity Index (PI) from native soil with soil that stabilized with volcanic ash and phosphoric acid. There are 3 types of volcanic ash sample variants to be used which are:6%, 8% and 10%. As for the mixture of phosphoric acid chemicals used by 10% for each mixture. From this research, it is proofed that volcanic ash and phosphoric acid can increase the carrying capacity and repair the characteristic of soft soil on slopes.

Keywords: *Stabilization, volcanic ash, phosphoric acid, plasticity index, USCS*

1. INTRODUCTION

Slopes are slanted geotechnical structures, formed naturally or artificially. The stability of the slope is a state of stability to form the dimension of a slope. On making a highway, it is necessary to do a slope geometry design that can be caused landslides. The problem is there is a process of degradation (decline) to landslides. This degradation will not be stopped before the land reaches a stable or balanced point [1]. In the research that has been done, using volcanic ash (ABVK) and tailing (TL) as additive. The percentage of volcanic ash is 8% and the tailing is 4%, 5%, and 6%. The results of this research are the value of Plasticity Index (PI) of original soil was decreased, from 43% to 28,2% (8% ABVK + 4%TL), 20% (8% ABVK + 5%TL) and 25% (8% ABVK + 4%TL) [2]. Based on this study, the application of a mixture of Phosphoric Acid (AF) solutions used was 4,5%, 7,5%, 10,5% and Palm Shell Ash (ABKS) is 8% for all samples. This research resulted in that addition of palm shell ash (ABKS) and phosphoric acid (AF) can decrease the value of plasticity index (PI), for example in the third mixture (ABKS 8% + 10,5% AF) plasticity index from original soil (47%) decrease to 9% and qualified for the minimum Plasticity Index (PI) value [3].Conduct stabilization of clay with additive phosphoric acid as subgrade with increment 0%, 2,5%, 5%, 7,5%, 10%, and 12,5%. In this study, the value of the Plasticity Index (PI) decreased because the addition of additives causing the liquid limit (LL) decreased. This indicates that binding of the additive and the grains of clay has caused the clay beads to bind [4]. The purpose of this research was to determine the soil classification using the USCS (Unified Soil Classification System) method. In addition, this test aims to determine the effect of the addition of volcanic ash and phosphoric acid stabilization to decrease the value of the Plasticity Index (PI).

2. MATERIALS

2.1. Soft Soil

Soft soil is a type of soil that is not good for construction. This is due to the characteristic of soft soil, namely the value of carrying capacity is small, it has large shrinkage properties, has large compression and etc. Soft soil has a moisture content value of 80 – 100%, liquid limit (LL) of 80 – 110%, plastic limit (PL) of 30 - 45%, and passes through sieve test no. 200 more than 90%. In general, soft soil also has a high plasticity index value [5].

2.2. Volcanic Ash

Volcanic ash is a material that generated from the eruption of volcanic mountains, consist of large and small rocks. In this research, the volcanic ash used came from Mt. Kelud which is located in East Java. Volcanic ash has various chemical contents, one of which is silica (±70%). With this abundant silica content, volcanic ash can be used as a soil stabilizer.

2.3. Phosphoric Acid

Phosphoric acid is a type of clear, odorless and volatile liquid. Phosphoric acid is believed to increase the strength of soil that contains a lot of water, because the phosphoric acid will react quickly and then will produce aluminum compounds that make soil binding.

2.4. Index Properties Test

The soil index properties test aims to determine the characteristics of soil, as well as provide to connect for the mechanical properties (engineering properties) such as strength, compression, development and permeability of the soil. The index testing to be performed can be seen in Table 1.

Table 1. Index Properties Test

No.	Testing Name	Testing Standard
1.	Atterberg Limit Test	ASTM D4318
2.	Specific Gravity Test	ASTM D854
3.	Water Content Test	ASTM D2216
4.	Soil Classification	AASHTO & USCS

2.5. Soil Classification

Soil classification is a way to determine and identify a type of soil in a systematic way to obtain compatibility with certain uses. Soil classification also functions as further learning about soil conditions and the needs for testing in determining technical properties such as compaction, strength, and etc. [6]. In planning a construction, some investigation must be carried out on soil classification properties that affect soil strength. The method of soil classification uses the USCS (Unified Soil Classification System) method. Basically, this method divides the type of soil into 2 parts, namely coarse-grained soil (gravel and sand) and fine-grained soil (silt and clay) [7].

2.6. Soil Stabilization

Soil stabilization is the process of mixing materials into the soil with the aim of improving the properties of soil, and can satisfy certain of technical requirements [8]. The addition of additives is expected to decrease the value of plasticity index (PI) and carrying capacity of the soil.

3. METHODOLOGY

This research uses 6%, 8%, and 10% variations of volcanic ash, and 10% of phosphoric acid for all samples. Soil samples used are located in Gedebage, which according to information is a soft soil type. The steps of this research are shown in Figure 1.

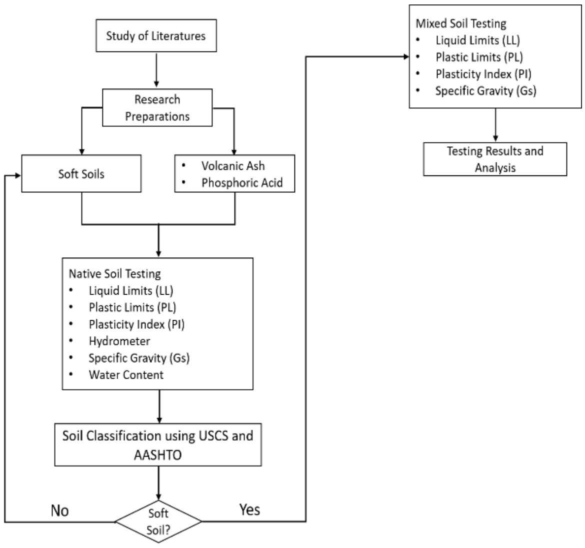

Figure 1 Methodology

4. RESULTS

4.1. Atterberg Limits Test of Native Soil

This test uses the regulations of ASTM D4318. Native soils that used, have a plasticity index (PI) value that is classified as high, namely 48% with a liquid limits (LL) value of 85% and plastic limits (PL) of 47%. The native soils also have a water content of about 50,89%. Table 2 is showing the detail of the testing.

Table 2. The Result of Native Soils Atterberg Limits Testing

Nr.	Index Properties	Symbol	Unit	Value
1.	Water Content		%	50,89
2.	Atterberg Limit			
2.1.	Plastic Limit	PL	%	37
2.2.	Liquid Limit	LL	%	85
2.3.	Plasticity Index	PI	%	48

4.2. Specific Gravity Test of Native Soil

Specific gravity test uses ASTM D854 as a standard of testing. Native soils that used have a specific gravity value of 2,59. The results of specific gravity testing can be seen on Table 3.

Table 3. The Results of Native Soil Specific Gravity Testing

Information	Symbol	Unit	Samples	
			1	2
Pycnometer Number			35	42
Pycnometer Mass + Cap	M_1	gr	54.00	66,10
Pycnometer Mass + Soil	M_2	gr	,50,37	52,84
Pycnometer Mass + Soil + Water	M_3	gr	159,88	159,73
Temperature + Water	t_1	˚C	20	20
Correction Factor	σ1	-	1	1
Pycnometer Mass + Water	M_4	gr	151,72	151,57
Water Temperatur	t_2	˚C	20	20
Correction Factor	σ2	-	1	1
Soil Weight	M_5	cm^3	5,16	5,10
Specific Gravity	Gs		2,58	2,60
Average of Specific Gravity	Gs		2,59	

4.3. Hydrometer and Grain Size Test of Native Soil

Hydrometer testing used SNI-3423-2008 as a standard of the test. The results obtained from this test are that natives soil has a grain size of 0% gravel (G), 4,62% of sand (S), 39,38% of silt (M) and 56% of clay (C). From the test results, native soil used is classified as clay silt mixed with sand. After this, the soil classification will be carried out and calculate the activeness level of the soil.

4.4. Soil Classification using AASHTO Method

Native soil included the type of clay soil with a specification that passing the sieve number 200 more than 35% with liquid limits (LL) value of 85% and plasticity index (PI) of 48%. the results that used AASHTO table classification of soil, can be seen in Table 4.

Table 4. Classification of Native Soil using AASHTO Table

General Classification	General Materials (35% or less passing 0.075 mm)							Silt-clay materials (more than 35% passing 0.075 mm)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
Sieve Analysis % passing 2.00 mm (No10) 0.425 mm (No40) 0.725 mm (No200)	50max 30max 15max	50max 25max	51min 10max	35max	35max	35max	35max	36min	36min	36min	36min
Characteristics of fraction passing Liquid limit Plastic Index	6max		N.P	40max 10max	41min 10max	40max 11min	41min 11min	40max 10max	41min 10max	40max 11min	40min 11min
Usual types of significant Constituent material	Stone fragment Gravel and sand		Fine Sand	Silty or clayey Gravel and sand				Silty soils		Clayey soils	
General rating	Excellent to Good							Fair to poor			

The native soil classified on a group of A-7-5, according to the regulations PI>(LL-30). The usability level as subgrade is fair to poor. Figure 2, will display the soil classification using the AASHTO graphic. The parameters used are the value of liquid limits (LL) vs plasticity index (PI).

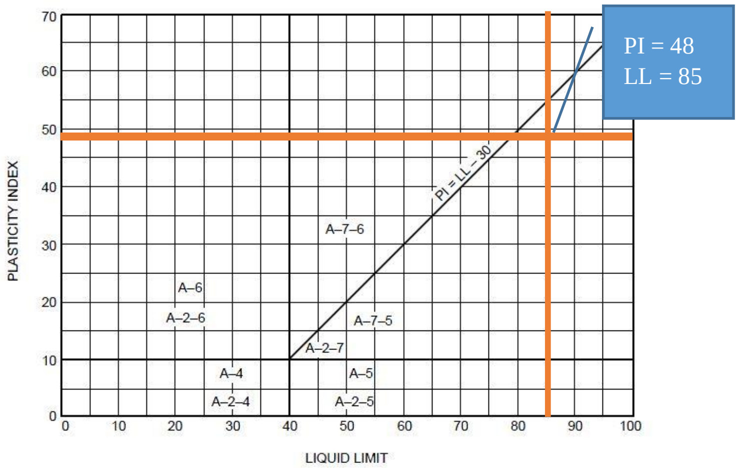

Figure 2 Classification of Native Soil using AASHTO Graphic

4.5. Soil Classification using the Unified Soil Classification System (USCS) Method

The parameters used for soil classification using the USCS method are the loose grain size number 200, value of liquid limits (LL), plastic limits (PL) and Plasticity Index (PI). According to the hydrometer test, the percentage of granules that passed sieve no. 200 is 97,52%, which means that this soil is classified as Fine–Grained Soils. The details can be seen in Table 5.

Table 5. Classification of Native Soil using USCS Method

Fine-Grained Soils

% passing #200?	LL > 50%?	PI > 0.73(LL-20)%?	USGS Symbol	USCS Name
>50%	yes	yes	CH	Fat clay
		no	MH	Elastic silt
	no	yes	CL	Lean clay
		no	ML	Lean silt

In figure 3 shows the soil classification using the USCS graphic by input the liquid limits (LL) value (85%) and plasticity index (PI) value (48%).

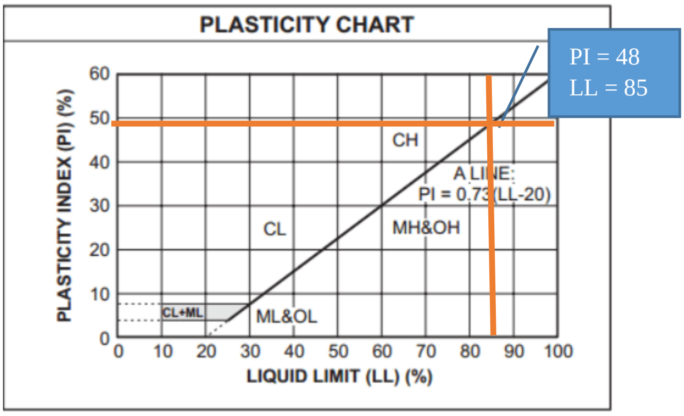

Figure 3 Classified Native Soil using USCS Method

From the results of soil classification using USCS method, it can be said that the original soil is classified as fat clay with CH symbol.

4.6. Index Properties Testing of Mixed Soil

After testing the index properties of native soil and soil classification, then tested the native soil that stabilize with volcanic ash (AV) and phosphoric acid (AF). Index properties tests are Atterberg limit (LL.PL.PI), specific gravity (Gs), the activity level of the soil (AC). The results of the test can be seen in Table 6.

Table 6. The Results of Index Properties of Mixed Soil

No.	Index Properties	Symbol	Unit	Variant			
				0	1	2	3
1.	Grain Size						
1.1.	Gravel	G	%	0,00	-	-	-
1.2.	Sand	S	%	4,62	-	-	-
1.3.	Silt	M	%	39,38	-	-	-
1.4.	Clay	C	%	56,00	-	-	-
2.	Specific Gravity	Gs	-	2,59	-	-	2,62
3.	Water Content		%	50,89	-	-	-
4.	Atterberg Limits						
4.1.	Plastic Limit	PL	%	37,00	33,03	32,83	30,35
4.2.	Liquid Limit	LL	%	85,00	57,22	51,00	44,57
4.3.	Plasticity Index	PI	%	48,00	24,19	18,16	14,22
4	Activity Level	AC	%	1,04	0,53	0,39	0,31

Information:
Variant 0 : Native Soil (Soft Clay Soil) Variant 2 : 8% AV + 10% AF
Variant 1 : 6% AV + 10% AF Variant 3 : 10% AV + 10% AF

On table 4 shows a decrease the value of plasticity index due the addition of increasing percentage of volcanic ash and the constant percentage of phosphoric acid.

4.7. Laboratory Resume

In Figure 4 (a), (b), and (c) shows the graphs of the Atterberg limit test, seen from the number of blow (x) vs percentage of water content (y) for all variants.

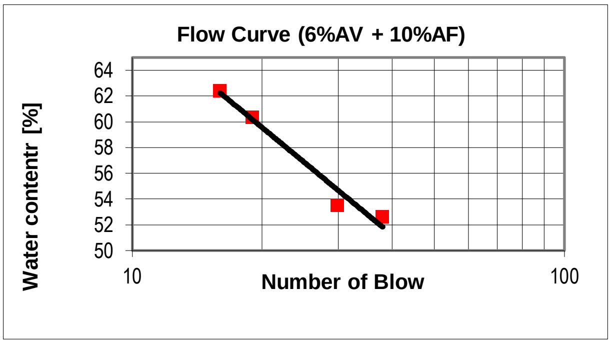

Figure 4 (a) Number of Blow vs Water Content (Variant 1)

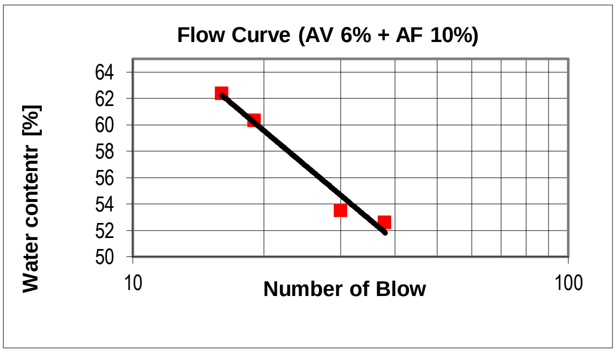

Figure 4 (b) Number of Blow vs Water Content (Variant 2)

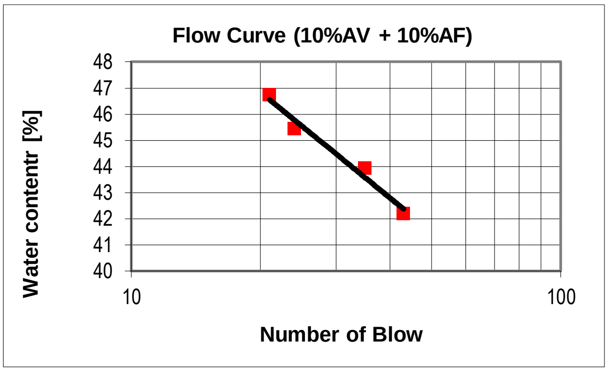

Figure 4 (c) Number of Blow vs Water Content (Variant 3)

Table 7 shows the liquid limits (LL), plastic limits (PL), and plasticity index (PI) of native soil and all variants.

Table 7. Liquid Limits, Plastic Limits and Plasticity Index of Samples

.	Native Soil	Variant 1	Variant 2	Variant 3
LL (%)	85	57,22	51,00	44,57
PL (%)	37	33,083	32,83	30,35
PI (%)	48	24,19	18,16	14,22

It can be seen in Figure 5 (a), (b), and (c) that the value of LL, PL, and PI, decreases with increasing levels of volcanic ash and the same levels of phosphoric acid

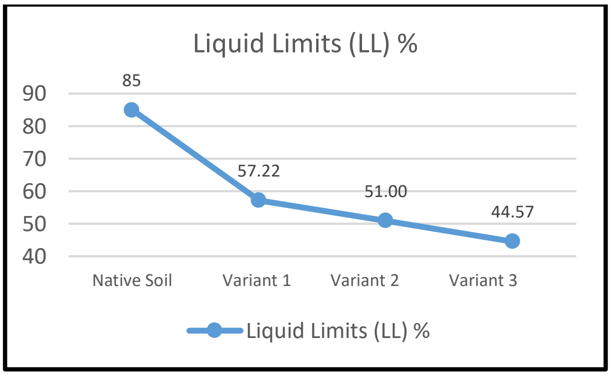

Figure 5 (a) Percentage of Liquid Limits

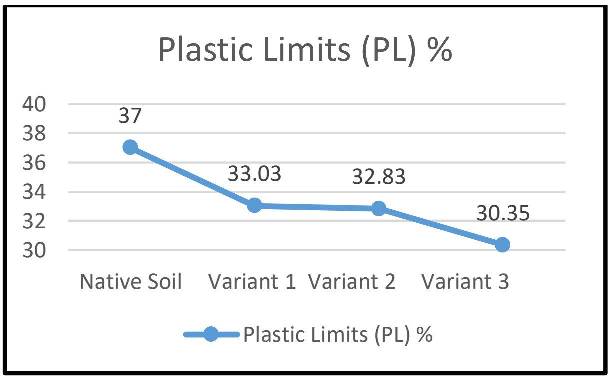

Figure 5 (b) Percentage of Plastic Limits

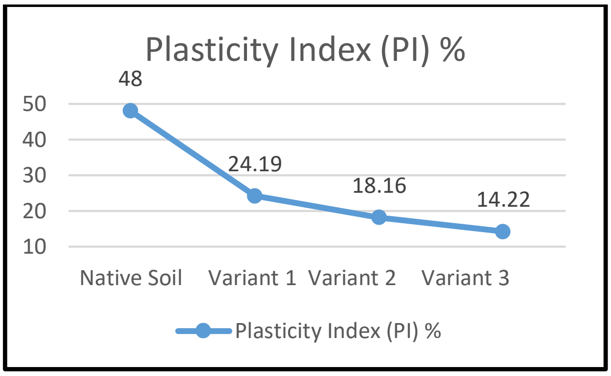

Figure 5 (c) Percentage of Plasticity Index

5. CONCLUSION

According to Pd T-10-2005-B, it shows that the native soil (variant 0) is a soft clay soil that has very high development properties with Plasticity Index (PI) value reaching 48%. The addition of volcanic ash (AV) with percentage 6%, 8%, 10% and phosphoric ash (AF) with a percentage of 10% for all mixed variant can cause the plasticity index (PI) value decrease. Mixed variant 3 (10% AV + 10% AF), has the largest decrease in plasticity index value was 70,37% from the plasticity index (PI) of the native soil. For the level of soil activeness with development potential, native soil has a percentage of 1,04% which classified as normal (0,75 – 1,25), while mixed soils classified as very low of soil activity (<0,75%). Soil stabilization on slope is causing the slope more stable, because of the plasticity index value decreases. The decrease of the plasticity index causing the soil activity value is small. This can reduce the movement that occurs on the ground because of the soil is unstable. From this research, it can be concluded that the addition of volcanic ash and phosphoric acid with a certain percentage can reduce the value of plasticity index (PI) on soft soil.

6. RECOMMENDATION

This research was using disturbed soil samples, it is recommended for further research to use undisturbed soil samples. It is necessary to the test reaction of phosphoric acid to volcanic ash before it is used for soil stabilization. For further research, it needs to add a variant of volcanic ash (more than 10%) or using volcanic ash from another mountain (this research using Mt. Kelud) because each volcanic ash has a different chemical composition. Then it is necessary to carry out an engineering test of soil so that it can be analyzed whether it can be used on construction.

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