Analysis of Soft Soil Shear Strength on Slopes Stabilized Using Volcanic Ash and Phosphoric Acid

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ABSTRACT

The main problem in construction is the lack of quantities of land to build the infrastructure, such as roads, buildings, dams, etc. Meanwhile, the technical specifications for soil are often not suitable for the requirements for the building base. Soft soil is a problem in construction due to its unsupportive characteristic to be used as a building base. One of the most important soil parameters is the value of soil shear strength. The parameter of shear strength is cohesion (c) and angle of internal friction (ϕ), needed to determine the soil bearing capacity and slope stability. Soil stabilization is the process of adding material into the soil to modify the properties of the original soil to obtain the desired properties. The methodology carried out is laboratory testing, consisting of Index Properties and Engineering Properties of original and stabilized soil. The stabilization material was volcanic ash (VA) mixed with phosphoric acid (PA) by 6%, 8 %, 10% for volcanic ash, and 10% for phosphoric acid. The purpose is to obtain the optimum variation of stabilization, in improving soil parameters, especially from the value of shear strength. The result of this research was decreasing the value of plasticity index of soft soil, reached ±70% from original soil. From UCS test, obtained maximum value on variant 3 (10% VA + 10% PA) which is 1,058 kg/cm^2, classified as a medium level of consistency. In addition, seen from the value of Triaxial U-U test, there is an increasing of cohesion and angle of internal friction value. From the results, it can be concluded that volcanic ash and phosphoric acid with an ideal composition are effective and can be used as an alternative material for stabilizing soft soil on slope structures.

Keywords: *Phosphoric_acid, shear_strength, stabilization, soft_soil, volcanic_ash.*

1. INTRODUCTION

Generally, in Civil Engineering, especially Geotechnical Engineering, it is always related to the characteristics and behaviour of soil and rock (1). Soil is an important element in construction, such as slopes, foundations, earthwork (excavations and embankments) and so on. To determine the characteristics of soil parameters, it can be done in various ways, including:

1. Laboratory test
2. On Site test (directly)
3. Testing and supervision during construction activities

Soft soil is one type of soil that is not recommended for the basis of a building or can also be referred to as “problematic soil” (2). In general, soft soils have a high plasticity index (PI) value, bearing capacity, low shear strength, and high compressibility (3,4). The low shear strength causes the working load to be limited, while the high compressibility can cause settlement problems in the future. The selection of technology or soil improvement method is very necessary for this situation because the future impact will be proper. One method that is often used is soil stabilization. Soil stabilization aims to change the heterogeneous nature of the soil to become homogeneous, such as adding lime to high clay soil, asphalt, cement, and other chemical substances (5). This research uses volcanic ash (VA) and phosphoric acid (PA) as stabilization materials. Volcanic ash is generally composed as mineralogical (6). Soil stabilization can improve the shear strength and bearing capacity of soft soil (7). Soil stabilization using volcanic ash and phosphoric acid can decrease the plasticity index parameters of soft soil, which is quietly high (8). This study hopes it can provide future references in overcoming problems regarding soft soil in the construction area.

This research takes several references from the following journals and articles. In the research of examining the effect of adding Mt. Kelud volcanic ash as a stabilizing clay material, the variation of volcanic ash used is 3%, 6%, and 9%. The results of this study said that the value of Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) increased and reached the optimum at 9% (9). Another research of soil stabilization using palm shell ash and phosphoric acid for subgrade, the variation of palm shell ash is 8% and the phosphoric acid 4,5%, 7,5% and 10%. From this research, obtain the increase of California Bearing Ratio value and the optimum result show in variant 3, with 10% phosphoric acid and 8% palm shell ash (10). In the research of soft soil stabilization using volcanic ash with percentage 6%, 8%, 10%, and phosphoric acid is 10% for all variants. This research obtains the decreasing plasticity index value and the increasing Unconfined Compressive Strength value, directly proportional to the increase of stabilizing material used, and reaches a maximum at variant 3 (10% volcanic ash + 10% phosphoric acid) (5). Also, the study about soil stabilization using volcanic ash and tailing with ripening time can increase the value Unconfined Compressive Strength value and decrease the plasticity index, as well as the activity of soft soil (11).

2. BACKGROUND

In this current era, land used for construction with good quality parameters is decreasing. Therefore, it requires a solution to fix this problem, especially the soft soil problem. The soft soil sample used was taken from Gedebage Area, Bandung City, which according to data and previous studies that have been carried out, is classified as soft soil, with the plasticity index and soil activity quietly high (12,13).

2.1. Slope Stability

In geotechnical engineering, slope stability is quite important. Slope stability is a structural condition where the slope can maintain its weight and force without experiencing displacement (landslide). The behaviour of slope stability can be seen from laboratory testing and software analysis. This study used laboratory testing methods by looking at the parameters and characteristics of soft soil on a slope and the value of shear strength on a slope.

2.2. Volcanic Ash (VA)

Volcanic ash is a natural material produced as a result of volcanic activity. Volcanic ash on each mountain has different characteristics and contents, but both have high silica content. This is one of the reasons for using volcanic ash as a stabilizing agent for soft soil. This study used volcanic ash from Mount Kelud. In addition to the silica content, another reason is that the size of volcanic ash is fine (almost like cement), so that it is expected to be able to fill the voids on soil so that the soil compaction becomes better (10). Figure 1 shows the volcanic ash material that used for this research.

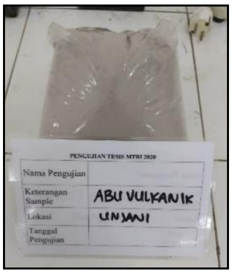

Figure 1. Volcanic Ash of Mt. Kelud

2.3. Phosphoric Acid (PA)

Phosphoric acid is a clear, odorless, and colourless chemical and has properties that easily react with the soil. Phosphoric acid mixed into the soil as a binder should not be too much because the remaining unreacted solution will damage the soil (14). Figure 2 is the phosphoric acid used for this research.

Figure 2. Phosphoric Acid

2.4. Soil Stabilization

The method of geotechnical engineering to improve the soil parameters and increase the value of shear strength is to use the soil stabilization method. Soil stabilization is alteration or increase in one or more soil characteristics. In a broad sense, stabilization combines several methods to modify the property and improve its engineering performance. The stabilization process can be achieved by mixing the original soil and stabilizing it with certain materials until the soil is homogeneous and seep into the soil cavity (15). The soil stabilization material that is often used is fly ash, cement, lime stone, etc.

2.5. Shear Strength

The value of shear strength is a mechanical parameter of soil required for calculating the bearing capacity of foundation and slope stability (16). The parameter of shear strength is cohesion (c) and inner shear angle (ϕ). The stabilization process can increase the parameters of shear strength as of forming a better soil structure. Soil shear strength can be determined by laboratory tests (by direct shear or triaxial tests) and in situ tests (using vane shear test). Figure 3 will show the laboratory test that used for this research (Triaxial U-U method).

Figure 3. Triaxial U-U for this Research

3. RESEARCH METHODS

This study used 3 variants of volcanic ash (VA) with the percentage of 6%, 8%, and 10%. Also, the binder is phosphoric acid (PA) with the percentage of 10% for all variants. The first step was to determine the original soil type by testing the index properties of soil, then classify the soil using the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Official (AASHTO). The next step was to carry out stabilization using volcanic ash (VA) and phosphoric acid (PA) for index and engineering properties tests. The research flow chart diagram can be seen in Figure 4.

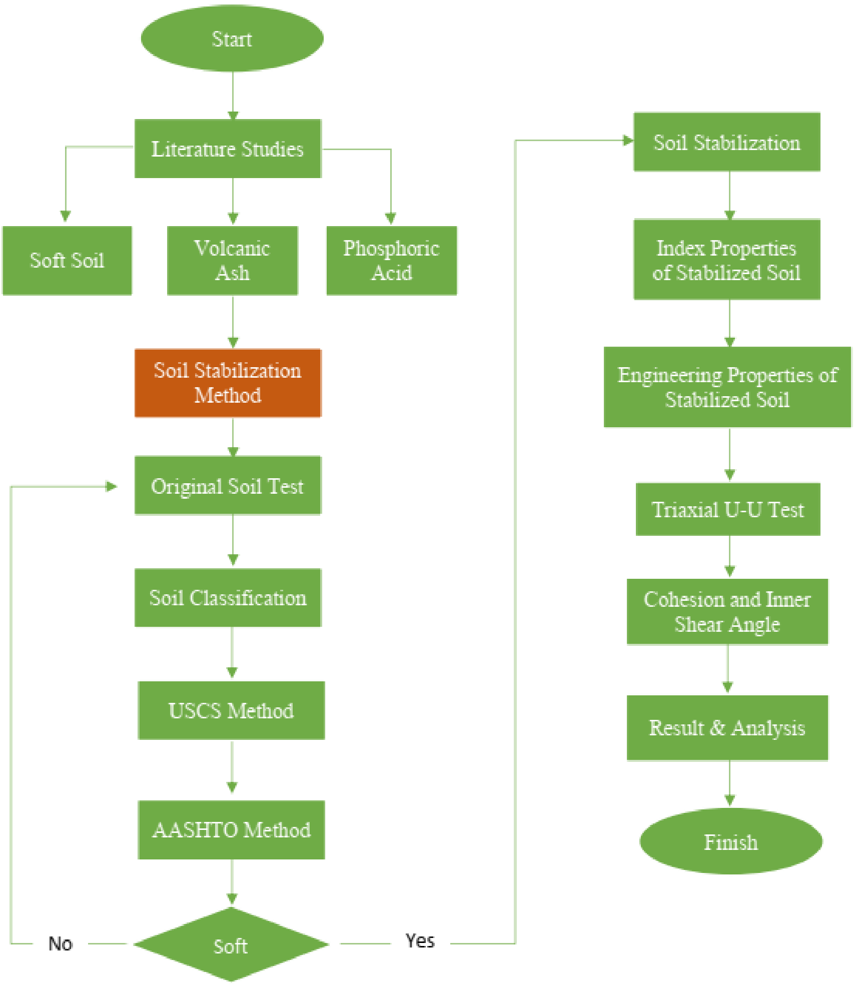

Figure 4. Flow Chart Diagram of Research

4. RESULT AND CONCLUSION

4.1. Original Soil Index Properties Test

In this study, it was found that the original soil was a soft soil type. In soil classification using USCS method, Gedebage soil is classified as soft soil with high plasticity or often referred to as “Fat Clay” with a “CH” symbol, while in soil classification using AASHTO. The original soil is classified as soft soil with code A-7-5. This allocation for road subgrade in the category is quite good to bad. The result of the original soil test can be seen in Table 1.

The test that carried out is Grain Size Analysis/Hydrometer test, Specific Gravity (Gs) Test, Atterberg Limit Test, and Soil Classification

Table 1. Index Properties Test of Original Soil

Nr.	Description	Result
	Grain Size Analysis	
1.	Clay	56%
2.	Silt	39%
3.	Sand	5%
4.	Gravel	0%
	Specific Gravity	
1.	Original Soil	2.496
	Atterberg Limit	
1.	Liquid Limit (LL)	85
2.	Plastic Limit (PL)	37
3.	Plasticity Index	48
4.	Shrinkage Limit (SL)	16
	Soil Classification	
1.	USCS Method	CH/Fat Clay
2.	AASHTO Method	A-7-5

4.2. Stabilization Soil Index Properties Test

The result of stabilization using volcanic ash (VA) and phosphoric acid (PA) are shown in Table 2. The material variants is: Variant 0 (Original Soil), Variant 1 (6% VA + 10% PA), Variant 2 (8% VA + 10% PA), Variant 3 (10% VA + 10% PA).

Table 2. Index Properties Test of Stabilization Soil

Atterberg Limit Test		
Sample	Unit	Plasticity Index
Variant 0 (Original Soil)	%	48.00
Variant 1 (6% K + 10% PA)	%	24.19
Variant 2 (8% K + 10% PA)	%	18.16
Variant 3 (10% K + 10% PA)	%	14.22
Specific Gravity Test		
Sample	Unit	
Variant 0 (Original Soil)		2.496
Variant 1 (6% K + 10% PA)		2.584
Variant 2 (8% K + 10% PA)		2.600
Variant 3 (10% K + 10% PA)		2.624
Soil Activity (AC)		
Sample	Unit	
Variant 0 (Original Soil)	%	1.07
Variant 1 (6% K + 10% PA)	%	0.53
Variant 2 (8% K + 10% PA)	%	0.39
Variant 3 (10% K + 10% PA)	%	0.31

From these results, there was a decrease in the value of the soil plasticity index due to the addition of volcanic ash and phosphoric acid. The increase in specific gravity value may be influenced by the additional weight of the volcanic ash. There is a decrease in soil activity (AC), and it is classified as inactive soil with low development potential (17). The Figures below show some testing activity.

Figure 5. Soil Preparation

Figure 6. Atterberg Limit Test

Figure 7. Specific Gravity Test

Figure 8. Grain Size Test

4.3. Compaction Test

The aim of the compaction test is to obtain the optimum moisture content (w-opt) and maximum dry density. The result of the compaction test from this research is shown in Table 3.

Table 3. Compaction Test Result

Description	Unit	Variant			
		0	1	2	3
W - Optimum	%	36.95	35.70	34.75	33.80
rd max	gr/cm^3	1.18	1.198	1.205	1.26

The value of optimum moisture content decreases due to the stabilization material fills the void of soft soil. And the unit weight increases due to the addition of stabilization materials.

4.4. Unconfined Compressive Strength (UCS) Test

This test aims to determine the strength of soil by applying one-way pressure (uniaxial). The sample used has a tube dimension from the results of soil compaction. The outcome from this test can be seen in Table 4.

Table 4. Unconfined Compressive Strength Test Result

Description	Unit	qu max average	Cohesion
Variant 0	kg/cm^2	0.755	0.377
Variant 1	kg/cm^2	0.810	0.405
Variant 2	kg/cm^2	0.980	0.490
Variant 3	kg/cm^2	1.091	0.546

The qu max average of Variant 0 (original soil) is 0.755 kg/cm^2, and the consistency is classified as "medium." The optimum qu max average found in Variant 3 (10% VA + 10% PA) with the value 1,091 kg/cm^2, and the consistency classified as "Stiff." Figure 9 is the UCS test of this research.

Figure 9. Unconfined Compressive Strength Test

4.5. Shear Strength using Triaxial U-U Test

The unconsolidated undrained triaxial test (Triaxial U-U) is a "quick test" type to obtain the value of shear strength of soil in short-term conditions. The output of this test is the cohesion (c) and inner shear angle (ϕ) value. Table 5 will show the result of the triaxial u-u test.

Figure 10. Triaxial U-U Test

Table 5. Triaxial U-U Test Result

Description	f	c	s (kg/cm^2)		
	o	kg/cm^2	0,5	1,0	1,5
Variant 0	17.00	0.390	1.330	1.692	2.108
Variant 1	18.77	0.400	1.390	1.692	2.188
Variant 2	19.39	0.450	1.763	2.570	3.123
Variant 3	20.04	0.500	1.782	2.632	3.156

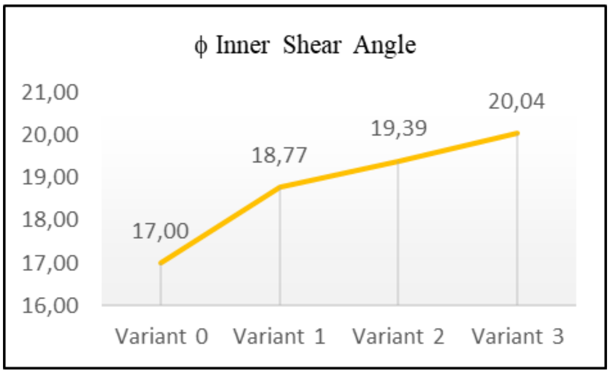

Figure 11. Graph of Inner Shear Angle

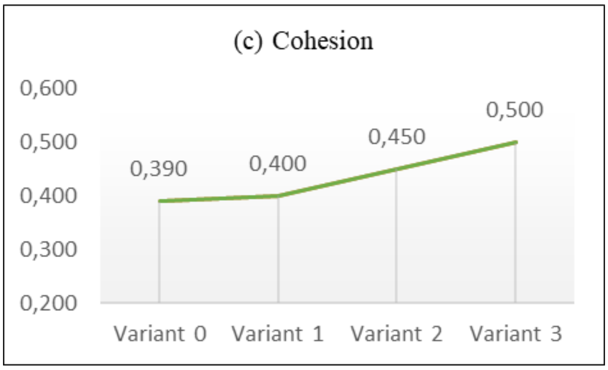

Figure 12. Graph of Inner Shear Angle

From this test, the value of cohesion (c) and inner shear angle (ϕ) is obtained, which is the parameters of soil shear strength. There is an increase in cohesion (c) value, which means the bond between particles is getting better (the cavity is filled with stabilizing material). The increases of inner shear angle (ϕ) due to the reducing of voids on soil, causing the friction between particles to increase, also if the soil is applied in slope, it will increase the stability of the slope.

From this research, it can be concluded that volcanic ash and phosphoric acid can be used for stabilization material. This can be seen from the improvement of soft soil parameters.

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