

# Reinforcement of Soft Soil on Slope Using Volcanic Ash and Phosphoric Acid Stabilization for Subgrade of Rigid Pavement

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## ABSTRACT

In infrastructure, soil has an important role to support the construction. The soil function as a basic foothold and accepts all loads caused by construction. In the implementation of road construction, its often found the condition of the soil with low bearing capacity, especially if the road construction in on slopes that are prone to landslides. One way to improve the carrying capacity of soils is stabilization. In this research will use volcanic ash and phosphoric acid for the mixture of soil stabilization. Volcanic ash is a pozzolanic material and contains a lot of silica. Volcanic ash has tiny particle size to cover cavities in the soil. Phosphoric acid can cause chemical reactions due to soil minerals, then it will form new compounds that bond the structure of soil minerals and form a hard layer that is insoluble in water. The purpose of this research is to determine the effect of addition volcanic ash and phosphoric acid as stabilized materials for rigid pavement subgrade and to increase the carrying capacity of native soil after stabilization based on the Unconfined Compression Strength (UCS) test. The test will be carried out of index properties and engineering properties test. The volcanic ash variants used are 6%, 8%, and 10%, while the phosphoric acid is 10% for all variants. From this research, it is proofed that the use of volcanic ash and phosphoric acid as stabilizing materials, can increase the carrying capacity of the slope, which is seen on the Unconfined Compression Strength (UCS) test.

**Keywords:** *Stabilization, volcanic ash, phosphoric acid, unconfined compression strength*

## 1. INTRODUCTION

Soft soils are cohesive soils which have low carrying capacity and has characteristic, that is low shear force, large of density, and low permeability coefficient [1]. Cohesive clay soils are classified as soft soils if they have bearing capacity less than 0,5 kg/cm<sup>2</sup> and the Standart Penetration Test (SPT) value less than 4 [2]. Generally, soft soils has a water content of 80 – 100%, liquid limit of 80 - 110%, plastic limit of 30 – 45%, and granules that pass the No. 200 filter more than 90% and have shear strength of 20 – 40 kN/m<sup>2</sup>. Slopes are geotechnical structures with oblique dimensions, and connecting higher ground to lower ground surfaces [3]. On slope case will produce gravity from the weight which tends to move of soil mass. In this research stabilization materials used were volcanic ash and phosphoric acid [4]. Using volcanic ash as added material to increase the carrying capacity of soil. Volcanic ash content used by 3%, 6% and 9%. Tests carried out are Unconfined Compression Strength (UCS) and California Bearing Ratio (CBR). The results of UCS and CBR test showed a significant increase occured in the addition of volcanic ash by 9% where the UCS value increased by 36,6% and the CBR

value increased by 6,15%. It can be concluded that volcanic ash can increase the carrying capacity of clay soil [5]. Using volcanic ash (ABVK) and tailings (TL) as stabilization materials for subgrade. The volcanic ash content used was 8% while the tailings were 4%, 5% and 6%. This research resulted the value of Unconfined Compression Strength (UCS) test on all variants increased, and concluded that the more tailings added, the carrying capacity of the subgrade will be higher [6]. Stabilized clay soils using phosphoric acid chemicals as a road foundation layers. Variant of phosphoric acid are 0%, 2,5%, 5%, 7,5%, 10%, and 10,5%. The results of Atterberg Limit test showed that the addition of phosphoric acid maked the liquid limit (LL) and the plastic limit (PL) of native soil decrease that makes the plasticity index (PI) decrease. Phosphoric acid causes gradual changes in the grains of the finer fraction decreases and the coarse fraction increases. CBR test results (soaked and unsoaked) resulted the carrying capacity of the soil increased and reaches the maximum point on 7,5% addition then the decline in the percentage of 10% and 12,5%. The addition of additives for soaked CBR testing on 4 days will improve the mechanical

properties of soil, because the additive covers the soil [7]. grains and work effectively so that made its strength increases and the swelling rate decreases. This research aims to obtain the characteristic of soil due the addition of volcanic ash and phosphoric acid which has been stabilized. In addition to increasing the carrying capacity (qu) of the native soil seen from the UCS test, and to see the increasing percentage in the bearing capacity of the soil that has been stabilized with volcanic ash and phosphoric acid.

2. MATERIALS

2.1. Soil Stabilization

Soil stabilization is a step to improve soil characteristics by adding additives with the aim to increasing the strength of soil and maintaining its shear strength. Soil stabilization aims to bind and combine material aggregates to dense the layer of soil. States that actions that need to be taken for stabilize soil is increasing soil density, adding material to improve rate of cohesion, adding material that make chemical changes, and decreasing groundwater level [8].

2.2. Index Properties Test

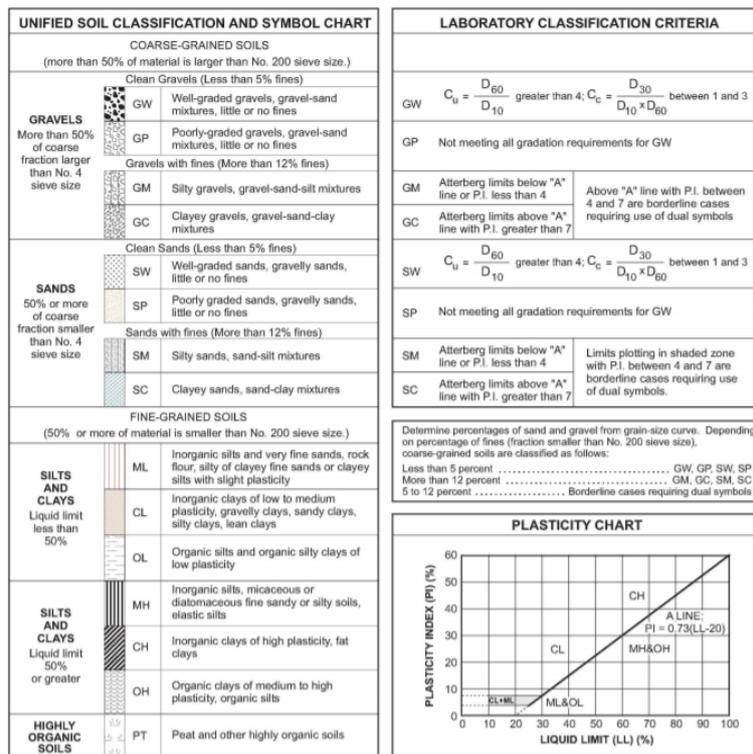
Soil properties index is a property or characteristic of soil that's related to the element of the compilation of existing soil mass [9]. Index properties test can be seen in Table 1.

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.	Volume Weight Test	ASTM D2216
5.	Soil Classification	USCS

2.3. Unified Soil Classification System (USCS)

Unified Soil Classification System (USCS) is soil classification system based on identifying the characteristic of soils according to their textural, quality of plasticity and then will be grouped into the group with same characteristic. USCS method is divided into two groups, namely coarse-grained soils (passing the sieve no. 200 <50%) and fine-grained soil (passing the sieve no. 200 >50%). The USCS chart can be seen in the Fig 1.



Source: California Department of Transportation  
Figure 1 USCS Chart

2.4. Unconfined Compression Strength (UCS) Test

Unconfined Compression Strength (UCS) is a simple soil testing method to acquire the engineering properties of fine-grained soils. The main purpose of this test is to

determine of compressive strength from soil and conducted to obtain the value of cohesion to permit of soil especially for clay or silt. The test starts by apply a constant axial strain of 0,5% - 2% per minute. The loading will be continued until the samples collapses and the load dial reading come down.

### 3. METHODOLOGY

In this study, three variants mixture of volcanic ash were used and mixed using phosphoric acid with same percentage for all mixtures. The location of soil used for the sample is from Gedebage, Bandung. According to information, the location of soil which is classified as poor – soil (soft), especially for construction. The research flow chart can be seen in Figure 2.

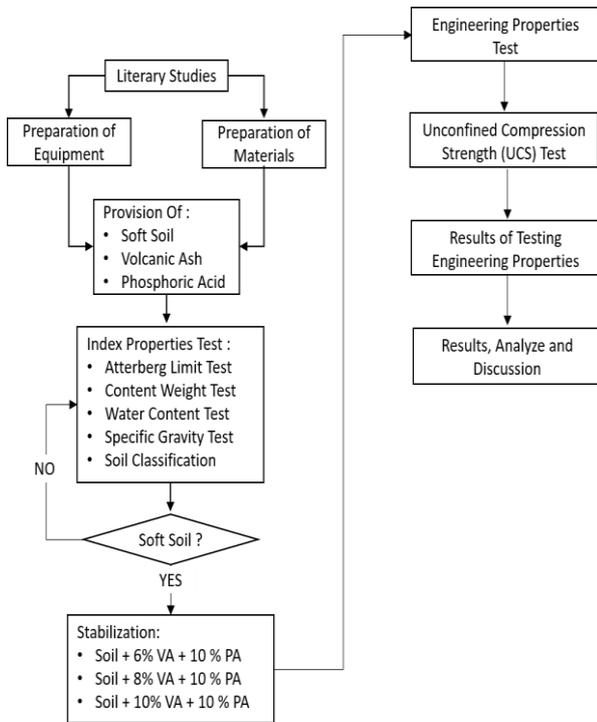


Figure 2 Research Flow Chart

### 4. RESULTS

#### 4.1. Index Properties Test Result of Native Soil

The soil used in this study is soft soil type with high plasticity, which can be seen from the plasticity index (PI) value reaching 48%. On Table 2 shows the native soil index properties test results.

Table 2. The Results of Native Soils Test

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
3.	Specific Gravity	Gs		2,59
4.	Grain Size			
	Gravel	G	%	0,00
	Sand	S	%	4,62
	Silt	M	%	39,38
	Clay	C	%	56,00
5.	Activity Level	AC	%	1,04

#### 4.2. Soil Classification

After conducting physical soil test (index properties), then carried out the soil classification using Unified Soil Classification System (USCS), to find out the type of soil. The native soil has percentage of passing the sieve no. 200 more than 50%, so it is classified as fine – grained soils. The soil has liquid limits (LL) value more than 50% (native soil = 85%) then it can be categorized as clay or silt with high plasticity. The native soil has PI value (48%) more than  $(0,73 \times (LL-20)\%)$ , and can be said as clay with USCS symbol CH.

#### 4.3. Stabilization using Volcanic Ash and Phosphoric Acid

The addition of volcanic ash and phosphoric acid to the native soil, resulted decreasing the value of plasticity index (PI) and the level of soil activity. The percentage of volcanic ash (AV) used in this study was 6%, 8% and 10%, then the percentage of phosphoric acid was 10% for all mixed variant. The results of the tests are shown in the Table 3.

Table 3. The Results of Mixed Soil Test

Nr.	Index Properties	Symbol	Unit	Value on the Mixture			
				0	1	2	3
1.	Atterberg Limits						
1.1.	Plastic Limit	PL	%	37,00	33,03	32,83	30,35
1.2.	Liquid Limit	LL	%	85,00	57,22	51,00	44,57
1.3.	Plasticity Index	PI	%	48,00	24,19	18,16	14,22
2.	Soil Activity Level	AC	%	1,04	0,53	0,39	0,31

Information:

Variant 0 : Native Soil (Soft Clay Soil)

Variant 1 : 6% AV + 10% AF

Variant 2 : 8% AV + 10% AF

Variant 3 : 10% AV + 10% AF

#### 4.4. Unconfined Compressive Strength Test Results

After carrying out the native soil physical test (index properties), soil classification and conducting the mixed soil physical test, the next step is compressive strength test using UCS. This test was conducted to determine the

effect of adding stabilizing materials on the compressive strength value of native soil. UCS samples were taken through standard compaction process, then formed using UCS mold by size 38 mm x 76 mm. The native soil has compressive strength value of 7,547 kg/cm<sup>2</sup>. The results of native soil compressive strength test and three variant samples that have been stabilized with volcanic ash and phosphoric acid, can be seen in the Table 4 below.

**Table 4.** The Results of Unconfined Compressive Strength Test

Nr.	Technical Properties	Symbol	Unit	Mixed Composition			
				0	1	2	3
1.	Unconfined Compressive Strength Test						
2.1.	Soil Bearing Capacity	qu	kg/cm <sup>2</sup>	7,547	8,095	9,798	10,914
2.2.	Soil Cohesion	c	kg/cm <sup>2</sup>	4,053	4,187	4,967	5,755

Information:

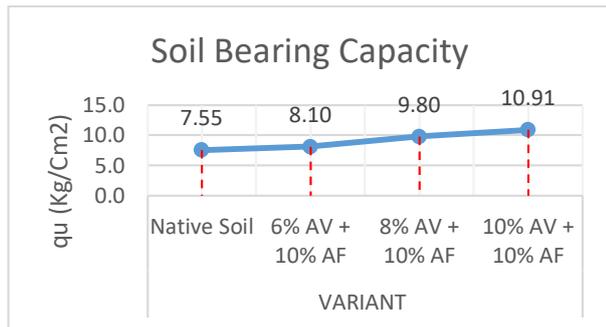
Variant 0 : Native Soil (Soft Clay Soil)

Variant 1 : 6% AV + 10% AF

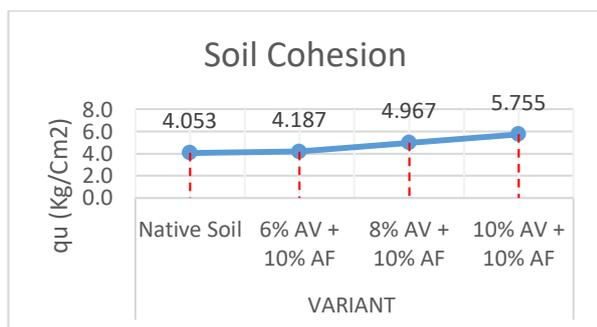
Variant 2 : 8% AV + 10% AF

Variant 3 : 10% AV + 10% AF

Figure 3(a) and (b) is a graph of the results of unconfined compressive strength test.



**Figure 3 (a)** The Results of UCS Test



**Figure 3 (b)** The Results of Cohesion Test

#### 5. CONCLUSION

From this research, it can be concluded that the native soil is soft clay with plasticity index value about 48%, and according to the Unified Soil Classification System (USCS), it is classified as Clay – High (CH) soil with quality as a subgrade in the category fair to poor with high plasticity. After soil stabilization by using volcanic

ash and phosphoric acid, the plasticity index value of native soil decreased, and reached maximum decrease in third variant (10% AV + 10% AF). Decreasing the value of plasticity index is likely caused by volcanic ash which contains a lot of silica ( $\pm 70\%$ ) so that it can absorb excess water contained on soil. In the Unconfined Compressive Strength (UCS) test, it was obtained an increase the value of soft soil bearing capacity (qu) along with the increase in % of volcanic ash and fixed % of phosphoric acid. The optimum increase is in the third composition variant (10% AV + 10% AF) with the value of qu reaching 10,914 kg/cm<sup>2</sup> with an increase about 45% from qu of native soil. Besides that, the value of soil cohesion has also increased, this is because the mixed soil is getting denser. This can be seen from the decrease plasticity index value of soil after stabilization. Thus, it can be concluded that the addition of volcanic ash and phosphoric acid with a certain percentage can increase the bearing capacity (qu) of soil also the value of soil cohesion

#### 6. RECOMMENDATION

In this study uses disturbed soil samples, for further research, try using undisturbed soil samples. In the Unconfined Compression Strength (UCS) testing, it has not taken into ripening time, so for further research it can be re-analysis by adding the time of ripening.

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