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The Effect of Adding Lime and Phosphoric Acid for Soft Soil Improvement on Unconfined Compressive Strength Value

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ABSTRACT
In construction design, several soil parameters are needed, especially the value of unconfined compressive strength. The value of unconfined compressive strength aims to determine the strength of soil when it receives pressure. The test that is often used is Unconfined Compressive Strength (UCS) which is carried out in the laboratory. This research uses stabilization method by using lime material (K) and phosphoric acid (AF) for increasing the soil parameter. Lime material is easy to react with the groundwater, so it can change the soil parameters. In addition, the lime material has a good adhesion so that it can overcome the soil softness, while phosphoric acid is expected as a binder because the characteristic of phosphoric acid is easy to react to. In this research, three variants are used with the percentage of lime material as follows: 6%. 8%, 10%, and 12%. Meanwhile, for the phosphoric acid, it is 5% for all variants. The purpose of this study is to obtain the optimum mixed variant that can improve soil parameters, especially soft soils. The results obtained from this study are decreasing the value of plasticity index (PI) from soft soil. Soft soil is classified as soft soil with a very high plasticity index (PI) value. In addition, there is an increase for each variant, and it reaches the optimum value in variant 3 as seen from the results of the unconfined compressive strength. Therefore, it can be concluded that the addition of lime and phosphoric acid, which is stabilized on soft soil, can improve the parameters of the soft soil.

Keywords: *stabilization, soft soil, lime, phosphoric acid, compressive strength.*

1. INTRODUCTION

Soil is one of the important geotechnical elements in Civil Engineering. The soil has functioned as a support for the structure above, such as buildings, bridges, roads, and other infrastructure. Not all soils have parameters that support construction activities, which is soft soil. Soft soil is a type of soil that has sticky-like clay and consists of very small grain sizes. Index properties end engineering properties of soft soil especially on subgrade requiring the improvement of parameters [1]. The subgrade of road construction on soft and expansive soil has several problems such as low bearing capacity and high swelling potential [2]. Soft soil properties are low shear force, coefficient of permeability, and bearing capacity, but have high compressibility. Soil that has poor parameters, such as soft soil, can be anticipated by using the stabilization process. Soil stabilization in general is improving soil properties by mixing a certain material into the soil. Generally, in construction, cement is usually used for stabilization material, but in this research, the material of stabilization is lime and phosphoric acid. Using lime as the material of stabilization as the cement substitute is a solution for increasing the bearing capacity of the subgrade layer. According to Bowles (1984), a soil condition with easily compressible properties, high plasticity index value, very high permeability, and other properties that are not supported in the construction sector, it is necessary to carry out a stabilization process. Stabilization is divided into two methods: mechanical and chemical stabilization [3]. This research will use the chemical stabilization method by using lime material and phosphoric acid as the binder. Lime is one of the most effective materials for the soil stabilization process. Lime material will form a strong and hard gel, namely calcium silicate and serves as a binder for soil when reacts with water. Phosphoric acid is used as a solvent because it reacts quickly with the soil, especially in high water content soils. Soil stabilization uses lime material with percentages of 3%, 6%, 9%, 12%, 15%, and 18% and applies the ripening period up to 90 days. From this study, the results of the unconfined compressive strength test reach the optimum at 18% percentage of lime [4]. The stabilization of soft soil uses volcanic ash and phosphoric acid. The percentage of variance used is 6%,8%, and 10% of

volcanic ash, and 10% of phosphoric acid. From this research, it was found that the plasticity index value of soft soil is decreasing until ±70%. In addition, there was an increase in Unconfined Compressive Strength value, and reaches the optimum on variant 3 (10% volcanic ash + 10% phosphoric acid) which was 10.91 kg/cm^2 and the cohesion value was 5.755 kg/cm^2 [5][6]. The research carried out expansive soil stabilization with the addition of lime at 3%, 6%, 9%, and 12%. The result of the test is a significant increase in the value of the California Bearing Ratio (CBR) of soil reaching 10.184% [7]. Soil stabilization with tailing and volcanic ash as the material can increase the *Unconfined Compressive Strength* (UCS) on variants 3 (8% Volcanic Ash + 6% Tailing) with 14 days of ripening time and reach the maximum results [8].

2. BACKGROUND

Soil behaviour is very important in the construction activity. Geotechnical works cannot be separated from the soil as most soil problems are caused by technical properties of soil [9]. Sometimes we do not pay attention to the long-term effects due to poor soil characteristics and one of which is soft soil problems. In this research, we will use soft soil samples in Bandung city area which have soft soil properties and are dangerous for construction. This is based on the increasing growth of construction and the depletion of construction sites, so it is necessary to seek ways of treating the soil with poor characteristics as the foundation of buildings and roads.

2.1. Soft Soil

One of the problems in infrastructure construction is the geotechnical condition. Soft soil is one of the geotechnical elements that have less favourable properties for construction. Generally, soft soil has a high water-content value, so that it can cause settlement activity [10]. In addition, the value of shear strength of soft soils is usually lower than that of coarse-grained soils. Soft soil needs a special treatment, so it can be used as the subgrade or base of construction in both roads construction and buildings construction.

2.2. Soil Stabilization

Soil stabilization is the soil improvement technology that is often known and used in construction [11]. The method used in stabilization is to mix other materials (like cement, lime, ash, etc.) to improve poor parameters or characteristics of soil, especially soft soil**.** In this research, a stabilization process with various percentages of the mixture will be planned, to determine the most optimum value to overcome the soft soil problems.

2.3. Lime

Many admixtures such as cement, volcanic ash, fly ash, lime, calcium chloride were used for soil stabilization [12]. One of the effective and efficient stabilization materials is lime (limestone) which contains calcium carbonate ($CaCo_3$). This lime material will form a chemical process that is insoluble when it is mixed with water. Besides that, if this lime material is reacted with chemicals (silicate and aluminate), it will form a binding gel [7]. Therefore, it is expected that the use of lime material as a stabilizing agent can efficiently solve the soft soil problems. Figure 1 will show an overview of lime for this research.

Figure 1 Lime

2.4. Phosphoric Acid

Phosphoric acid is a chemical solution with a clear physical form (colourless) that is usually used in the industrial. Phosphoric acid is produced by smelting anhydrite phosphate into the water [13]. The use of phosphoric acid as a stabilizing agent aims to create new reactions in the soil so it can form a new substance that is expected to improve the soft soil properties. Figure 2 will show an overview of phosphoric acid for this research.

Figure 2 Phosphoric Acid

2.5. Soil Test

Soil testing activities can usually be carried out on-site directly and testing in the laboratory. Laboratory testing aims to investigate the natural soil with admixture materials [14]. This soil test is carried out to determine the characteristic of soil so it can be used as a reference for planning the foundation of buildings. Geotechnical laboratory tests are often are index properties soil test and engineering properties soil test. The index properties test aims to determine the properties of soil for soil

classification. The test to be carried out in this research show in Table 1 and Table 2

Table 1. Index Properties Test

Nr.	Test	Guidelines
1.	Index Properties	
	Grain Size Analysis	SNI 3423 - 2008
	Specific Gravity	SNI 1964 - 2008
	Atterberg Limit	SNI 1967 - 2008

Table 2. Engineering Properties Test

Nr.	Test	Guidelines
1.	Engineering Properties	
	Compaction (Standard)	03-1742-2008
	Unconfined Compressive Strength (UCS)	ASTM D2166

3. RESEARCH METHODS

This research will use four mixture variants with the percentage of lime as 6%, 8%, 10%, and 12% and 5% phosphoric acid for all mixtures. This research will refer to SNI and ASTM regulations with the stabilization chemical method. The flowchart of this study can be seen in Figure 3.

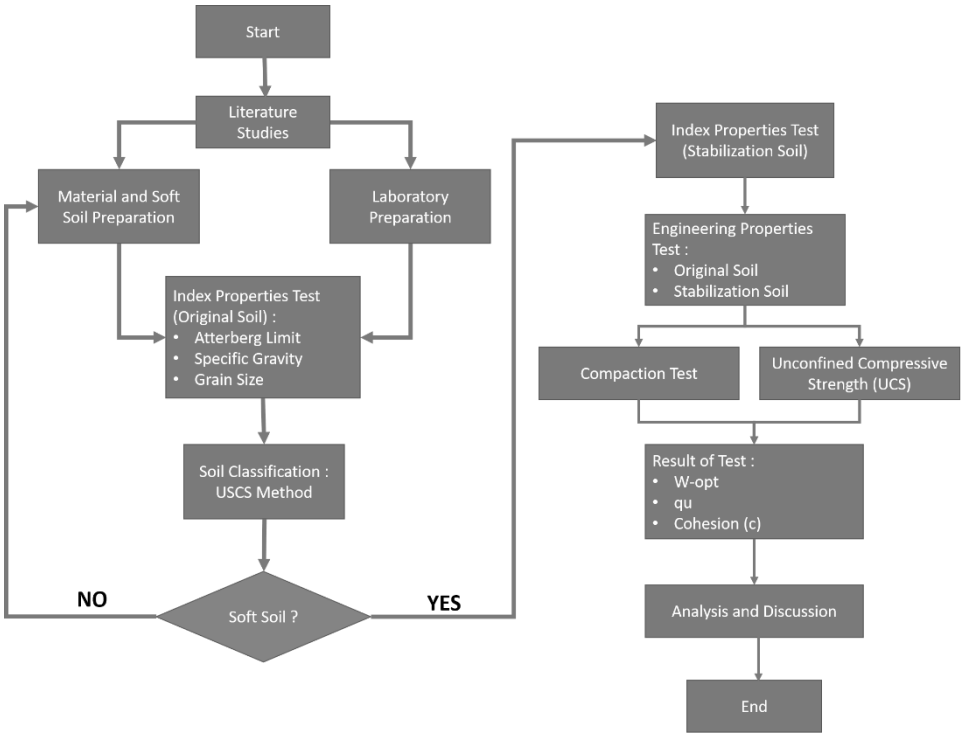

Figure 3 Research Flow Chart

The output of index properties of a soft soil test is the liquid limit (LL), plastic limit (PL), plasticity index (PI), hydrometer test, and specific gravity. The data will be used for soil classification by using the Unified Soil Classification System (USCS) method. After that, the stabilization process with lime material and phosphoric acid will be implemented. The output is to find the mixture that has the most optimum performance that can be carried out in the stabilization process. After the index properties test is completed, it is continued for the engineering properties test, namely the Unconfined Compressive Strength Test.

The research resulted in the decrease of Plasticity Index (PI) value due to the addition of lime material and phosphoric acid. There is also an increase in the value of Unconfined Compressive Strength (UCS) from soft soil.

4. CONCLUSION

4.1. Grain Size Analysis

This test refers to SNI 3423 – 2008 regarding the grain size analysis. Soft soils are classified as fine-grained soils. The grain size analysis will be used as soil classification parameters. The result of the test will show in Figure 4.

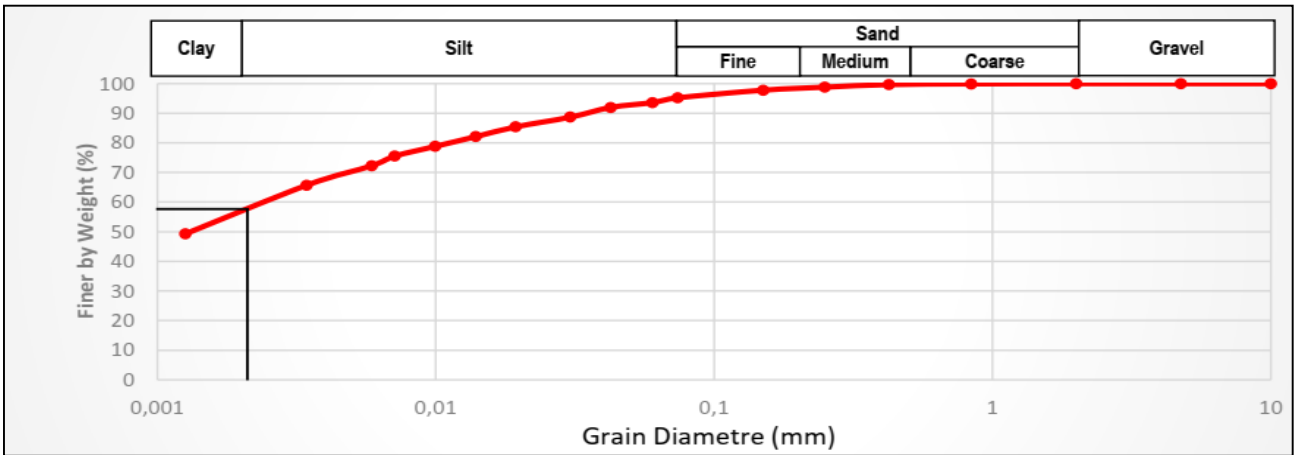

Figure 4 Graph of Grain Size

From this graph, the percentage result is 58% clay, 37% silt, 5% sand, and 0% gravel. Therefore, it can be said that the soil used is clay with few silty soils.

4.2. Specific Gravity (Gs)

This test refers to SNI 1964 – 2008. The result of the test is shown in Table 3.

Table 3 Specific Gravity (Gs) Result

Soil Variation	Gs
Variant 0 (Soft Soil)	2.539
Variant 1 (6% K + 5% AF)	2.598
Variant 2 (8% K + 5% AF)	2.637
Variant 3 (10% K + 5% AF)	2.676
Variant 4 (12% K + 5% AF)	2.701

From this result, there is an increase in the value of specific gravity (Gs) from the original soil because there is an increase in the grain weight due to adding lime and phosphoric acid as material stabilization.

4.3. Atterberg Limits

The others parameters to classify the original soil are liquid limit, plastic limit, and plasticity index value. From the Atterberg limit test of the original soil, the soil was classified using the Unified Soil Classification System (USCS) as clay soil (fat clay) with a CH symbol. The result of Atterberg limits is shown in Table 4.

Table 4 Atterberg Limit Result

Soil Variation	Unit	Plasticity Index
Variant 0 (Soft Soil)	%	47.00
Variant 1 (6% K + 5% AF)	%	34.90
Variant 2 (8% K + 5% AF)	%	28.84
Variant 3 (10% K + 5% AF)	%	24.24
Variant 4 (12% K + 5% AF)	%	16.19

From this test, there is a decrease in the value of the Plasticity Index (PI) from variant 1 to variant 4. The optimum decrease occurs in variant 4 with a plasticity index (PI) value of 16.19%. According to Farhandasi (2020), the plasticity index (PI) value minimum for subgrade is <18%.

4.4. Compaction

This test refers to SNI 1964 – 2008. The result of the test is shown in Table 3. The method of compaction is the standard proctor for all variants.

Table 5 Compaction Result

Description	Unit	V0	V1	V2	V3	V4
W-Opt	%	36.2	35.7	35.0	33.8	33.6
· d max	gr/cm^3	1.19	1.21	1.22	1.26	1.27

The graph of W – optimum (%) and □d max (gr/cm^3) can be seen in Figure 5 and Figure 6.

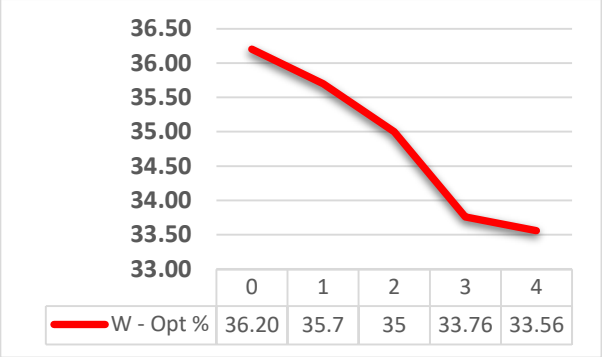

Figure 5 Percentage of W-Optimum

The W-Optimum value decreased as the stabilization material increased because the stabilization material fills the void on the soil. There was an increase in ρd max of the soil due to the dry volume weight being increased and due to the presence of stabilizing material.

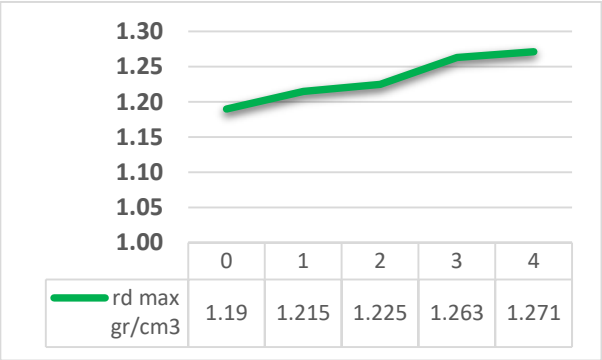

Figure 6 Percentage of ρd max

4.5. Unconfined Compressive Strength

Unconfined Compressive Strength (UCS) test is to obtain the value of the compressive strength of soil until the soil grains are separated and also to measure the strain of soil due to the pressure. The result of the UCS test can be shown in Table 5.

Table 6 Unconfined Compressive Strength Results

Nr.	Description	Unit	Qu max average	Cohesion
1.	Variant 0	kg/cm2	0.738	0.369
2.	Variant 1	kg/cm2	0.800	0.400
3.	Variant 2	kg/cm2	0.980	0.490
4.	Variant 3	kg/cm2	1.111	0.556
5.	Variant 4	kg/cm2	1.148	0.574

Description:
Variant 0 : Soft Soil
Variant 1 : 6% K + 5% AF
Variant 2 : 8% K + 5% AF
Variant 3 : 10% K + 5% AF
Variant 4 : 12% K + 5% AF

From this result, the addition of lime and phosphoric acid as soil stabilization materials can increase the value of compressive strength and the cohesion of soil. Due to the adding of lime and phosphoric acid. It can be used an increasing the bearing capacity of the soil.

It can be concluded that the soil parameters from index properties and engineering properties show positive results, starting from the decrease of the plasticity index value, the increase of specific gravity, the decrease of w-optimum of soil, and the increase of compressive strength and cohesion value of soil. For the slope, the soil with stabilization method using lime and phosphoric acid is more stable.

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REFERENCES

[1] Jafer HM, Obaid HA, Babylon) AHH(C of E /University of. Stabilization of Soft Soil Subgrade Layers by Using Lime-Micro Silica Fume Mixture. Euphrates J Agric Sci [Internet]. 2013;5(1):44–53. Available from: http://www.iasj.net/iasj?func=fulltext&aId=70619

[2] Kumalasari D, Prayogo RDRB, Febriansya A. Expansion Potential and Plasticity Index Value of Expansive Soil Stabilization with Vermiculite and Bledug Kuwu Mud. In: International Seminar of Science and Applied Technology (ISSAT 2020). 2020. p. 479–83.

[3] Joseph B, Johan K. Hainim. Sifat - Sifat Fisis dan Geoteknis Tanah: Mekanika Tanah. 2nd ed. Jakarta: Erlangga; 1984. 549 p.

[4] Miqueleiz L, Ramírez F, Seco A, Nidzam RM, Kinuthia JM, Tair AA, et al. The use of stabilised Spanish clay soil for sustainable construction materials. Eng Geol [Internet]. 2012;133–134:9–15. Available from: http://dx.doi.org/10.1016/j.enggeo.2012.02.010

[5] Syahril S, Suyono A, Prajudi IR. Study of Soft Soil Stabilization on Slope Using Volcanic Ash and Phosphoric Acid Concerning of Plasticity Index. In: Proceedings of the International Seminar of Science and Applied Technology (ISSAT 2020) [Internet]. Paris, France: Atlantis Press; 2020. Available from: https://www.atlantis-press.com/article/125949763

[6] Syahril S, Suyono A, Prajudi IR. Reinforcement of Soft Soil on Slope Using Volcanic Ash and Phosphoric Acid Stabilization for Subgrade of Rigid Pavement. In: Proceedings of the International

Seminar of Science and Applied Technology (ISSAT 2020) [Internet]. Paris, France: Atlantis Press; 2020. Available from: https://www.atlantis-press.com/article/125949751

[7] Sutikno, Damianto B. Stabilisasi Tanah Ekspansif Dengan Penambahan Kapur (Lime): Aplikasi Pada Pekerjaan Timbunan. J Tek Sipil dan Perenc. 2009;11(2):101–8.

[8] Syahril S, Somantri AK, Haziri AA. Study of stabilized soil clay soil characteristics using vulcanic ash and tailing as subgrade layers. IOP Conf Ser Mater Sci Eng. 2020;830(2).

[9] Oktaviana D, Rifa'i A, Basah K. Effect of Kelud volcanic ash utilization on the physical properties as stabilizer material for soil stabilization. Electron J Geotech Eng [Internet]. 2016;21(March):1679–87. Available from: http://volcanoes.usgs.gov/ash/properties.html

[10] Majeed ZH, Taha MR, Jawad IT. Stabilization of soft soil using nanomaterials. Res J Appl Sci Eng Technol. 2014;8(4):503–9.

[11] Arifin YF, Rahman G. Stabilization of Soft Soil with Cement and Palm Kernel Shell Ash Admixture. MATEC Web Conf. 2019;280:04011.

[12] Phan VTA, Pham KNA. Improvement in engineering properties of soft-soil using cement and lime additives: A case study of southern Vietnam. IOP Conf Ser Earth Environ Sci. 2018;143(1).

[13] Farhandasi R, Syahril S. Effect of palm shell ash and phosphoric acid chemical solution on subgrade material towards CBR value. IOP Conf Ser Mater Sci Eng [Internet]. 2020;732:12015. Available from: http://dx.doi.org/10.1088/1757-899X/732/1/012015

[14] Zaika Y, Fahara A, Safira N, Darmawan W. THE EFFECT OF CEMENT ADDITIVE TO IMPROVE STRENGTH. In: 10th Int Conf on Geotechnique, Construction Materials and Environment. Melbourne, Australia: GEOMET; 2020. p. 11–3.