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Utilization of fly ash and bottom ash to increase the value of unconfined compression strength on subgrade

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ABSTRACT

Soil is the most important part to support all traffic loads or construction loads placed on it. Soils that have low bearing capacity, such as clay, need stabilization techniques to increase the carrying capacity of the soil. One of the stabilization techniques is to mix the soil with Fly ash and Bottom ash. The purpose of this study was to determine the effect of Fly ash and Bottom ash on the physical properties of the soil and the value of unconfined compression strength test. The variations of Fly ash and Bottom ash used were Fly ash 0% and 20% and variations of Bottom ash 0%, 10%, 20% and 30% with curing time of 0, 7, 14 and 28 days. Soil is classified according to the Unified Soil Classification System (USCS) method. The results showed that the soil classification was classified as OH, namely organic clay with high plasticity of 21.08%. The results of the unconfined compression strength test show that the addition of fly ash and bottom ash increases the qu value of the clay soil. The optimum qu value was obtained at variation B (Bottom ash 10% and Fly ash 20%) with 28 days curing time of 2.994 kg/cm^2. The decrease in the value of qu occurred in variation C (Bottom ash 20% and Fly ash 20%) and variation D (Bottom ash 30% and Fly ash 30%). Soil with the addition of 0% and 20% Fly ash and Bottom ash at variations of 0%, 10%, 20% and 30% showed a decrease in the value of the soil plasticity index from 21.083% to 7.511%.

ABSTRAK

Tanah merupakan bagian yang terpenting untuk mendukung seluruh beban lalu lintas atau beban kontruksi yang ditempatkan di atasnya. Tanah yang memiliki daya dukung rendah seperti tanah lempung, perlu dilakukan teknik stabilisasi untuk meningktkan daya dukung tanah tersebut. Salah satu teknik stabilisasi yaitu melakukan pencampuran tanah dengan Fly ash dan Bottom ash. Tujuan penelitian ini adalah untuk mengetahui pengaruh Fly ash dan Bottom ash terhadap sifat fisik tanah dan nilai kuat tekan bebas. Variasi Fly ash dan Bottom ash yang digunakan yaitu Fly ash 0% dan 20% serta variasi Bottom ash 0%, 10%, 20% dan 30% dengan lama pemeraman 0, 7, 14 dan 28 hari. Tanah diklasifikasikan berdasarkan metode Unified Soil Classification System (USCS). Hasil penelitian menunjukkan klasifikasi tanah termasuk ke dalam jenis OH yaitu tanah lempung organik dengan plastisitas tinggi sebesar 21,08%. Hasil pengujian kuat tekan bebas menunjukkan penambahan Fly ash dan bottom ash meningkatkan nilai qu tanah lempung. Nilai qu optimum diperoleh pada varaiasi B (Bottom ash 10% dan Fly ash 20%) dengan lama pemeraman 28 hari sebesar 2.994 kg/cm^2. Penurunan nilai qu terjadi pada variasi C (Bottom ash 20% dan Fly ash 20%) dan variasi D (Bottom ash 30% dan Fly ash 30%). Tanah dengan penambahan 0% dan 20% Fly ash dan Bottom ash pada variasi 0%, 10%, 20% dan 30% menunjukkan adanya penurunan nilai indeks plastisitas tanah dari 21.083% menjadi 7.511%.

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1. Introduction

In building a road, soil is the most important part to support the entire traffic load or construction load placed on it. Therefore, in planning a construction, an investigation must be carried out on the characteristics and strength of the soil, especially the soil properties that affect the bearing strength of the soil in resisting the load of the construction on it. Clay soils generally have soil technical properties such as the bearing capacity of CBR and very low unconfined compression strength [1]. A road pavement structure after being implemented will experience changes in the rainy and dry seasons. In the rainy season, the subbase layer will experience waterlogging which is a problem that must be overcome [2]. Soil stabilization is a method that aims to improve the basic properties of the soil so that the carrying capacity of the soil becomes more stable and the carrying capacity of the soil becomes greater so that it can withstand the load acting on it [3]. Soil stabilization must be carried out if the soil found in the field is very easily compressed, or if it has an inappropriate consistency index, permeability is too high, or other undesirable properties that are not suitable for a development project [4]. Chemical stabilization is a stabilization that combines an element with another with the aim of getting a new element [5]. The purpose of soil stabilization is to improve the soil in order to obtain a stable subgrade in all conditions. To overcome the problem of soil bearing capacity so that the strength of road construction is appropriate and feasible to use and it is necessary to make efforts to improve soil through soil stabilization efforts [6].

According to developments in the field, soil stabilization technology has improved. One of them is mixing soil with chemicals. One mixture of chemicals that can improve soil quality is fly ash and bottom ash. In the content of fly ash and bottom ash in the form of these chemical compounds, they have a self-cementing property (the ability to harden and to increase strength when reacted with liquids such as water). Based on FHWA (2003), utilization of bottom ash can be used as a filler in concrete mixtures, such as to reduce the use of sand material. For this reason, the use of bottom ash can be combined with fly ash in subgrade stabilization as well as for soil improvement. The addition of fly ash can lower the value of the liquid limit and limit plastic [7].

Fly ash is used with alkaline materials and as an activator NaOH and sodium silicate (Na_2SiO_3) are used so that a polymerization process occurs which can then bind the aggregates [8]. The use of bottom ash can be combined with fly ash in the manufacture of concrete mixtures (structural concrete and road pavement), aggregate foundation layers, subgrade stabilization as well as for soil improvement [9]. Bottom ash is waste ash whose size is larger than fly ash, so bottom ash will fall to the bottom of the furnace (boiler) [10]. Fly ash and bottom ash are solid wastes produced from burning coal in power plants. There are three types of coal burning in the electricity industry, namely dry bottom boilers, wet-bottom boilers, and cyclon furnaces [11].

Bottom ash and fly ash are used as subgrade stabilization agents because they contain quite high silicon dioxide (SiO_2), namely 61.79% (SiO_2 content in Bottom ash) and 41.96% (SiO_2 content in Fly ash). The chemical composition of Bottom ash and Fly ash is shown in Table 1.

Table 1. Chemical composition of bottom ash and fly ash

Parameter	Bottom Ash (Lignite or sub-bitumen)	Fly Ash (Class C – sub bitumen)
Loss On Ignition	1.18	0.12
Unburned Carbon	0.02	0.01
Silicon Dioxide (SiO_2)	61.79	41.96
Aluminium Trioxide (Al_2O_3)	12.62	21.00
Iron Trioxide (Fe_2O_3)	15.05	16.6
Calcium Oxide (CaO)	4.03	11.79
Magnesium Oxide (MgO)	1.58	3.06
Potassium Oxide (K_2O)	0.46	0.57
Sodium Oxide (Na_2O)	0.84	0.66
Manganese Dioxide (MnO_2)	0.17	0.60
Titan Dioxide (TiO_2)	1.33	1.64
Phosphorus Pentaoxide (P_2O_5)	0.54	0.53
Sulfur Trioxide (SO_3)	0.95	0.98
Undetermined	0.64	0.61

(Source: PT. Indonesia Power Unit Jasa Pembangkitan PLTU Banten 3 Lontar)

Kusuma's research (2017) shows that Fly Ash can increase the value of the unconfined compression strength (qu) of clay soils up to 202.38% with a percentage of 20% Fly Ash mixture [12] . Another study by Monang, L. (2020) showed that BAFA (Bottom Ash and Fly Ash) can increase the value of the unconfined compression strength (qu) of clay with a mixed percentage of 16% [13]. According to Hauashdh, A. (2020) BAFA (Bottom Ash and Fly Ash) shows that this material has cementation features and also confirms the possibility of utilizing coal ash waste as a binder [14]. Zega's research (2020) shows the results that the addition of cement and BAFA in stabilizing high plasticity soft soils can increase the UCS value, which is greatest in soils with 5% cement and 16% BAFA with 28 days curing [13]. The increase in the value of qu in the UCS sample was greatest in the variation of the sample A-S5-B16-C28 with a value of 94.79 kPa, this increase was 76.57% when compared to the value of qu A of 22.04 kPa. Triadi (2020) in his research showed the results that the addition of fly ash to ordinary embankment soil can increase the value of the unconfined compression strength of the original soil by 4.389 kg/cm^2 to 11,600 kg/cm^2 curing for 28 days in a 5% fly ash mixture, so the use of fly ash can be used for stabilization on ordinary embankment soil [15]. Turan (2020) in his research showed the results that the soil gradually increased with increasing levels of fly ash, the parameter of stable soil strength in fly ash variations with 7 and 28 days of curing was much higher than that of stable soil with 1 day of curing [16]. The highest qu value was obtained from soil with fly ash content of 20% with a curing time of 28 days which resulted in a qu value of 6.118 kg/cm^2. According to Arrofiq (2016), explaining that from the results of the unconfined compression strength test carried out in the laboratory, the longer the curing time is carried out the higher the value of the unconfined compression strength, therefore the authors use a curing time of 0 days, 7 days, 14 days, and 28 days [17]. This study aims to determine the effect of Fly ash and Bottom ash on the physical properties of the soil and the value of unconfined compression strength. The variations of Fly ash and Bottom ash used were Fly ash 0% and 20% and variations of Bottom ash 0%, 10%, 20% and 30% with curing time of 0, 7, 14 and 28 days. The use of BAFA (Bottom ash Fly ash) is expected to increase the value of qu and decrease the plasticity index of the soil.

2. Research Methodology

In this study, bottom ash and fly ash were used which were taken from PT. Indonesia Power Unit PLTU Banten 3 Lontar Generation Services as a material for subgrade stabilization. The soil sample used is distrub soil which is located on Jl. Raya Kadomas, Pandeglang District, Pandeglang Regency, Banten. The research was conducted in several stages, firstly testing the physical properties of the soil and analyzing the grain size to determine the type of soil. Then perform a compaction test to determine the optimum moisture content and maximum dry density of the soil. After that, make the test object with the addition of 0% and 20% Fly Ash percentage variations and 0%, 10%, 20%, and 30% Bottom Ash presentation variations 0, 7, 14, and 28 days. After curing is complete, do the Unconfined Compression Strength Test (UCT), or also called the unconfined compression strength test to get the value of the bearing capacity of the soil. In addition to the UCT test, the soil physical properties were also tested to determine the effect of adding BAFA (Bottom Ash and Fly Ash) waste to the physical properties of the soil.

3. Result and Discussion

3.1. Soil Property Data

In this study, the property data used were secondary data as presented in Table 2.

Table 2. Native soil property

No	Basic Soil Property	Value
1	Specific Gravity (Gs)	2.296
2	Liquid Limit (%)	65.7
3	Plastic Limit (%)	44.62
4	Plastic Index (%)	21.083
5	Optimum Water Content (%)	22
6	Maximum Dry Density (g/cm^2)	1.978

3.2. Analysis of Grain Size Test

Based on the sieve analysis test, it was found that the weight value of the severed soil on sieve no. 200 132, the percent value of passing sieve number 200 was 52.2%, which was greater than 50% as shown in Figure 2.

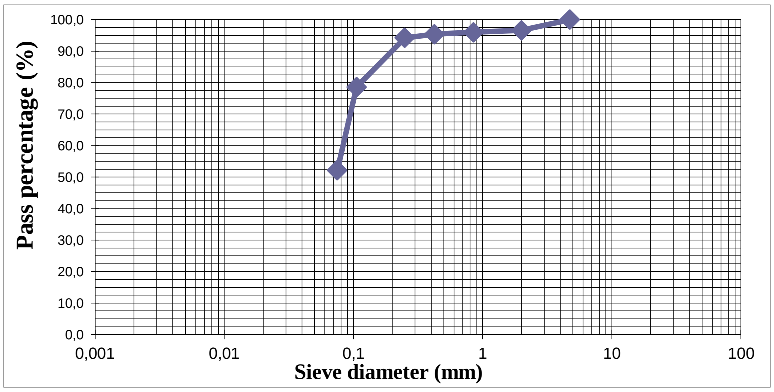

Figure 2. Relationship of percent pass to sieve diameter.

3.3. Soil Classification

This soil classification is used to determine the type of soil. Based on the results of the sieve analysis test, the percentage of passing sieve number 200 was >50%. According to the USCS soil classification system, if it passes the sieve number 200 > 50%, then the soil is classified as fine-grained soil. The next classification is seen from the results of the liquid limit and plastic limit tests. Based on the liquid limit test, the result is 66%. The plasticity index value is obtained from the difference between the liquid limit and the plastic limit, which is 21.08%. Referring to the classification system table, the soil is classified as OH. Thus, it can be concluded that the type of soil used according to the USCS classification system is OH, namely organic clay with medium to high plasticity. The results are shown in Figure 3.

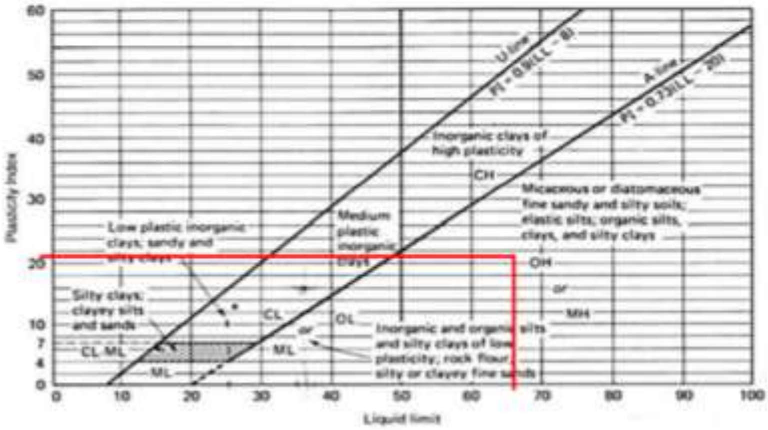

Figure 3. Graph of the relationship between the liquid limit and the plasticity index (Source: Hardiyatmo, 1992) [18].

3.4. Result of Physical Properties of Mixed Soil

Testing of soil physical properties includes soil density test, liquid limit, and plastic limit. The following are the results of these tests:

1. Specific gravity value
   Specific gravity values will affect several things such as soil strength, soil self-weight, and determination of sedimentation rate, movement of particles by water and wind. The following are the results of the specific gravity test after mixing.

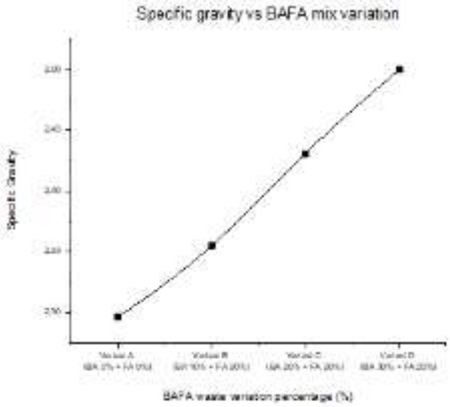

Figure 4. Graph of specific gravity relationship with BAFA variations.

Based on the graph in Figure 4 shows that the addition of bottom ash and fly ash increases the value of the specific gravity of the soil.

2. Liquid limit value
   The liquid limit of the soil is the minimum water content at which the properties of a soil change from a liquid state to a plastic state.

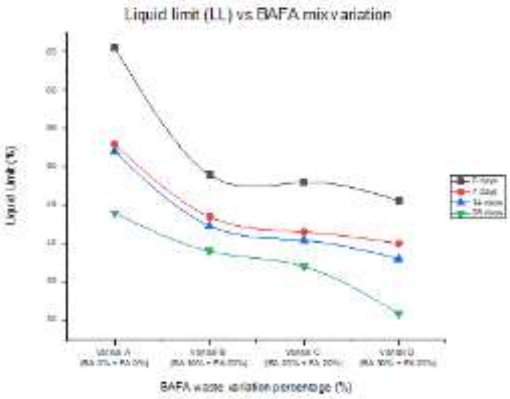

Figure 5. **Graph of liquid limit relationship with BAFA variation.**

Based on the graph in Figure 5 shows that the liquid limit value decreased with increasing BAFA waste content and with increasing curing time, the liquid limit value with BAFA content and curing time was in the high limit to intermediate limit category.

3. Plastic limit value

The plastic limit (PL) is the water content at which a soil changes from a plastic state to a semi-solid state. Plastic limit is calculated based on the percentage of water weight to dry soil weight on the sample soil test.

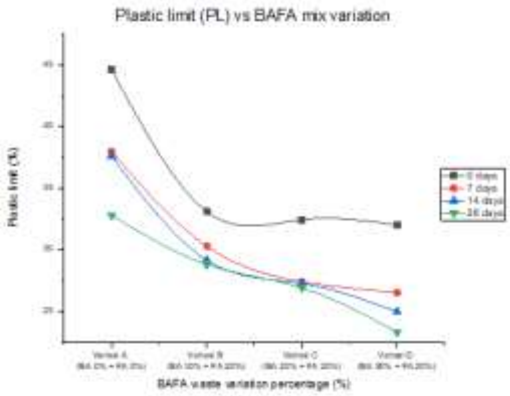

Figure 6. Graph of plastic limit relationship with BAFA variation.

Based on the graph in Figure 6, it shows that the plastic limit value decreased with increasing content of BAFA waste as a soil mixture and similarly with increasing curing time the plastic limit value decreased.

4. Plasticity index

   Soil Plasticity Index figures were obtained after the Liquid Limit and Plastic Limit tests were completed. Soil Plasticity Index is the difference between the liquid limit (LL) and the plastic limit (PL).

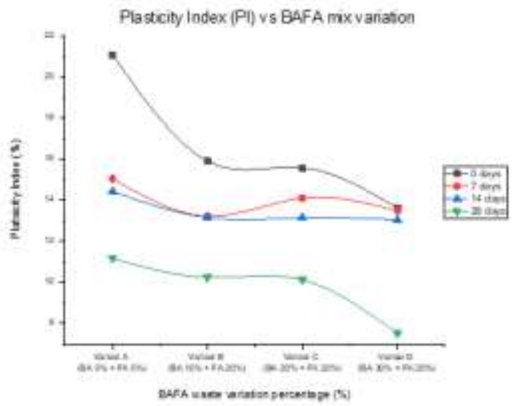

Figure 7. Graph of relationship between plasticity index and BAFA variation.

Based on the graph in Figure 7, it shows that the plasticity index value decreased with increasing BAFA waste content and curing time, which means that the addition of BAFA waste had a good effect on the value of the soil plasticity index on Jalan Raya Kadomas, Pandeglang District, Pandeglang Regency, Banten.

3.5. Compaction

The compaction test aims to determine the value of the optimum moisture content and maximum dry density of the soil, following are the results of the compaction test:

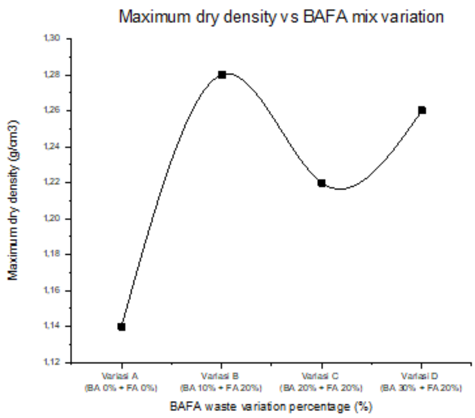

Figure 8. Graph of relationship between maximum dry density and variation of BAFA.

Based on the graph in Figure 8, it shows that the increase in the maximum density value (γd max) is due to a change in the particle size of the soil grains which becomes larger/coarser due to the reaction of mixing the soil with coal burning waste (bottom ash and fly ash).

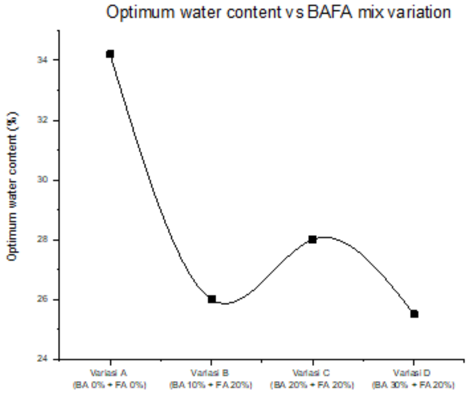

Figure 9. **Graph of the relationship between optimum water content and variations in BAFA**

Based on the graph in Figure 9 shows that the increase in the value of the optimum water content (wopt) is due to when the soil is mixed with coal burning waste (bottom ash and fly ash) and then water is added, a segmentation process (binding) occurs, causing clumping and water content in the soil. land will also increase. Therefore, the greater the addition of BAFA waste, the increase and decrease in the value of the maximum bulk weight and optimum water content will occur.

3.6. Uconfined Compression Strength Test

3.6.1. Unconfined Compression Strength Test of Native Soil

The type of soil used is clay soil classification USCS OH. The water content used for the test object is the optimum water content.

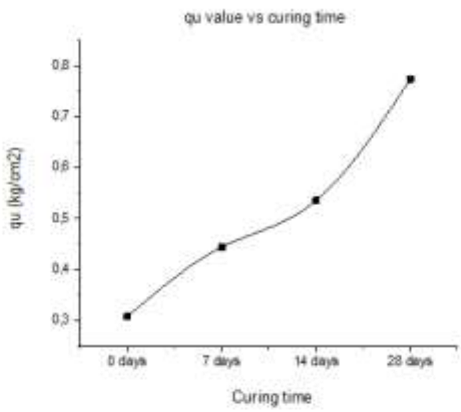

Figure 10. **Comparison graph of the original soil qu value against curing time.**

Based on Figure 10, it can be seen that the results of the unconfined compression strength test on the original soil produced a maximum qu value of 2,505 kg/cm^2 at 28 days of curing. According to Hardiyatmo (1992), the qu value of 2,505 kg/cm^2 of the original soil is classified as very stiff with a qu value of 2 - 4 kg/cm^2 [18].

3.6.2. Comparison of Qu Values with Variations

The following is a comparison of the value of qu with the BAFA variation:

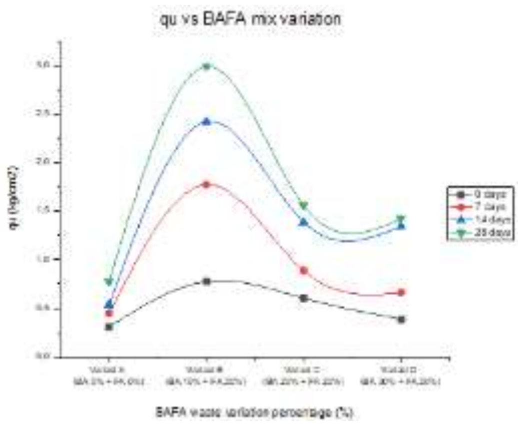

Figure 11. Graph of Relationship between qu value and BAFA variation

Figure 11 shows that the addition of bottom ash and fly ash variations increases the qu value until the variation levels of bottom ash are 10% and fly ash is 20%. At the levels of variations in bottom ash 20% and fly ash 20% and variations in bottom ash 30% and fly ash 20% the test specimens decreased so that it can be concluded that the effect of using optimum water content in each mixture on the value of unconfined compression strength makes the value of qu more objective. because the water content used in each mixture is the optimum water content in each mixture.

3.6.3. Comparison of Qu Value with Curing Time on Bafa Variation

The following is a comparison of the value of qu to the duration of curing

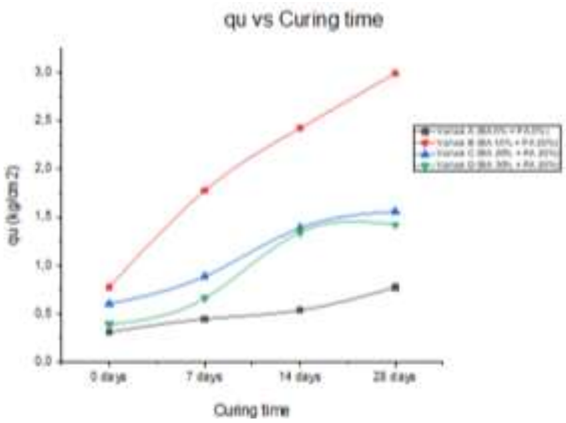

Figure 12. Graph of the relationship between the value of qu and curing time.

Figure 12 shows that the value of qu always increases with increasing curing time. In all variations of the addition of BAFA waste, 28 days has the greatest value, which means that it can be concluded that the qu value of the soil increases due to the pozzolanic nature of BAFA waste so that when mixed with water, the soil will become harder as the curing time increases.

4. Conclusion

Based on the results of research and testing carried out, it can be concluded that soil stabilization using BAFA (Bottom Ash and Fly Ash) waste on the soil on Jalan Raya Kadomas, Pandeglang District, Pandeglang Regency, Banten, is as follows:

1. In testing the physical properties of the original soil, the soil at that location according to the USCS classification system, the soil is included in the OH classification with a plasticity index value of 21.08%, namely organic clay. Because the soil is classified as clay and has high plasticity, it is necessary to improve the soil.
2. In the unconfined compression strength test, BAFA waste (Bottom Ash and Fly Ash) can increase the value of the unconfined compression strength which was originally in the original soil condition of 0.740 kg/cm^2 belonging to medium consistency, in variation B (Bottom Ash 10% and Fly Ash 20 %) added material with a curing time of 28 days to 2,994 kg/cm^2 is classified as very stiff consistency which is the optimum qu value, in variation C (Bottom Ash 20% and Fly Ash20%) added material with a curing time of 28 days becomes 1,469 kg/cm^2 classified as stiff consistency, and in variation D (Bottom Ash 30% and Fly Ash 20%) the added material with a curing time of 28 days became 1.4 kg/cm^2 classified as stiff consistency.
3. In this study, BAFA (Bottom Ash and Fly Ash) waste can affect the physical properties of clay. This is indicated by a decrease in the value of the soil plasticity index in the original soil condition of 21.08% which includes high plasticity pure clay, in variation B (Bottom Ash 10% and Fly Ash 20%) with a curing time of 28 days, the plasticity index value becomes 10.23%. , in variation C (Bottom Ash 20% and Fly Ash 20%) with a curing time of 28 days the plasticity index value becomes 10.12%, which is a medium plasticity index and belongs to silty clay and in variation D (Bottom Ash 30% and Fly Ash 20%) with a curing time of 28 days, the plasticity index value to 7.511% is a low plasticity index and belongs to the silt soil.
4. In this study, taking into account the requirements that apply to the subgrade from the value of qu and the value of the plasticity index, what can be used for subgrade improvement is the use of added material B (Bottom Ash 10% and Fly Ash 20%) where the value of qu is 2,994 kg /cm^2 and a plasticity index of 10.230% have met the specified requirements.

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