STABILIZATION OF EXPANSIVE CLAY SOIL WITH FLY ASH AND GROUND GRANULATED BLAST FURNACE SLAG MATERIALS ON UCT VALUES (Case Study: Sudimanik Village Road, Cibaliung District, Pandeglang Regency, Banten)

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ABSTRACT

Land is one of the important elements in construction projects and must have a high bearing capacity to support the structure above it. Civil construction, whether roads, buildings, or other structures, will last a long time if one of the factors is supported by a good subgrade. The location of the road in Sudimanik Village has soil classified as expansive clay, which has a high shrinkage capacity due to changes in water content. One way to improve unstable soil is by adding materials such as Fly Ash and Ground Granulated Blast Furnace Slag (GGBFS). The purpose of this study was to determine the characteristics of the soil based on the classification and physical properties of the soil using the Unified Soil Classification System method and to determine the characteristics of the soil and the effect of adding consistent variations of fly ash at 20% and variations in the percentage of GGBFS 0%, 10%, 20%, and 30% as additional material for soil stabilization against the Unconfined Compression Test value with variations in curing time of 0, 7, 14 and 28 days.

The addition of fly ash and GGBFS/slag cement substantially increased the unconfined compressive strength of the soil over time. The maximum mixture for increasing the unconfined compressive strength was achieved with 20% fly ash and 30% GGBFS in variation E, indicating that this combination is very effective for increasing the soil strength in this area.

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1. INTRODUCTION

In civil engineering, the soil is a collection of minerals, organic materials, and relatively loose deposits located on bedrock. The terms sand, clay, silt, or mud describe the particle size at a predetermined limit [1]. In the implementation of construction, a road is often found in poor soil conditions because the base soil has cohesive properties and has high shrinkage (plastic), which causes damage to the road structure and makes the road wavy or cracked[2]. With the soil conditions in the Cibaliung road case study to be studied, the bearing capacity value of the soil taken through DCP testing has a bearing capacity of less than 3%, so the road is used as a case study in this study. Many materials can be used as soil stabilization materials. Some can use materials such as lime, cement, slag cement, fly ash, etc. This study it is planned to use stabilization materials derived from PT KSI waste in the form of Slag Cement, the use of Slag Cement as a soil stabilization material is a form of effort to utilize waste that is no longer useful to be more helpful and valuable, by the vision and mission of the UNTIRTA Campus regarding the Smart & Green concept[3]. In several previous studies, soil stabilization using Slag Cement using the CBR method at an optimum value for the addition of 15% slag cement for high plasticity clay soil obtained a CBR value of 15.25% with the addition of water on the wet side of the optimum water content [4]. Soil stabilization using Slag Cement on the CBR value on Jl Munjul with a curing time of 7 days was able to increase the CBR value from 2.4% to 16% with the addition of 10% Slag Cement [5]. Soft clay soil stabilized with slag cement has properties similar to cemented soil, which effectively increases the bearing strength of soft clay soil [6].

The problem on the Sudimanik Village road, Cibaliung, is the damaged road section, which makes it difficult for vehicles to pass, especially during the rainy season, because the road base soil has cohesive and plastic properties which result in damaged road sections such as deflection and erosion of the road which only leaves stones and base soil. Based on the problems above, the author formulates. What type of soil is on the Cibaliung road based on the unified classification system and How does the addition of constant Fly Ash (FA) at 20% and Ground Granulated Blast Furnace Slag (GGBFS) as soil stabilization (with variations of 0%, 10%, 20%, and 30%) with a curing period of 0.7, 14, 28 days affect the Compressive Strength value.

To determine the type and physical properties of the soil to be tested, and the value of soil bearing capacity against the addition of GGBFS and FA on the Sudimanik Village road, Cibaliung District, Pandeglang Regency with the Unconfined Compressive Test (UCT). To find the optimal percentage level with the addition of a GGBFS mixture to the soil-bearing capacity.

This study is expected to provide knowledge in civil engineering in the improvement of expansive soft soil, significantly indicating that GBBFS and FA can significantly increase the value of soil bearing capacity on high plasticity clay soil for road base soil, houses, and other building construction. Slag cement is expected to be an alternative solution to improve the bearing capacity and high plasticity of problematic soil[7]. This study will obtain variations and methods of soil improvement using GGBFS and reduce and reuse waste from the KSI Factory and the Lontar Banten PLTU into products that can be used in the community. Waste from the KSI Factory into products that can be used in the community.

2. METHODS

This study used soil samples obtained from Sudimanik Village Road, Cibaliung District, Pandeglang Regency, Banten, with coordinates of -6.7520470, 105.7273263 refers to figure 1(a). The samples were mixed with fly ash material from Banten 3 Lontar PLTU, which produces +13700 tons of fly ash every month, and GGBFS obtained from PT. Krakatau Semen Indonesia (KSI).

(a) (b)

Figure 1. (a) location map; (b) soil sample

The method of taking soil samples is done by digging the soil to a depth of approximately 10-20 cm from the surface of the soil refers to figure 1(b). The soil that will be sampled is first cleaned from roots, garbage, and other objects; then the soil is put into a sack to be taken to the testing location, Untirta Civil Engineering Laboratory refers to figure 2(a).

(a) (b) (c)

Figure 2. (a) air dry soil sample; (b) GGBFS; (c) FA

Fly ash is the residue from coal combustion in power plants refers to figure 2 (c). Ground Granulated Blast Furnace Slag (GGBFS) is cement produced from Grinding Blast Furnace metal processing mixed with gypsum limestone. Slag cement contains silica compounds (SiO2) and has cementitious characteristics that can harden and increase strength if used as an additive refers to figure 2 (b) .

This study began with collecting the required data followed by a field survey and taking soil samples, FA, GGBFS. The original soil samples were then tested with soil physical tests (soil water content, atterberg limit, Specific Gravity, Grain Size Analysis, Standard Proctor Compaction). Making test samples from a mixture of original soil added with 20% FA and GGBFS Variations (0%, 10%, 20%, 30%) with a fermentation time (0.714, and 28 days). The test samples were then tested using the UCT method according to the fermentation time. Soil physical data, UCT sample test data were analyzed to determine the effect of adding FA and GGBFS to the soil and to draw conclusions about this study refers to figure 3.

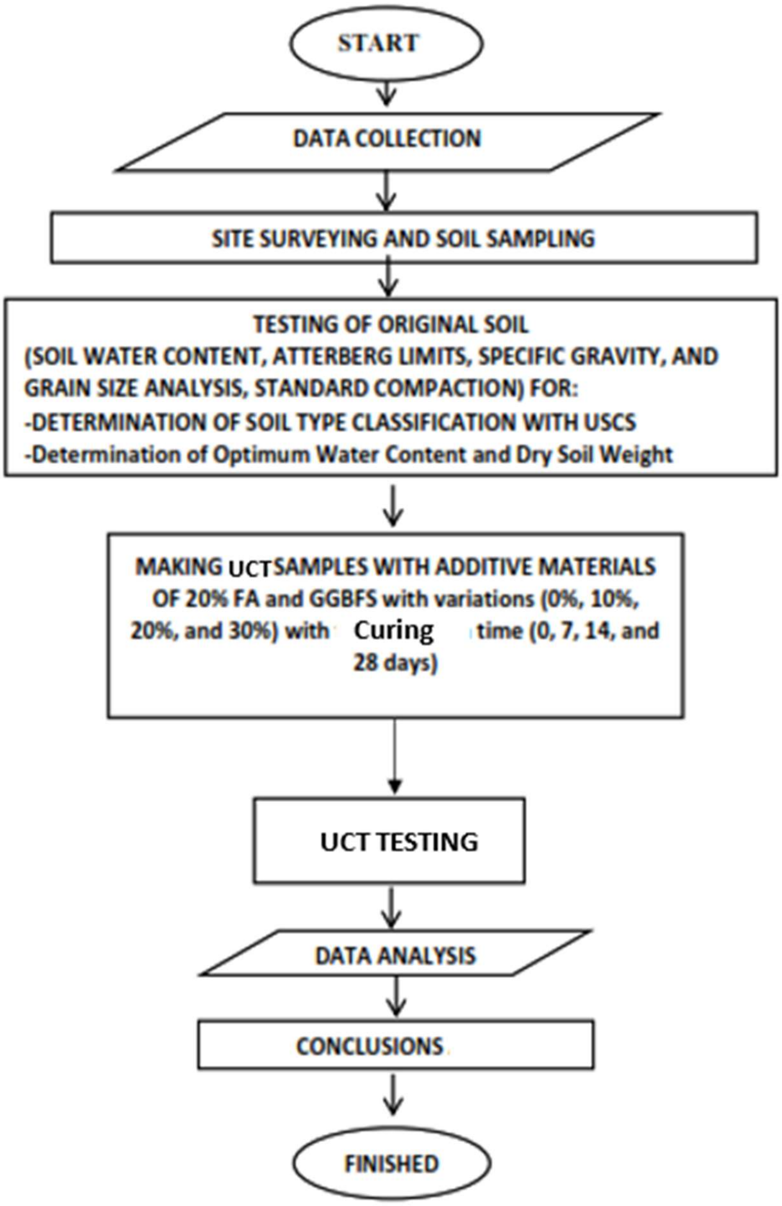

Figure 3. Research flow chart

3. RESULTS AND DISCUSSION

3.1 RESULTS OF PHYSICAL TESTING OF NATIVE SOIL AND MIXED SOIL VARIATIONS

Physical testing of soil in this study includes testing of grain size analysis, water content, grain specific gravity, liquid limit and plastic limit. This physical testing of soil is carried out to determine the physical properties of the soil that will be needed as data for the classification of research soil. All physical soil testing is carried out at the UNTIRTA Civil Engineering Laboratory refers to table 1.

Table 1 Recapitulation of Original Soil Physical Properties Test Results

Compaction test	Value	Information
Grain Size Analysis	51,5%	Fine grained soil with percentage passing sieve No. 200
Water content	23,578%	
Content Weight	1,978 gr/cm^3	
Specific gravity	2,123	Organic Clay
Liquid Limit	45%	The liquid limit value of the original soil is included in the Intermediate Limit category.
Plastic Limit	32,85%	
Plasticity Index	12,15%	The Plasticity Index value is included in the moderate plasticity category.

3.1.1 Grain Size Analysis

The results of the grain size analysis are included in the category of silt and clay soil because the fine-grained soil or that passes the No. 200 sieve is more than 50% (0.075 mm). According to the USCS soil classification from the data obtained in the table below, the soil in this study is included in silt and clay soil with a percentage of passing the No. 200 sieve of 51.5%.

3.1.2 Specific Gravity (GS)

Specific Gravity testing is a comparison of the weight of soil particles and the weight of distilled water at the same volume and temperature. This test is carried out to determine the specific gravity of material grains, which are the solid part of the soil. Based on SNI 1964:2008, the sample used is oven-dry soil that passes sieve No.4 and sieve No.10. Based on the results of tests that have been carried out has a soil-specific gravity of 2.123. This Specific Gravity test is carried out on each mixture variation to determine the effect of adding fly ash and GGBFS waste on the soil-specific gravity value. The results of the soil-specific gravity test increased along with the increasing percentage of fly ash and GGBFS content in the soil mixture, and the Gs value was obtained as in Table 2. The increasing addition of GGBFS to the soil and FA results in an increasing Specific Gravity value where the comparison between the weight of soil grains and the weight of the volume of water with the same volume at a certain temperature means that the soil has soil grains that are increasingly full and dense, One of them is influenced by the addition of GGBFS which has a higher GS value than the GS value of the original soil [8].

Table 2 Specific Gravity Results for Original Soil and Additional Material Variations

Variation	Specific gravity
A (Fly Ash 0%, GGBFS 0%)	2,123
B (Fly Ash 20%, GGBFS 0%)	2,148
C (Fly Ash 20%, GGBFS 10%)	2,146
D (Fly Ash 20%, GGBFS 20%)	2,247
E (Fly Ash 20%, GGBFS 30%)	2,347

3.1.3 Liquid Limit

Liquid limit is a test to determine the water content of the soil at the transition limit from liquid to plastic. Based on the SNI 1967:2008 testing standard, the determination of the liquid limit is carried out using a Cassagrande tool. This test uses soil that passes sieve No. 40 (0.425 mm) as much as 50 grams. Based on the results of the liquid limit test on soil, with variations in additional materials used, the following liquid limit values were obtained refers to table 3. The addition of GGBFS to the soil and FA causes the liquid limit value to decrease, this is caused by changes in the volume of the soil due to the cementation process in clay soil particles [9].

Table 3 Liquid Limit Analysis

Variation	Liquid Limit Value %	information
A (Fly Ash 0%, GGBFS 0%)	45,00%	
B (Fly Ash 20%, GGBFS 0%)	44,86%	*Intermediate Limit*
C (Fly Ash 20%, GGBFS 10%)	44,80%	*Intermediate Limit*
D (Fly Ash 20%, GGBFS 20%)	44,50%	*Intermediate Limit*
E (Fly Ash 20%, GGBFS 30%)	40,47%	*Intermediate Limit*

3.1.5 USCS Soil Classification System

This study used the determination of soil classification based on the USCS (Unified Soil Classification System) system. Several tests required for USCS soil classification include grain size analysis, liquid limit, and plastic limit tests. The results of previous tests were:

a. Grain size analysis

The amount of soil passing the No. 200 sieve is more than 50%, which is included in fine grained soil.

b. Liquid limit (LL)

Liquid limit value (LL) = 45%.

c. Plasticity index (IP)

Plasticity index value (IP) = 12.15%.

From the results of the soil test, it is included in the OL soil type, namely organic silt and organic silty clay with moderate plasticity.

3.1.6 Unconfined Compression Test (UCT) Results

Unconfined Compression Test (UCT) is obtained from laboratory soil compaction testing, of which samples are taken. Then, it was removed with an unconfined soil compressive strength test specimen removal tool. Checking the unconfined compressive strength by controlling the strain and measuring the length of the test specimen using a caliper with a balanced accuracy of 0.1 cm. Then, place the test specimen on the machine centrically or by adjusting the machine so that the top plate touches the surface of the test specimen.

Based on the soil was then matched with the USCS soil classification system table obtained from Sudimanik Village Road, which is, OL soil, namely organic silt and organic silty clay with moderate plasticity. Based on the test results above, it can be seen that the liquid limit ratio (LLR)[10] value in the original soil in this study is 0.65, which is less than 0.75. So the research soil can be classified into OL or organic silt and organic silty clay with low plasticity.

Table 4 Recapitulation of qu values for the addition of fly ash and GGBFS waste according to Curing time

Variation/Days	A	B	C	D	E
0	0,5306	0,7428	0,79	0,66	0,578
7	0,36913	0,5424	0,92	1,097	1,545
14	0,50702	0,8725	1,167	1,368	1,745
28	0,6603	1,0494	1,403	1,58	2,287

From Table 4, it can be seen that the test results show that the addition of fly ash and GGBFS (slag cement) materials has an effect on the compressive strength value of the soil. For a curing period of 0 days, the optimum qu value increased in variations B and C, then decreased in variations D and E. While for curing for 7 days, 14 days, and 28 days, the optimum qu value increased along with the increasing GGBFS content in the soil.

Table 5 Results of qu values for variations in fly ash and GGBFS waste

Curing Time	Waste Variations	Qu value (kg/cm2)	Consistency
0 days	A (Fly Ash 0%, GGBFS 0%)	0,5306019	Medium
	B (Fly Ash 20%, GGBFS 0%)	0,74284266	Medium
	C (Fly Ash 20%, GGBFS 10%)	0,790007273	Medium
	D (Fly Ash 20%, GGBFS 20%)	0,660304586	Medium
	E (Fly Ash 20%, GGBFS 30%)	0,577766513	Medium
7 days	A (Fly Ash 0%, GGBFS 0%)	0,369130655	Soft
	B (Fly Ash 20%, GGBFS 0%)	0,542393053	Medium
	C (Fly Ash 20%, GGBFS 10%)	0,91970996	Medium
	D (Fly Ash 20%, GGBFS 20%)	1,09657726	Stiff
	E (Fly Ash 20%, GGBFS 30%)	1,544641086	Stiff
14 days	A (Fly Ash 0%, GGBFS 0%)	0,507019593	Medium
	B (Fly Ash 20%, GGBFS 0%)	0,872545346	Medium
	C (Fly Ash 20%, GGBFS 10%)	1,16732418	Stiff
	D (Fly Ash 20%, GGBFS 20%)	1,367773786	Stiff
	E (Fly Ash 20%, GGBFS 30%)	1,745090693	Stiff
28 days	A (Fly Ash 0%, GGBFS 0%)	0,660304586	Medium
	B (Fly Ash 20%, GGBFS 0%)	1,049412646	Stiff
	C (Fly Ash 20%, GGBFS 10%)	1,403147246	Stiff
	D (Fly Ash 20%, GGBFS 20%)	1,580014546	Stiff
	E (Fly Ash 20%, GGBFS 30%)	2,287483746	Very Stiff

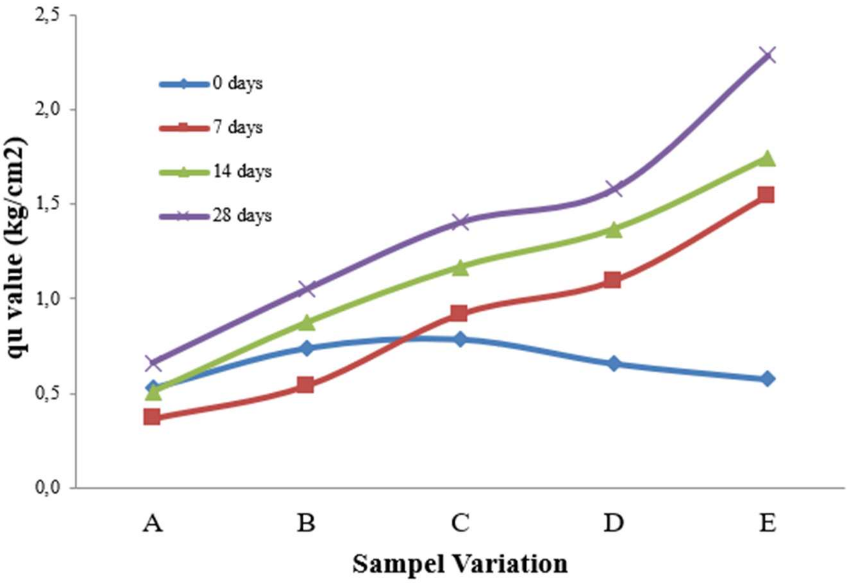

Figure 4 Graph of the Relationship between Value qu and Variation of FA and GGBFS Waste

From figure 4, the addition of GGBFS to the soil and FA resulted in an increasing UCT value, up to the addition of 30% GGBFS in Variation E. The UCT value is 2.287 Kg/Cm^2 which still has the potential to increase along with the addition of GGBFS. This is caused by the pozzolanic reaction between GGBFS, FA and water materials making the bonds between soil grains stronger and hardening like the properties of cement [11]. However, in this study, the optimum UCT value of stabilized soil has not been found, so further research is needed by adding more than 30% GGBFS refers to figure 5.

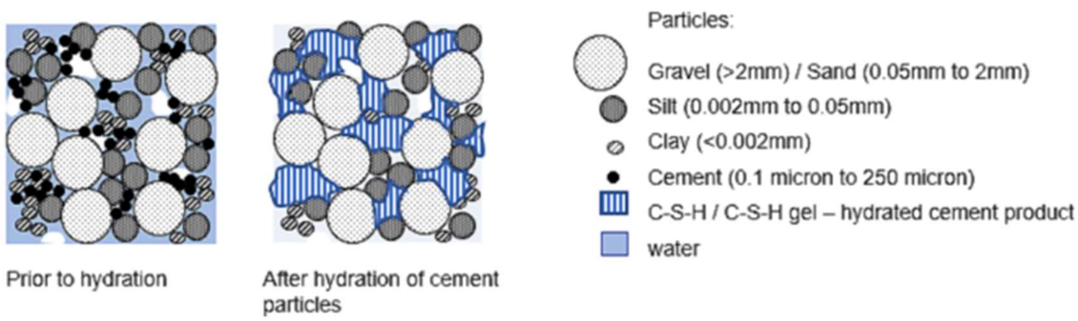

Figure 5. Structure of soil prior and after hydration/ curing of cement binder[12]**.**

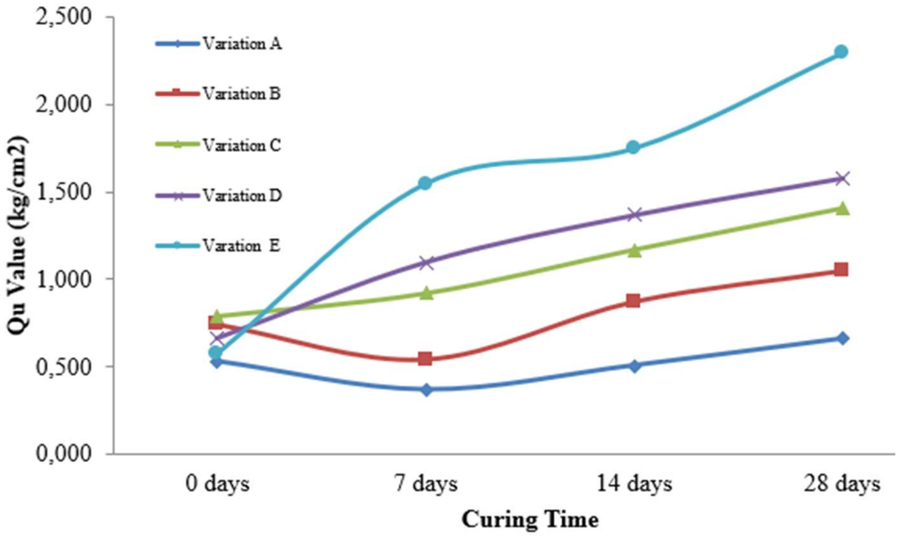

Figure 6 Graph of the Relationship between Value qu(UCT) and Curing Time

Based on Table 5, the qu value always increases in variations C, D, and E. While in variations A and B, it decreases during the 7-day curing period and increases again during the 14-day and 28-day curing periods. In all variations of the addition of fly ash and GGBFS materials, the 28-day time has the largest value, which means that it can be concluded that the qu value of the soil increases due to the pozzolanic properties of fly ash and GGBFS waste materials so that when mixed with water, the soil will become harder as the curing time increases[13][14]. From the previous recapitulation of qu values, it can be concluded that both the addition of fly ash and GGBFS waste given or the curing time of both will affect the qu value. This influence is in the form of an increase in the qu value (soil strength)[15].

4. CONCLUSION

Based on the research and testing conducted, the following conclusions were drawn regarding soil stabilization using fly ash and GGBFS/slag cement on the soil in Sudimanik Village, Cibaliung District, Pandeglang Regency, Banten: Soil Classification and Plasticity Index: According to the USCS classification, the original soil is categorized as OL, meaning it consists of organic silt and silty clay with low plasticity, showing a plasticity index of 12.15%. The addition of fly ash and GGBFS impacted the soil's compressive strength but did not significantly alter its physical properties. In particular, variation E (20% fly ash and 30% GGBFS) resulted in a plasticity index of 12.69%, showing a decline after initial increases in previous variations. All variations (A through E) maintained a plasticity index below 15%, indicating suitability for subgrade use.

Unconfined Compression Test (qu): The addition of fly ash and GGBFS/slag cement substantially increased the soil's unconfined compressive strength over time. The original soil exhibited a qu value of 0.531 kg/cm² at zero days of curing, which rose to 0.660 kg/cm² after 28 days. The qu values for different variations after 28 days were as follows:

Variation B: 1.049 kg/cm² (stiff consistency);Variation C: 1.403 kg/cm² (stiff consistency);Variation D: 1.580 kg/cm² (stiff consistency); Variation E: 2.287 kg/cm² (very stiff consistency and maximum result).
The maximum mixture for improving unconfined compressive strength was achieved with 20% fly ash and 30% GGBFS in variation E, indicating that this combination is highly effective for enhancing soil strength in this area.

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