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The Effect of Wood Charcoal Powder and Pumice Powder on The Parameters of Shear Strength of Clay Soil

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ABSTRACT Soil as a foundation must have sufficient bearing capacity when receiving the load acting on it. However, not all soil types have these characteristics, especially soft clay. The problems encountered in soft clay for construction are generally large settlements and low bearing capacity. Overcoming the problem of lack of bearing capacity in soft clay can be done with improvements. A simple improvement is done by the chemical stabilization method. Chemical stabilization is carried out by mixing soft clay and other materials such as pumice powder and wood charcoal powder. Variations in the addition of these materials in the study were 2% and 4% pumice powder and 15%, 20%, and 25% wood charcoal powder. Based on the test results, it was found that the increase in pumice powder and wood charcoal powder caused changes in physical and mechanical parameters in the soil sample. For physical parameters due to the addition of pumice powder and wood charcoal powder, the water content and liquid limit values decreased, while the specific gravity values, plastic limits, and shrinkage limits in the soil samples increased compared to the original soil samples. Meanwhile, the mechanical parameters in terms of the unconfined compressive strength test, due to the addition of pumice powder and wood charcoal powder caused the value of the unconfined compressive strength (q_u) and the undrained shear strength (s_u) to increase. The biggest change in the parameters of the unconfined compressive strength and undrained shear strength of the soil sample was found in the addition of 4% pumice powder and 25% wood charcoal powder with an increase of 15.58% compared to the original soil sample.

KEYWORDS u*nconfined compressive strength, soft clay, pumice powder, wood charcoal powder, chemical stabilization*

1 INTRODUCTION

Soil stabilization is one method of soil improvement that aims to improve soil properties so that it can be used to meet construction needs (Sianturi and Agustina, 2020, Ludfian and Wibowo, 2017). Stabilization by using additional chemicals or additives is a repair method that is often used (Fathonah et al, 2020; Hendry and Amalia Dewi, 2016). Many studies have been carried out on soil improvement, especially clay soils using chemical stabilization by adding additives. Additives and materials derived from waste that has been carried out in clay stabilization research, including cement and regolith, lime, glass powder, husk ash, wood charcoal powder, pumice powder, and other materials (Kholis et al, 2018; Panjaitan, 2017; Firdaus et al, 2018; Kusumastuti and Sepriyanna, 2019; Pahrida et al, 2021; Runturambi et al, 2020).

Regarding the use of wood charcoal powder as an additive in stabilizing clay, some researchers state that the addition of 8% wood charcoal can increase the carrying capacity of clay in Cibaliung, Pandeglang in terms of the CBR value after a 3-day curing period (Kusuma et al, 2022). Clay soil with the addition of 7% wood charcoal can reduce its plasticity and with a curing period of 7 days, it can increase the CBR_{design} value (Pahrida et al, 2021). The addition of wood charcoal can reduce plasticity and friction angle in clay soils and increase its cohesion value (Rini & Ardan, 2018).

Based on previous research regarding the stabilization of clay soil with the addition of wood charcoal, causes changes in parameters. The parameters that have changed include plasticity, bearing capacity as seen from the CBR value, and shear strength parameters. However, the change in the shear strength parameter is not significant because it can cause an increase in the cohesion value while the friction angle value decreases. So, in this study, additional materials will be used which will be mixed with wood charcoal powder, namely the use of pumice powder.

The use of pumice, especially pumice powder, as an additive in stabilizing clay has also been investigated. Some researchers state that the addition of a mixture of cement and pumice can reduce the potential for shrinkage in expansive soils and increase the CBR value (Legas, 2020). The addition of 4% pumice to clay can increase the CBR value from 15.23% to 23.34% (Runturambi et al, 2020). A 10% addition of pumice powder to organic clay can increase the value of unconfined compressive strength with a curing period of 3 days.

Based on this description, in this study, a test will be carried out on the addition of wood charcoal powder (CP) and pumice powder (PP) as clay soil stabilizing agents. The addition of wood charcoal powder and pumice powder to clay soil will be reviewed on its physical and mechanical parameters. Physical parameters will be analyzed based on the value of water content, specific gravity, and consistency limits. While the mechanical parameters to be analyzed are the shear strength parameters from the unconfined compressive strength test, this is because previous studies have seen more of the CBR value.

2 METHODOLOGY

2.1 Sampling Design

In this study, the test object made was a mixture of clay with wood charcoal powder and pumice powder. The clay used was taken at a depth of ± 1 m and came from Reudeup Village, Montasik, Aceh Besar, Aceh. For added materials, wood charcoal powder and pumice powder are used after going through the screening process and passing No. 200. The clay that has been taken is then stored in the laboratory for later testing. Variations in the addition of wood charcoal powder (CP) and pumice powder (PP) are as follows:

1. Clay soil
2. Clay + 2% PP
3. Clay + 2% PP + 15% CP
4. Clay + 2% PP + 20% CP
5. Clay + 2% PP + 25% CP
6. Clay + 4% PP + 15% CP
7. Clay + 4% PP + 20% CP
8. Clay + 4% PP + 25% CP

2.2 Data Collection Method

In this study, both primary and secondary data were utilized. Secondary data is derived from secondary sources such as books, scientific publications, and testing techniques. Laboratory examination of clay soil provides the primary data. These tests consist of:

2.2.1 Water Content

The water content test in this study aims to determine the water content contained in the clay and changes in the water content due to the addition of wood charcoal powder and pumice powder to the clay soil. The water content test refers to SNI 1965-2008 regarding "Cara Uji Penentuan Kadar Air Untuk Tanah dan Batuan". The value of water content will be calculated by the following equation: Soil samples that have been taken are then stored in the laboratory for later testing. The soil sample to be tested consists of the following soil variations:

$$w = \frac{W_1 - W_2}{W_2 - W_3} \, x \, 100\% \qquad (1)$$

Where:
w is water content (%)
$W_1 - W_2$ is the weight of water (grams)
$W_2 - W_3$ is dry soil weight (grams)

2.2.2 Specific Gravity

Specific gravity testing in this study was carried out on clay soil, wood charcoal powder, pumice powder, and clay that had been mixed with wood charcoal powder and pumice powder. The specific gravity test procedure refers to SNI 1964:2008 regarding “Cara Uji Berat Jenis Tanah”. The specific gravity value is calculated by the following equation:

$$\frac{Specific\ gravity, T_x}{(20^oC)} = \frac{W_t}{[W_t + (W_4 - W_3)]} \quad (2)$$

Where:
W_t is the weight of the oven dry soil sample (grams)
W_4 is the weight of the pycnometer filled with water at temperature T_x (grams)
W_3 is the weight of the pycnometer filled with water and soil at temperature T_x (grams)
T_x is the temperature of the water in the pycnometer when the weight W_3 is determined (°C)

2.2.3 Liquid Limit

The liquid limit test aims to determine the consistency of the soil, and the value of the liquid limit will be used to determine the plasticity index value after deducting the plastic limit value. The determination of the liquid limit value is seen in the water content for the 25th beat. The procedure for testing the liquid limit refers to SNI 1967:2008 regarding “Cara Uji Penentuan Batas Cair Tanah”. The equation for determining the water content for the liquid limit is used with the following equation:

$$\%\ Liquid\ Limit = \frac{weight\ of\ water}{weigh\ \ of\ dry\ soil} x100\% \quad (3)$$

2.2.4 Water Content

Plastic limit testing aims to determine the minimum value of water content in plastic soil conditions and the value of the plasticity index. The procedure for testing the liquid limit refers to SNI 1966:2008 regarding “Cara Uji Penentuan Batas Plastis Dan Indeks Plastisitas Tanah”. The plastic limit moisture content is determined using the equation:

$$\%\ Plastic\ Limit = \frac{weigh\ \ of\ water}{weigh\ \ of\ soil} x100\% \quad (4)$$

2.2.5 Shrinkage Limit

The shrinkage limit test aims to determine the maximum water content when the water content is reduced but the volume of the soil mass does not change. The shrinkage limit testing procedure refers to SNI 3422:2008 regarding “Cara Uji Penentuan Batas Susut Tanah”. The soil shrinkage limit value is found by using the following equation to figure out how much water is in the soil:

$$w = \frac{W - W_0}{W_0} x100 \quad (5)$$

Where:
w is soil water content (%)
W is the weight of wet soil (grams)
W_0 is dry soil weight (grams)
After calculating the value of water content using equation (5), the value of the shrinkage limit is determined by the following equation:

$$S = w - \left(\frac{V - V_0}{W_0}\right) x100 \quad (6)$$

2.2.6 Unconfined Compression Strength

The unconfined compressive strength test in this study refers to SNI 3638:2012 regarding "Metode Uji Kuat Tekan-Bebas Tanah Kohesif". In the unconfined compressive strength test, the values of unconfined compressive strength (q_u) and shear strength (s_u) will be obtained. The procedure for testing the unconfined compressive strength is to give a load to the test object. The load will produce an axial strain. The loading process is carried out until the specimen collapses or the axial strain of 15% is reached. The value of unconfined compressive strength (qu) is determined based on the value of the maximum compressive stress or compressive stress that has reached 15% axial strain. The calculation of the compressive strees value uses the following equation:

$$\sigma_c = \frac{P}{A_c} \tag{7}$$

Where:
σ_c is compressive stress (kN/m^2)
P is the applied load (kN)
A_c average cross-sectional area or corrected area (m^2)

Figure 1 Unconfined Compressive Strength Test at Unsyiah Soil Mechanics Laboratory

2.3 Analysis of Test Result

In this analysis step, the things that are done are to collect all the test data from each soil variation that has been completed. Test data is calculated according to the standards or guidelines used when testing takes place. The test results are grouped into each type of test to then be analyzed for data acquisition. Based on the test results, it will be seen whether the optimum percentage of addition of wood charcoal powder and pumice powder will be obtained.

3 RESULTS AND DISCUSSION

3.1 Material Preparation

Before the whole series of tests is carried out, the first thing to be prepared is to provide wood charcoal powder and pumice powder. Wood charcoal powder and pumice powder used and mixed with clay are wood charcoal powder and pumice powder that have passed the No. 200 sieve. The weight of wood charcoal powder and pumice powder added to the clay is adjusted to meet the needs of predetermined variations. With a total of 183 specimens made, the need for wood charcoal powder is 2.39 kg and for pumice powder is 0.95 kg.

Figure 2 Sample of Soil that Has Been Mixed with Pumice Powder and Wood Charcoal Powder

3.2 Water Content

The water content test was carried out on clay soil and clay that had been mixed with wood charcoal powder and pumice powder. The value of water content in each test object is determined by equation (1). The results of the water content test are as follows:

Table 1. Testing of Water Content in Stabilized Soil

Variation of Mixed Wood Charcoal Powder (CP)	Variation of Mixed Pumice Powder (PP)	
	2%	4%
Soil + 0% CP	6,146%	6,084%
Soil + 15% CP	5,805%	4,866%
Soil + 20% CP	5,517%	4,445%
Soil + 25% CP	5,213%	3,981%

Based on the results of the water content test in Table 1, it can be seen that the addition of wood charcoal powder and pumice powder to the clay affects the water content value. The more ingredients are added, the more the value of the water content decreases. A significant decrease in water content was seen in the addition of 4% pumice powder and 25% wood charcoal powder, with the largest decreasing value being 34.57%. The reduced value of water content is due to the silica content in pumice powder, which is able to absorb water.

3.3 Specific Gravity Test

Apart from being carried out on clay and clay that has been mixed with wood charcoal powder and pumice powder, the specific gravity of wood charcoal powder and pumice powder has also been examined. The results of the specific gravity test are as follows:

Table 2. Specific Gravity Test on Stabilized Soil

Variation of Mixed Wood Charcoal Powder (CP)	Variation of Mixed Pumice Powder (PP)	
	2%	4%
Soil + 0% CP	2,626	2,668
Soil + 15% CP	2,710	2,745
Soil + 20% CP	2,737	2,735
Soil + 25% CP	2,751	2,718

According to the results of the specific gravity test on the soil that had been combined with wood charcoal powder and pumice powder, the specific gravity value increases with the addition of varying amounts of wood charcoal powder to the addition of 2% pumice powder. However, this does not apply to the addition of 4% pumice powder, for which the specific gravity value reaches its maximum with the addition of 15% wood charcoal powder and subsequently drops as the amount of wood charcoal powder is increased.

3.4 Consistency Limit Test

Consistency limit testing in this study includes liquid limit testing, plastic limit testing, and shrinkage limit testing. This consistency limit test aims to determine the consistency of the clay soil after it is mixed with wood charcoal powder and pumice powder. The results of the consistency limit test are as follows:

Table 3. Liquid Limit Test On Stabilized Soil

Variation of Mixed Wood Charcoal Powder (CP)	Variation of Mixed Pumice Powder (PP)	
	2%	4%
Soil + 0% CP	76,489%	76,429%
Soil + 15% CP	74,768%	71,058%
Soil + 20% CP	72,174%	71,005%
Soil + 25% CP	71,985%	69,988%

Table 4. Plastic Limit Test On Stabilized Soil

Variation of Mixed Wood Charcoal Powder (CP)	Variation of Mixed Pumice Powder (PP)	
	2%	4%
Soil + 0% CP	25,241%	26,725%
Soil + 15% CP	27,672%	30,516%
Soil + 20% CP	28,264%	31,655%
Soil + 25% CP	29,156%	32,644%

Table 5. Shrinkage Limit Test On Stabilized Soil

Variation of Mixed Wood Charcoal Powder (CP)	Variation of Mixed Pumice Powder (PP)	
	2%	4%
Soil + 0% CP	21,209%	22,068%
Soil + 15% CP	24,337%	27,854%
Soil + 20% CP	25,177%	28,429%
Soil + 25% CP	26,422%	31,196%

Based on the results of the consistency limit tests in Table 3 to Table 5, respectively, regarding the liquid limit, plastic limit, and shrinkage limit, it can be seen that in the liquid limit test, along with changes in water content, the percentage amount of pumice powder and wood charcoal powder is added. The liquid limit decreases. And inversely proportional to the results of the plastic limit and shrinkage limit, which show the increasing percentage of pumice powder and wood charcoal powder, the value is increasing. With the decrease in the liquid limit value and the increase in the plastic limit, the plasticity index value in the stabilized soil sample will decrease, so as to reduce the potential for shrinkage in the soil sample. Improvements in soil workability can also be seen from the decrease in the plasticity index (Diana et al, 2021).

3.5 Unconfined Compressive Strength

After testing the physical parameters, the next step is to test the mechanical parameters, especially the shear strength parameters. The determination of shear strength parameters in this study was done by using the unconfined compressive strength test. The unconfined compressive strength test is used because the soil sample obtained is cohesive soil and the value of the unconfined compressive strength can be directly used in planning the bearing capacity of the foundation.

Table 6. Test Of Unconfined Compression Strength In Stabilized Soil

Variation of Mixed Wood Charcoal Powder (CP)	Variation of Mixed Pumice Powder (PP)			
	2%		4%	
	q_u (kg/cm^2)	c_u (kg/cm^2)	q_u (kg/cm^2)	c_u (kg/cm^2)
Soil + 0% CP	2,79	1,395	2,83	1,415
Soil + 15% CP	2,88	1,44	2,99	1,495
Soil + 20% CP	2,91	1,455	3,03	1,515
Soil + 25% CP	2,97	1,485	3,19	1,595

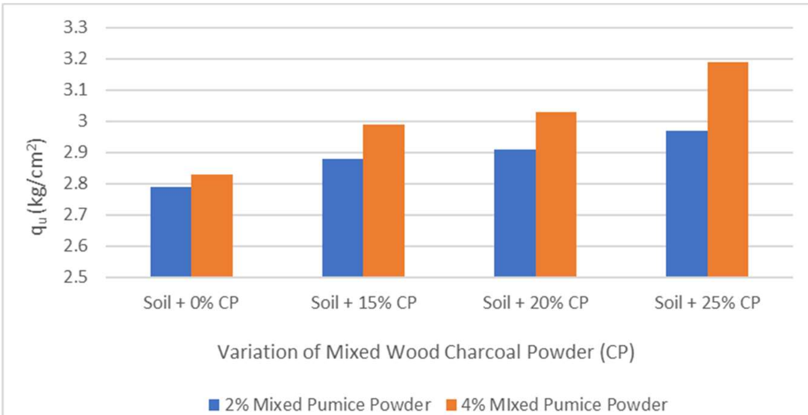

Figure 3 Variations in The Value of Unconfined Compression Strength (Q_u) In Stabilized Soil with Wood Charcoal Powder and Pumice Powder

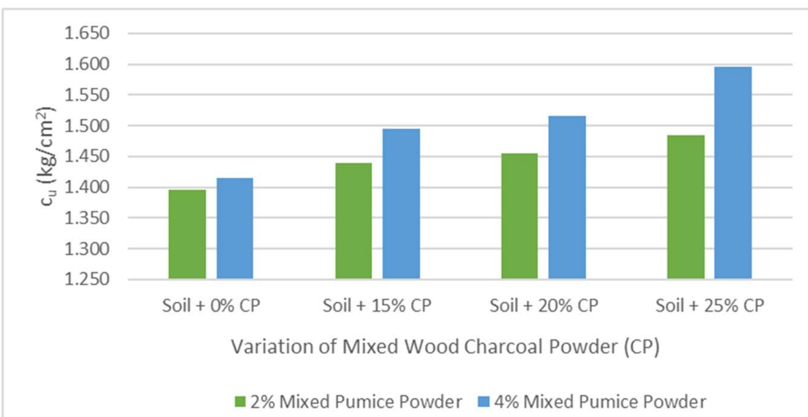

Figure 4 Variations in The Value of Shear Strength (C_u) In Stabilized Soil with Sawdust and Pumice Powder

According to the findings of the unconfined compressive strength test on the stabilized soil sample (Figure 3 and Figure 4), the unconfined compressive strength and shear strength continue to rise with the addition of 2% and 4% pumice powder and additional wood charcoal powder. In this study, the optimal conditions for stabilized soil samples were unknown, particularly when the wood charcoal powder was added.

The value of unconfined compressive strength and shear strength was greatest with the addition of 4% pumice powder and 25% wood charcoal powder, with an increase of 15.58% compared to the original soil sample. The greater the value of the unconfined compressive strength obtained, the consistency of the soft soil becomes more rigid (Darmawandi et al, 2020). This is often due to the decrease in the value of the water content and liquid limit of the stabilized soil sample; the more pumice powder and wood charcoal powder, the water content and liquid limit values decrease. So, the lower the water content, the stabilized soil sample will be stiffer and its strength will be greater.

4 CONCLUSIONS

Based on the test results of soil samples taken in the Kabupaten Aceh Besar, it is known that the soil sample is a type of clay with a high level of plasticity (CH). After the soil sample was stabilized by adding 2%, 4% pumice powder, and 15%, 20%, and 25% wood charcoal powder, the physical and mechanical parameters of the soil sample changed. Along with the addition of pumice powder and wood charcoal powder, the value of the moisture content and liquid limit of the soil sample also decrease, while the values of specific gravity, plastic limit, and shrinkage limit increase, as well as the value of unconfined compressive strength and undrained shear strength, continue to increase. In this study, the optimum value for adding pumice powder and wood charcoal powder was not obtained, so it was possible for further research to add wood charcoal powder and pumice powder to clay soil.

DISCLAIMER

The authors declare no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

All data are available from the author.

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