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EFFECT OF ADDING COCONUT SHELL CHARCOAL POWDER ON CLAY IMPERMEABLE LAYER SMALL DAM CORE MATERIAL

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Abstract. Clay soil is widely chosen to be used as a waterproof core layer material in ponds because there is a tendency to have water-tight properties. However, in general conditions, clay soil has several weaknesses and causes problems in civil construction, such as low shear strength and high plasticity. The existence of this condition is certainly a consideration to improve the mechanical properties of the clay when it is to be used as a waterproof core layer in the reservoir. This effort is carried out to increase the shear strength of the soil and reduce its permeability so that it can meet the requirements as soil for an impermeable core layer. The permeability coefficient for the minimum pond core material is less than or equal to $1x10^{-6}$ cm/sec.
In this study, coconut shell charcoal was used as a stabilizing agent for clay soil. The percentage variations of the coconut shell charcoal mixture used were 0%, 5%, 10%, 15%, and 20%.
This study aims to determine the effect of coconut shell charcoal powder on the permeability coefficient, and the shear strength of clay soil which will be used as the core material of the watertight reservoir. The tests carried out in this study were atterberg limit testing, grain gradation analysis, compaction, shear strength, and permeability.
Based on the results of testing with soil samples varying from a mixture of 0% to 20% coconut shell charcoal, it was found that the best addition of coconut shell charcoal for shear strength testing was a mixture variation of 15% with a cohesion value of 0.353 kg/cm^2 and a mixture variation of 20 % with a sliding angle value of 43.2580. Whereas in the permeability test on the coconut shell charcoal mixture of 15% is the best addition of coconut shell charcoal with a permeability coefficient of $2.106x10^{-7}$ cm/second.

Keywords **-** clay, small dam, coconut shell charcoal, shear strength, permeability.

I. INTRODUCTION

Reservoirs are water structures that have been built as a solution to various problems related to water resources, including utilization, management, preservation, and handling of the destructive power of water.

Clay in a dry condition will shrink in volume so that if it is used as a waterproof layer in the reservoir, leakage will occur through the body of the reservoir. Based on these conditions, it is necessary to research clay which is used as a waterproof core layer in the reservoir by adding other materials.

According to SNI 8065 (2016), the permeability coefficient of the core material of the dam/reservoir is at least less than or equal to 1x10-6 cm/second. The permeability coefficient mainly depends on the average pore size which is influenced by the particle size distribution, particle shape, and soil structure. In general, the smaller the particle size, the smaller the pore size and the lower the permeability coefficient.

Karaseran (2015) conducted a study on how the addition of coconut shell charcoal affected the stability of expansive clay soils because it reduced swelling in the soil, reduced soil plasticity and improved water and air circulation, as a medium that can bind carbon.

Artiani and Handayasari (2018) conducted research that used coconut shell charcoal as a clay soil stabilizing agent because it increases shear strength and reduces the soil permeability coefficient with an optimal value at 10% mixing of $0.921x10^{-5}$ cm/second.

The utilization of coconut shells so far is still not optimal. The availability of coconut shells which are quite a lot, easy to obtain, and their low selling value encourages optimizing the value of these coconut shells. This is the background for using coconut shell charcoal as a stabilizing agent.

The coconut shell charcoal used will be crushed by grinding it into a fine powder so that later it can blend with the clay soil more optimally. The variations in the addition of coconut shell charcoal powder each used are 0%, 5%, 10%, 15%, and 20% of the dry weight of clay soil. From the research results it is hoped that the addition of charcoal powder can improve its physical and mechanical properties by fulfilling the requirements for a waterproof core layer with a permeability coefficient of less than or equal to 1x10-6 cm/sec. The location for taking soil samples was taken at the Embung Kampung Banjar, Office of the Governor of Banjarbaru.

II. RESEARCH METHODS

This study used an experimental method by making a mixture of clay and coconut shell charcoal powder with a mixture of 0%, 5%, 10%, 15% and 20% by weight of dry clay soil and then testing the physical properties and mechanical properties of the soil.

Research Procedure

1. Preparation Stage

a. Collecting references and literature studies regarding watertight reservoirs and coconut shell charcoal and ASTM and SNI testing standards related to research.
b. Inventory of research locations.
c. Preparation of equipment and materials.
   Preparation of equipment to be used and testing of physical and mechanical properties of materials carried out at the Banjarmasin State Polytechnic Geotechnical Laboratory, Soil Mechanics Laboratory, Faculty of Engineering, Lambung Mangkurat University. The test materials used in this study are :
   a. Soil
      The soil used is included in the disturbed clay category.
   b. Coconut Shell Charcoal
      The coconut shell charcoal used is taken from burning coconut shells in the home industry in Sungai Tabuk District, Banjarbaru.

2. Field Stage

The samples taken were disturbed soil samples originating from the Banjarbaru area, the Office of the Governor of the Provincial Government of South Kalimantan, which is currently in the process of making a small dam.

3. Laboratory Stage

At this stage, the testing of clay soil with a mixture of coconut shell charcoal powder was carried out for analysis of testing the physical properties of the soil and testing mechanical properties of the soil. The percentage variations of the coconut shell charcoal powder mixture used were 0%, 5%, 10%, 15%, and 20%. The coconut shell charcoal used is crushed by pulverizing it into a fine powder with a size that passes sieve no. 40 so that later it can blend with the clay soil more optimally. The results obtained in the laboratory for each variation of coconut shell charcoal powder mixture are as follows :

a. Testing of soil physical properties
   i) Specific gravity test to determine the value of Specific gravity (Gs) according to SNI 1964 : 2008 rules.
   ii) The Atterberg test includes the liquid limit test (LL) to determine the liquid limit according to SNI 1967 : 2008 regulations and the plastic limit (PL) test to determine the plastic limit so that the plastic index (PI) value is obtained according to SNI 1966 : 2008 rules.
   iii) Testing of granular analysis
   From the grain analysis test which consists of sieving analysis testing on samples of test objects with SNI 03 – 1968 – 1990 rules so that the percentage of passing sieve no. 4, No. 10, No. 20, No. 80, no. 100, and No. 200 and hydrometer testing with SNI 3423:2008 rules.

b. Testing the mechanical properties of the soil
   i) Compaction test
   Compaction test to determine the maximum dry unit weight (γdmax) and optimum water content (Wopt) for each mixture according to SNI 1742: 2008 rules.
   ii) Permeability testing
   Permeability test to determine the magnitude of the permeability coefficient (k) at a density of 95% for each mixture variation with the rules of SNI 03-6870: 2002.
   iii) Direct shear test

Direct shear test to determine the magnitude of cohesion (c) and internal shear angle (ϕ) for each mixture variation with the rules of SNI 2813: 2008.

4. Data Stage

Data obtained from the results of laboratory testing in the form of soil physical properties and soil mechanical properties are then analyzed, resulting in a statement regarding:

a. How does the variation in the percentage of coconut shell charcoal powder affect the permeability coefficient value of the clay that will be used as the core material for the small dam.
b. To what extent does the variation in the percentage of coconut shell charcoal powder affect changes in the value of the shear strength of the clay that will be used as the core material for a watertight small dam.
c. Can coconut shell charcoal powder be used as a watertight reservoir core material? What is the percentage of coconut shell charcoal powder so that it can be used as an alternative additive to mixtures of clay for the core material of impermeable small dam.

5. Research Flow Chart

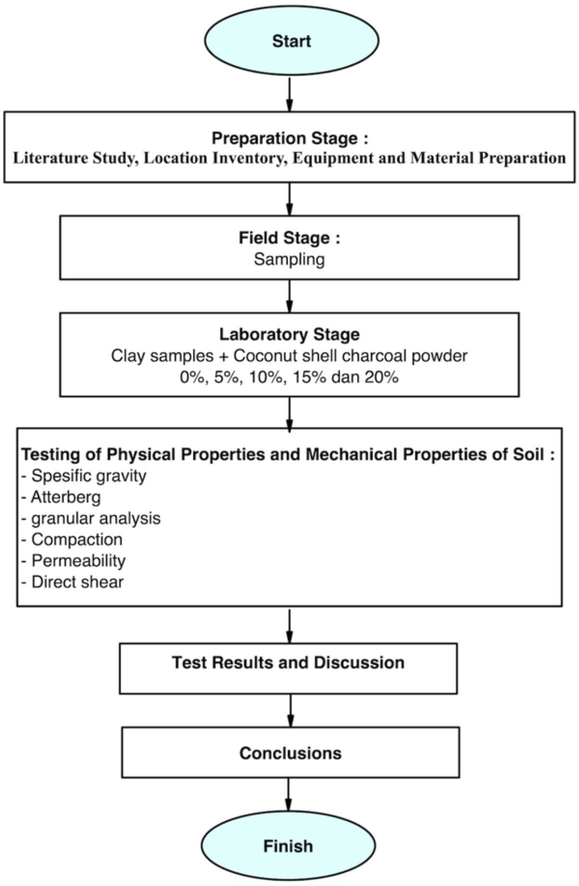

Figure 1. Research Flowchart

III. TEST RESULTS AND DISCUSSION

The type of soil material used in this test is disturbed loamy soil was taken from a point location in the Embung Kampung Banjar, Office of the Governor of Banjarbaru. This test was for samples of clay and coconut shell charcoal powder with a mixture of 0%, 5%, 10%, 15%, and 20% by weight of the clay used in the study included testing the physical properties of the soil and the mechanical properties of the soil. After carrying out several series of tests in the form of testing the physical properties and mechanical properties of the soil (compact, direct shear strength, permeability) the following values were obtained.

Testing Of Soil Physical Properties

After carrying out several tests on the physical properties of the soil which included testing for specific gravity (Gs), liquid limit (LL), plastic limit (PL), plasticity index, and grain gradation analysis in the laboratory, values were obtained as shown in Figure 2 and Table 1.

Table 1. Soil Physical Properties Testing Results

No	Testing	Unit	Test Results				
			0%	5%	10%	15%	20%
1	Spesific gravity (Gs)		2.68	2.49	2.45	2.34	2.25
2	liquid limit (LL)	%	28.67	29.17	30.23	31.19	26.67
3	plastic limit (PL)	%	18.62	19.19	20.90	22.72	19.96
4	Plastic Index		10.05	9.99	9.23	8.47	6.71
5	Granular Analysis						
	Passing Sieve No 4		99.71	99.367	99.233	99.350	98.000
	Passing Sieve No 10		99.55	98.650	97.983	98.433	96.583
	Passing Sieve No 20		96.25	94.533	93.833	93.333	92.117
	Passing Sieve No 40		85.00	80.100	78.883	77.233	76.683
	Passing Sieve No 80		71.83	64.267	62.883	59.633	58.933
	Passing Sieve No 100		70.66	62.150	61.050	57.250	56.817
	Passing Sieve No 200		59.64	50.750	49.383	44.433	44.583

Table 2. Results of Gradation Analysis of Original Soil Grain

Test	Gravel	Sand	Silt	Clay
	76.2-2 mm (%)	2-0.075 mm (%)	0.075-0.002 mm (%)	< 0.002 mm (%)
Grain Gradation Analysis	0.45	39.91	29.19	30.45

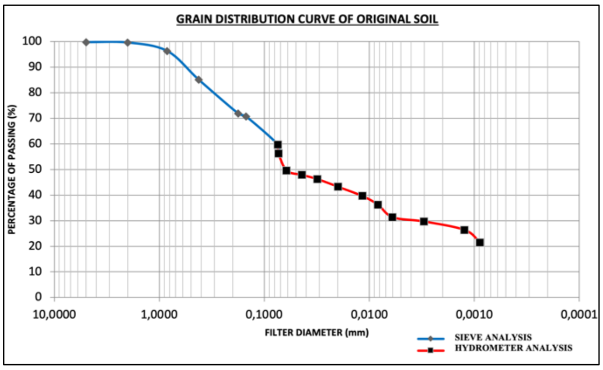

Figure 2. Original Soil Grain Distribution Curve

The results of the original soil grain gradation analysis test in Table 2 and Figure 1 can be concluded that this native soil contains a clay fraction of 30.45%, silt of 29.19% and sand of 39.91%. Meanwhile, the results of the soil grain analysis test for each variation of coconut shell charcoal powder mixture can be seen in Figure 3.

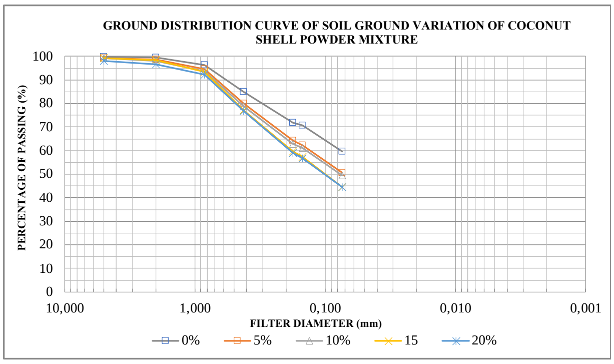

Figure 3. Mixed Variation Granule Distribution curve
Coconut Shell Charcoal Powder

Based on the USCS Soil Classification System, the results of sieving analysis and hydrometer analysis on clay native soils with disturbed conditions originating from the Banjarbaru area, the Office of the Governor of the Provincial Government of South Kalimantan, show that the laterite soil has a percentage of material that passes sieve no. 200 of 59.64 % (more than 50%) then the soil is included in the classification of fine grained soil. The results of examining the Atterberg boundaries, obtained the liquid limit value (LL) on average is 28.67 (less than 50%), then the soil is in the ML or CL group. From the liquid limit (LL) and plasticity index (PI) graphs, after the LL and PI values are plotted, the point is above line A and above the shaded area, then the soil is in the CL group, namely non-organic clay with low plasticity, which can be seen in Figure 4

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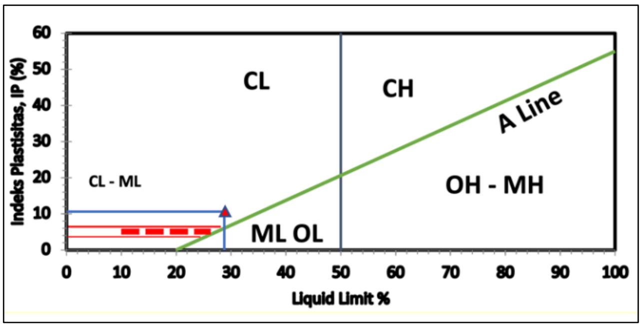

Figure 4. Graph of USCS Soil Classification Plasticity

Compaction Testing (Standart Proctor)

From the compaction test of clay soil mixed with coconut shell charcoal powder with variations of 0%, 5%, 10%, 15%, and 20%, the maximum dry unit weight (γ_{dmax}) and optimum water content (W_{opt}) were obtained for each variation of the mixture as in Table 3.

Table 3. Compaction Test Results

No	Mixed Variations of Shell Charcoal Powder	Max. Dry Unit Weight	Optimum Water Content	Specific Gravity
	%	gr/cm³	%	
1	0	1.69	16.70	2.68
2	5	1.58	16.90	2.49
3	10	1.48	18.5	2.45
4	15	1.42	18.9	2.34
5	20	1.37	20.8	2.25

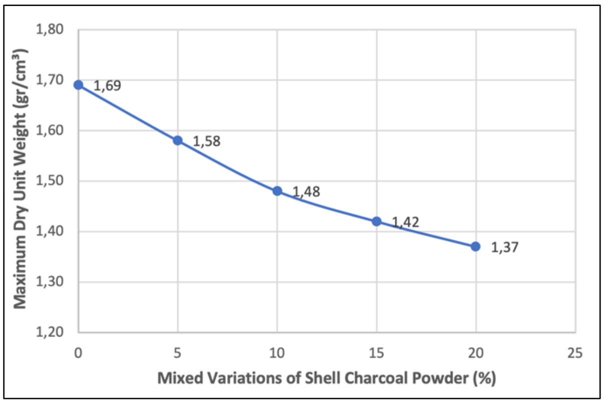

Figure 5. The Curve Of Dry Content Weight Of Mixed Coconut Shell Charcoal Powder Mixture

Figure 5. It can be seen that the dry unit weight decreased as the percentage of charcoal powder added to the soil increased. Conversely, the optimum water content increases with an increasing percentage of charcoal powder

mixed with soil. In Figure 6. it can be seen that the highest optimum water content in the addition of 20% charcoal powder is 20.8%

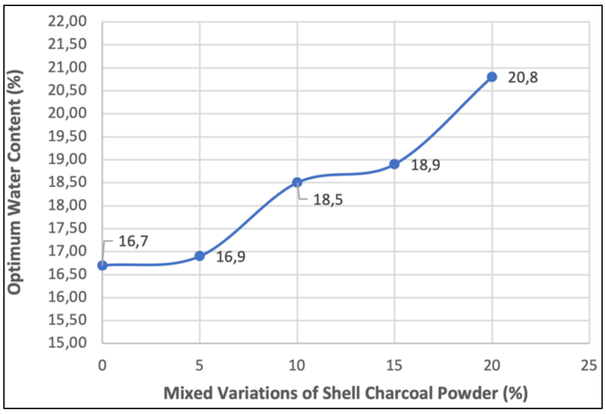

Figure 6. Optimum Moisture Content Curve for Variation of Coconut Shell Charcoal Powder Mixture

The Effect of Coconut Shell Charcoal Powder on the Permeability Coefficient of Clay Soil

Permeability testing aims to obtain the value of the permeability coefficient in soil samples. Because the soil sample used is clay, the method used with Falling Head is based on the guidelines on SNI 03-6870:2002. From the results of this test, it was obtained that the permeability coefficient for each variation of coconut shell charcoal powder mixture at a density of 95% is shown in Table 4.

Table 4. Permeability Test Results

No	Mixed Variations of Shell Charcoal Powder	Permeability Coefficient
	%	cm/sec
1	0	1.460×10^{-6}
2	5	1.266×10^{-6}
3	10	1.122×10^{-6}
4	15	2.106×10^{-7}
5	20	6.173×10^{-6}

From Table 4 and Figure 7. it can be seen that the addition of the percentage of coconut shell charcoal powder affects the soil permeability coefficient, indicating that the value of the permeability coefficient decreases with the addition of the percentage of coconut shell charcoal powder in the soil mixture. The greater the percentage of coconut shell charcoal powder the value of the permeability coefficient tends to decrease. Based on the picture above, the permeability coefficient value reached the lowest peak which is thought to have occurred in soil samples mixed with 15% coconut shell charcoal powder, namely 2.106×10^{-7} cm/sec.

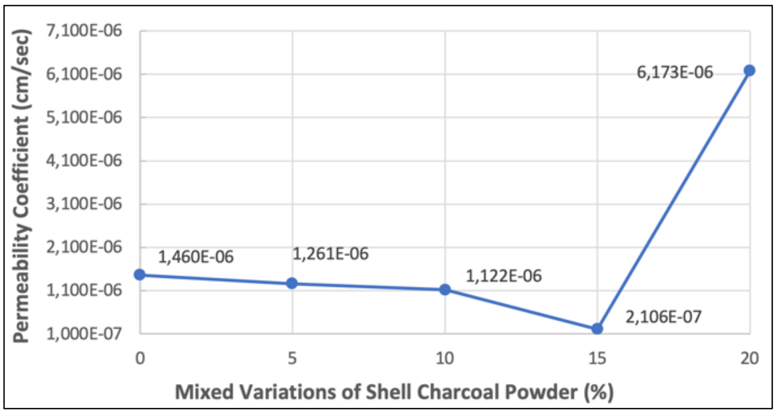

Figure 7. Graph of Permeability Coefficient of Mixed Coconut Shell Charcoal Powder

When adding 20% coconut shell charcoal powder, water absorption increased so that the permeability coefficient increased to $6.173 x 10^{-6}$ cm/sec. and it is necessary to carry out further testing with a variation of more than 20% in order to obtain the true lowest peak value.

The permeability coefficient increased when the variation was the addition of 20% coconut shell charcoal powder in loamy soil because the properties of the test specimens which were a mixture of 20% coconut shell charcoal powder behaved like coarse-grained soils or granular soils where the granular soil is a water permeable soil, so when the clay soil is added with a variation of 20% coconut shell charcoal powder, the test difference behaves like a coarse-grained soil so that the pereability coefficient value tends to increase. This is evidenced by the value of the grain gradation analysis when the variation in the addition of coconut shell charcoal powder by 20% tends to be higher compared to the previous variations and this shows in the grain distribution chart the variation in the mixture of coconut shell charcoal powder tends to increase after the variation in the addition of shell charcoal powder coconut 15.20% and so on, meaning that the different tests experience a change in characteristics to become similar to granular soil that passes water.

The decrease in the value of the permeability coefficient is due to coconut shell charcoal powder filling the original soil pore voids, where in the original soil conditions the pore spaces are filled with water and air. In addition, the substances contained in coconut shell charcoal can bind carbon between the soil.

The Effect of Coconut Shell Charcoal Powder on the Shear Strength of Clay Soil

The Direct Shear test aims to obtain the shear resistance value of the soil at a certain normal stress. From the direct shear test, the parameters of shear strength in the form of soil cohesion (c) and angle of internal friction (φ) will also be obtained for each variation of coconut shell charcoal powder mixture. The shear strength test was carried out based on the guidelines in SNI 2813:2008. Soil samples that have been added with coconut shell powder with variations of 0%, 5%, 10%, 15% and 20%, were carried out 3 times the direct shear strength test with 3 different normal loads, so the total shear strength test in this study was 15 times with a total of 15 sample specimens. The following values of normal stress and shear stress for each variation of coconut shell charcoal powder mixture can be seen in Table 5.

Table 5. Normal Stress and Shear Stress Values

No	Mixed Variations Of Shell Charcoal Powder	Normal Stress	Shear Stress
		kg/cm^2	kg/cm^2
1	0%	0.118	0.280
		0.221	0.326
		0.321	0.397
2	5%	0.118	0.358
		0.221	0.401
		0.321	0.480
3	10%	0.118	0.396
		0.221	0.458
		0.321	0.542
4	15%	0.118	0.471
		0.221	0.514
		0.321	0.649
5	20%	0.118	0.178
		0.221	0.245
		0.321	0.369

In this shear strength test, after the normal stress and shear stress values are obtained, the parameters cohesion (c) and angle of internal friction (ϕ) can be calculated as shown in Table 6 and Figure 8.

Table 6. Cohesion Value and Inner Shear Angle

NO	Mixed Variations Of Shell Charcoal Powder	Cohesion (kg/cm²)	Internal Shear Angle (°)
1	0	0.207	30.130
2	5	0.281	31.022
3	10	0.308	35.665
4	15	0.353	41.215
5	20	0.058	43.258

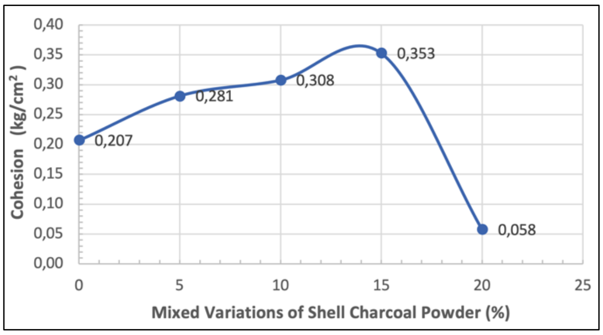

Figure 8. Cohesion curve of Coconut Shell Charcoal Powder Mix Variation

Figure 8 above shows that the cohesion value increases with the addition of the percentage of coconut shell charcoal powder in the soil mixture. The greater the percentage of coconut shell charcoal powder, the greater the cohesion. From the test results on adding the percentage of 15% coconut shell charcoal powder, the cohesion value is thought to reach the optimum value of 0.353 kg/cm2. Cohesion decreased to 0.058 kg/cm2 when the variation was the addition of 20% coconut shell charcoal powder in clay soil because the nature of the specimen mixed with 20% coconut shell charcoal powder behaved like a coarse-grained soil or granular soil where the granular soil is non-cohesive soil (does not have cohesion), so when clay soil is added with a variation of 20% coconut shell charcoal powder, the test difference behaves like a coarse-grained soil so that the cohesion value tends to decrease. This is evidenced by the value of the inner shear angle when the variation of adding coconut shell charcoal powder by 20% tends to be higher compared to the previous variations and this shows on the graph of the shear angle in the variation of adding coconut shell charcoal powder tends to increase after the variation of adding charcoal powder coconut shell 15.20% and so on, meaning that the different tests experience a change in characteristics to become similar to non-cohesive granular soil.

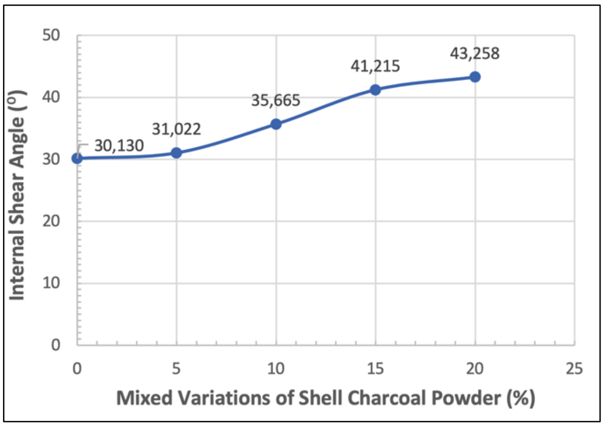

Figure 9. Angle of Internal Friction Curve in A Mixture of Coconut Shell Charcoal Powder

From Figure 9. above shows that the value of the internal friction angle increases with the addition of the percentage of coconut shell charcoal powder in the soil mixture. The greater the percentage of coconut shell charcoal powder, the greater the inner shear angle. At the addition of the percentage of 20% coconut shell charcoal powder, the value of the inner shear angle is thought to reach the optimum value of 43.25^0.

It can be concluded that the greater the percentage of coconut shell charcoal powder, the greater the cohesion and angle of internal friction. The increase in cohesion is due to the chemical elements in the coconut shell charcoal added to the clay where ion exchange occurs and is absorbed by the surface of the clay grains

Identification of Mixed Variations of Coconut Shell Charcoal Powder on Clay Soil

Based on the results of testing the mechanical properties of the soil, it was concluded that the addition of coconut shell charcoal powder affected the value of the shear strength and the permeability coefficient of the soil. Cohesion and internal shear angle tend to increase with the addition of the percentage of coconut shell charcoal powder in the soil and have met the standard requirements specifications for the small dam. While the permeability coefficient tends to decrease with the addition of the percentage of coconut shell charcoal powder in the soil.

The results of testing the values of the coefficients of permeability and cohesion presumably that the best addition of the percentage of coconut shell charcoal powder in this study to obtain optimal values of the coefficients of permeability and cohesion is a 15% mixture variation of $2.106x10^{-7}$ cm/sec and 0.353 kg/cm2 respectively. According to SNI 8065 (2016), the permeability coefficient of the minimum small dam core material is smaller or equal to $1x10^{-6}$ cm/sec, so the permeability coefficient of adding coconut shell charcoal powder at a variation of 15% meets the requirements and can be used as an alternative added ingredient to mixtures of clay. for watertight small dam core material. While the value of the permeability coefficient on the addition of coconut shell charcoal powder at variations of 0%, 5%, 10%, and 20% has not reached the requirements for the core material of the small dam.

The results of testing the values of the coefficients of permeability and cohesion suggest that the best addition of the percentage of coconut shell charcoal powder in this study to obtain optimal values of the coefficients of permeability and cohesion is a 15% mixture variation of $2.106x10^{-7}$ cm/sec and 0.353 kg/cm^2 respectively. According to SNI 8065 (2016), the permeability coefficient for the core material of the dam is at least less than or equal to $1x10$-^{6} cm/sec, so the permeability coefficient for adding coconut shell charcoal powder at a variation of 15% meets the requirements and can be used as an alternative additive to mixtures of clay for watertight small dam core material.

IV. Conclusions

From the data obtained through testing in the laboratory, the results of the analysis and discussion can be concluded several things as follows :

1. The effect of adding coconut shell charcoal powder to clay soil can reduce the value of the permeability coefficient. The lowest permeability coefficient is found in the percentage of 15% coconut shell charcoal powder with a value of $2.106x10^{-7}$ cm/second which is categorized as an almost impermeable layer so that it can be used as a small dam core material.
2. The effect of adding coconut shell charcoal powder to clay soil can increase the cohesion value and internal shear angle. The test results for the cohesion value (c) are thought to reach the optimal value when the coconut shell charcoal powder is added at a percentage of 15%, namely 0.353 kg/cm^2. The value of the inner shear angle (ϕ) is thought to reach the optimum value occurring in the addition of coconut shell charcoal powder at a percentage of 20%, namely 43.258^0.
3. The results of testing the values of the coefficients of permeability and cohesion suggest that the best addition of the percentage of coconut shell charcoal powder to obtain the optimal values of the coefficients of permeability and cohesion is a 15% mixture variation. The permeability coefficient of adding coconut shell charcoal powder at a variation of 15% has met the requirements of SNI and can be used as an alternative additive made from clay for a watertight small dam core material. While the value of the permeability coefficient on the addition of coconut shell charcoal powder at variations of 0%, 5%, 10%, and 20% has not reached the requirements for the core material of the small dam.

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