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The Effect of Addition of Palm Shell Ash on the Physical and Mechanical Properties of Clay Soil

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Abstract**—** *In general, construction damage often occurs because it has a low subgrade bearing capacity which is commonly found in clay soils, which are very cohesive, have low shear strength and slow consolidation process, from these problems it is necessary to carry out soil stabilization. This study aims to determine the effect of adding oil palm shell ash to clay on the value of specific gravity (Gs), plasticity index (PI), shear strength and consolidation coefficient (C_v) with variations in addition of 6%, 8%, 10%, 12 % and 14%. The soil used in this study based on the AASHTO classification was included in group A-7-5 with the clay soil, Gs value of 2.61, the PI value of 14.40%, the shear strength value of 73.19 kPa and the value of C_v at a stress of 50 kPa is 0.00502 cm^2/s, a stress of 100 kPa is 0.00315 cm^2/s, a stress of 200 kPa is 0.00224 cm^2/s and a stress of 400 kPa is 0.00127 cm^2/s. In the Gs test with the addition of palm shell ash, there was a decrease in each variation with the largest decrease in the 14% variation of 2.22 and from the PI test there was an increase to 8% variation of 23.53%. In the direct shear test, the optimum shear strength value occurs at a variation of 8% with a value of 52.60 kPa. In the consolidation coefficient there is a decrease in each addition variation with the largest decrease in the 14% variation with stress 50 kPa, 100 kPa, 200 kPa and 400 kPa of 0.00326 cm^2/s, 0.00261 cm^2/s, 0.00205 cm^2/s and 0.00167 cm^2/s.*

Keywords**—** *Clay Soil: Consolidation Coefficient*: *Palm Oil Ash: Soil Shear Strength.*

I. INTRODUCTION

In road construction, damage often occurs such as road collapses, potholes, bumps and even cracks caused by low soil bearing capacity and differential settlement. Clay soil is a material that has low bearing capacity and shear strength. Low permeability, very cohesive, high swelling and shrinkage and a slow consolidation process are the properties of clay according to Hardiyatmo (1999) in Fadillah (2021).

One of the biggest crops in East Kalimantan is palm oil, based on data from the East Kalimantan Provincial Plantation Service for 2021 it is known that in 2020 there will be 10 districts producing palm oil mills with a total production of 17,721,970 tons. Of the total production, quite a lot of palm oil waste is produced, one of which is palm oil shell ash waste. Palm shell ash is produced from the residue of burning palm shells.

Consolidation is the process of flowing water from the pores of a saturated soil with low permeability due to loading, which in this process is affected by the rate of release of pore water from the voids in the soil, as measured by the value of the consolidation coefficient. The rate of settlement of the soil needs to be considered if the consolidation settlement is very large (Hardiyatmo, 2003).

II. LITERATUR REVIEW

A. Soil

In general, soil is a composite material between aggregates (granules) of solid minerals that are not chemically bound to each other and organic matter with solid particles that have decayed accompanied by liquids and gases that fill the empty spaces between the solid particles (Das, 1995). Hardiyatmo (2017) in Fadillah (2021) suggests that the particle size at the grain size limit of soil and the description of special soil properties can use terms such as sand, clay, or silt.

B. Soil Stability

Hardiyatmo (2002) explained that the purpose of soil stabilization is to increase the bearing capacity of the soil with several soil modification methods such as compaction, mixing soil with granular materials and mixing soil with added materials.

One of the added materials that can be used as an alternative to stabilizing clay soil is oil palm shell ash. Graille et al. 1985 in Fadillah (2021) explains the application of oil palm shell ash in civil engineering which is utilized in various fields including:

a. As an additive to replace cement in high strength concrete design
b. Road filler and pavement layer
c. A stabilizing agent for a mixture of clay and subgrade in road layers.
d. An added ingredient to replace cement in a mixture of paving block materials and is also a pozzolanic material.

C. Ash of the Palm Shell Waste

In the journal Sarifah (2017) it is said that Palm Shell Ash is one of the remaining wastes from burning oil palm shells in a furnace. Inside the ash of the palm shell contains a lot of Silicate and Inorganic Cations such as Potassium and Sodium. Hayward (1995) in Fadillah (2021) states that in pozzolanic materials there are two main compounds that play an important role in the formation of cement, namely SiO_2 and Al_2O_3 and melt so that these two compounds become reactive to lime ($Ca(OH_2)$). Palm shell ash is a pozzolanic material that does not bind like cement, but contains active Silica Oxide (SiO_2) compounds which when reacted with lime or calcium hydroxide ($Ca(OH_2)$) and water will form a cement-like material, namely Calcium Silica Hydrate.

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III. Research Methodology

The entire study was conducted at the Samarinda State Polytechnic Laboratory. The research was carried out in stages, including testing the physical and mechanical properties of the clay soil, testing the physical and mechanical properties of clay with added ingredients. The equipment used for testing the physical properties of the soil are sieving analysis, hydrometer analysis, water content, specific gravity and atterberg limits and soil mechanical properties testing tools are standard compaction, direct shear and consolidation.

The soil used in this study is clay with a classification based on AASHTO A-7-5 obtained from Bukit Pinang Bahari, Samarinda Seberang. The soil used is disturbed soil and there is no special treatment for the soil. The palm shell ash used passes through sieve no. 200 obtained from PT Niagamas Gemilang which is located in Jonggon Village, Loa Kulu, Kutai Kertanegara.

TABLE I. Calculation of Mixed Material Requirements

Mixed Ingredients	Material Weight in Each Variation of Palm Shell Ash (gram)					
	0%	6%	8%	10%	12%	14%
Clay Soil	2500	2350	2300	2250	2200	2150
Palm Shell Ash	0	150	200	250	300	350

TABLE II. Clay Soil Testing Method

No.	Test Type		Standard Test	Number of Tests	Test Sample
1	Soil Physical Properties				
	a.	Sieve Analysis	SNI 3423:2008	1	1
	b.	Hydrometer Test	SNI 3423:2008	1	1
	c.	Liquid Limit	SNI 7658:2010	2	4
	d.	Plastis Limit	SNI 7658:2010	2	2
	e.	Water Content	SNI 1965:2008	3	2
	f.	Specific Gravity	SNI 1964:2008	2	2
2	Soil Mechanical Properties				
	a.	Standard Compaction	SNI 1743:2008	1	5
	b.	Direct Shear	SNI 2812:2011	2	3
	c.	Consolidation	SNI 3420:2016	2	1

TABLE III. Number of Test Samples Mixed Clay and Palm Shell Ash (PSA)

No.	Test Type		Number Sampel in Each Variation of Palm Shell Ash					
			0%	6%	8%	10%	12%	14%
1	Soil Physical Properties							
	1	Atterberg Limit						
	a.	Liquid Limit	2	2	2	2	2	2
	b.	Plastis Limit	2	2	2	2	2	2
	2	Specific Gravity	2	2	2	2	2	2
2	Soil Mechanical Properties							
	1	Standard Compaction	1	1	1	1	1	1
	2	Direct Shear	2	2	2	2	2	2
	3	Consolidation	2	2	2	2	2	2

The stages of the research included preliminary testing which was carried out to determine the parameters of the physical and mechanical properties of the clay soil. The next stage is the preparation of the test sample consisting of the clay soil test sample, the soil test sample mixed with palm shell ash and the mixing of the test sample. Mixing of the test samples was carried out by dividing the soil and the palm shell ash into three parts and mixing them evenly. Calculation of the need for each mixed ingredient is shown in Table I.

The next step in this research is to test the physical and mechanical properties of the soil. The method for testing the physical and mechanical properties of the clay soil and soil-palm shell ash mixture can be seen in Table II and the number of samples tested in Table III.

IV. Results and Discussion

A. Clay Soil Testing

Recapitulation of test results on clay soil which includes testing of physical and mechanical properties can be seen in Table IV.

TABLE IV. Recapitulation of Clay Soil Testing Results

No.	Test Type		Test result	Unit
1	Sieve Analysis			
	a.	Sand	40.4	%
	b.	Silt-clay	59.6	%
2	Water Content (w)		26.79	%
3	Specific Gravity (Gs)		2.61	
4	Atterberg Limit			
	a.	Liquid Limit (LL)	52.38	%
	b.	Plastis Limit (PL)	38.04	%
	c.	Plasticity Index (PI)	14.46	%
5	Soil Classification Based on AASHTO		A-7-5	
6	Direct Shear			
	a.	Kohesi (c)	69.00	kPa
	b.	Internal Friction Angle (ϕ)	21.18	°
7	Consolidation			
	Consolidation Coefficient (Cv)			
	stress (kPa)	50	0.00502	cm^2/s
		100	0.00396	cm^2/s
		200	0.00309	cm^2/s
		400	0.00229	cm^2/s

TABLE V. Summary of Mixed Soil Physical Properties Testing Results

Variations of the Addition of Palm Shell Ash (PSA)	Specific Gravity	Plasticity Index (%)
Clay Soil + PSA 0%	2.61	14.40
Clay Soil + PSA 6%	2.56	22.44
Clay Soil + PSA 8%	2.44	23.53
Clay Soil + PSA 10%	2.41	16.82
Clay Soil + PSA 12%	2.34	12.71
Clay Soil + PSA 14%	2.22	9.20

B. Testing the Physical Properties of Clay Soil with the Addition of Palm Shell Ash

Testing of physical properties with the addition of palm shell ash was carried out with several variations, namely 6%, 8%, 10%, 12% and 14%. Tests carried out include testing specific gravity and consistency limits which are reviewed based on the value of the plasticity index (PI). The results of the recapitulation of the average value of testing the physical properties of the clay soil with a mixture of palm shell ash are

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in Table V.

C. *Testing the Mechanical Properties of Clay Soil with the Addition of Palm Shell Ash*

The mechanical properties tests carried out included direct shear and consolidation tests with variations in the addition of palm shell ash of 6%, 8%, 10%, 12% and 14%. Table VI shows the results of the recapitulation of the average value of testing the mechanical properties of the clay soil with a mixture of palm shell ash.

TABLE VI. Soil Mechanical Properties Test Results

Palm Shell Ash (PSA) Substitution Variations	Direct Shear			Consolidation Coefficient, Cv (cm^2/s)			
	Cohesion (kPa)	Internal Friction Angle (°)	Shear Strength (kPa)	Stress (kPa)			
				50	100	200	400
Clay Soil + PSA 0%	67.93	21.18	73.19	0.00502	0.00396	0.00309	0.00229
Clay Soil + PSA 6%	48.10	27.38	55.11	0.00419	0.00316	0.00235	0.00203
Clay Soil + PSA 8%	44.59	30.63	52.60	0.00400	0.00315	0.00230	0.00179
Clay Soil + PSA 10%	51.78	35.76	61.55	0.00365	0.00303	0.00229	0.00180
Clay Soil + PSA 12%	57.99	32.47	66.61	0.00363	0.00299	0.00227	0.00180
Clay Soil + PSA 14%	63.64	19.32	68.39	0.00326	0.00261	0.00205	0.00167

D. Discussion of Test Results

The specific gravity test was carried out with the aim of knowing the effect of adding each variation of the addition of palm shell ash. The graph of the specific gravity test results is shown in Fig. 1.

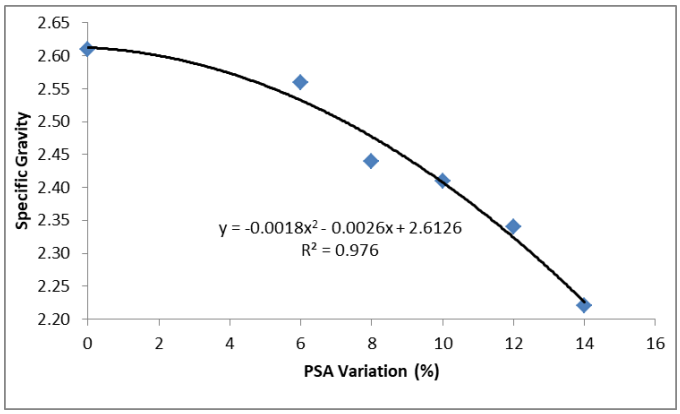

Fig. 1. Graph of the Relationship of Palm Shell Ash Variations to Specific Gravity Values

Fig. 1 shows that oil palm shell ash can decrease the specific gravity value as the variation of oil palm shell ash increases. The specific gravity value of the clay soil was 2.61, the greatest decrease was in the addition of 14% palm shell ash to 2.22. The decrease that occurred in the specific gravity value occurred due to the reduced soil weight due to the addition of palm shell ash which tends to be lighter so that the specific gravity value gets smaller.

In testing the consistency limits in terms of the plasticity index (PI) value, a graph is obtained as shown in Fig. 2.

A decrease in the value of the plasticity index occurs when the variation of palm shell ash used is more than 6%. In the ash of palm oil shells there is a lot of Silicon Dioxide (SiO_2) content, one of the applications of which is often used in the construction sector, such as making cement and has the form of sand minerals. Palm shell ash also contains Potassium Oxide (K_2O) and Magnesium Oxide (MgO), which are one of the ingredients for making cement and contains Calcium Oxide (CaO), which when reacted with water will absorb the water and form lime. Based on these ingredients, the greater the variation of the mixture used, the smaller the plasticity index value because the addition of palm shell ash will change the soil properties which were initially very plastic to become less plastic.

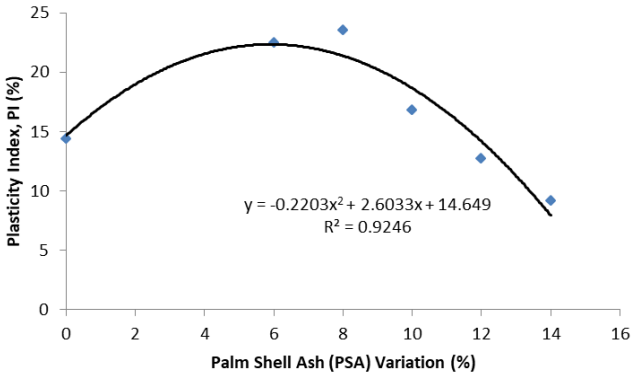

Fig. 2. Graph of Relationship of Variation of Addition of Palm Shell Ash to IP

The application of the addition of 14% palm shell ash with a PI value of 9.20% in the field based on the Director General of Highways (2018) can be carried out in construction work as a substitute for ordinary embankment soil. Comparison of Test Results (2022) with the Director General of Highways (2018) is in Table VII.

TABLE VII. Comparison of Test Results with Bina Marga Specifications

No.	Type of Embankment	PI Value (%) of Clay Soil Mixture with PSA (%)						Bina Marga Specifications (2018)	Description
		0	6	8	10	12	14		
1	Fill	14.4	22.44	23.53	16.82	12.71	9.20	11% (max)	Fulfill
2	Selected Fill							7% (max)	Not Fulfilled
3	Selected Fill over the Swamp							6% (max)	Not Fulfilled

Direct shear testing was carried out to determine the effect of adding palm shell ash on the shear strength value obtained from the cohesion value and the soil internal friction angle. Fig. 3, Fig. 4 and Fig. 5 are graphs of the results of the direct shear test based on the value of cohesion, internal friction angle and shear strength.

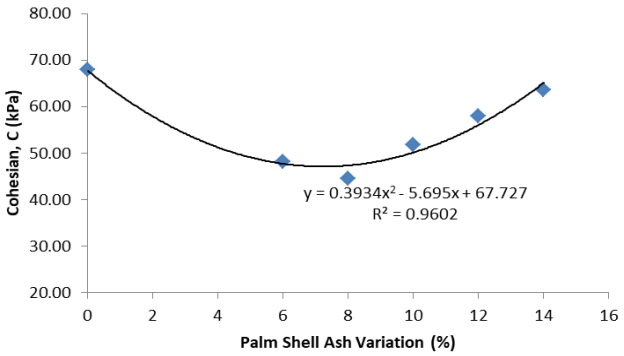

Fig. 3. Graph of the Relationship between Palm Shell Ash Variation and Cohesion Value

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In this test, the addition of palm shell ash showed that the soil cohesion value decreased from the clay soil to the soil with the addition of 6% and 8% variation. The cohesion value in the clay soil was 67.93 kPa and then decreased at 8% variation to 44.59 kPa. Then the cohesion value increased at variations of 10%, 12% and 14%. The greatest increase in cohesion value occurred at 14% variation with a cohesion value of 63.64 kPa.

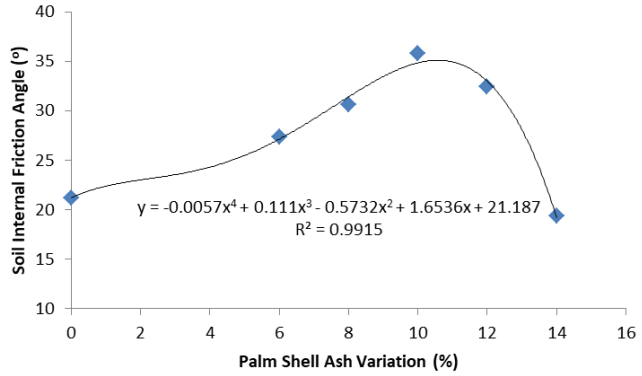

Fig. 4. Graph of Relationship between Palm Shell Ash Variations and Soil Internal Friction Angle Values

In Fig. 4, the value of the internal friction angle has increased up to a 10% addition variation is 35.76° from the clay soil 21.18°. Then the internal friction angle value decreased until 14% variation with 19.32°.

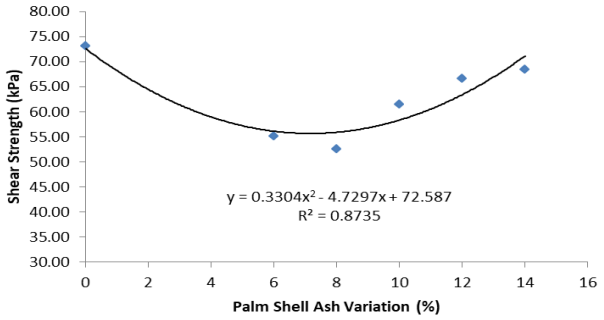

Fig. 5. Graph of the Relationship of Palm Shell Ash Variations to Shear Strength Values

Based on the Fig. 5, it is found that the addition of palm shell ash has an effect on the shear strength value. In the shear strength value, the shear strength value obtained at the initial load 1 of 73.19 kPa decreased to a variation of 8% addition to 52.60 kPa and then increased to a variation of 14% addition of 68.39 kPa.

Consolidation tests were carried out to determine the effect of adding palm shell ash in terms of the value of the consolidation coefficient (C_v). The graph of the test results based on the consolidation coefficient values is shown in Fig. 6.

Based on Fig. 6, the result is that the addition of palm shell ash has an effect on the value of the consolidation coefficient. This is indicated by a decrease in the value of the consolidation coefficient for each variation. The biggest decrease occurred in the 14% addition variation. The consolidation coefficient value of the clay soil at a stress of 50 kPa, which was initially 0.00502 cm^2/s, decreased to a variation of 14% addition to 0.00326 cm^2/s. At a stress of 100 kPa, which was originally 0.00396 cm^2/s, it became 0.00261 cm^2/s at a variation of 14%. The C_v value at a stress of 200 kPa also decreased with a variation of 14%, from 0.00309 cm^2/s to 0.00205 cm^2/s. At a stress of 400 kPa it shows that the C_v value also decreased from 0.00229 cm^2/s to 0.00167 cm^2/s.

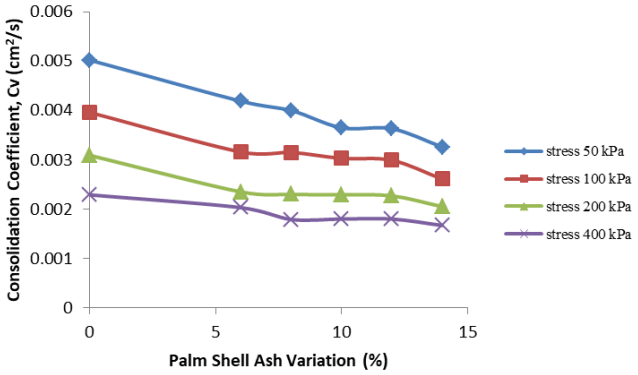

Fig. 6. Graph of the Relationship of Palm Shell Ash Variations to Cv

This shows that the addition of palm shell ash does not make the soil condition better based on the consolidation coefficient parameters because in each variation the addition of palm shell ash makes the settlement time slower.

V. CONCLUSION

Based on the Bina Marga Specifications (2018) for the PI value, the addition of 14% palm shell ash can be used as ordinary fill with shear strength value 68.39 kPa.

REFERENCES

[1] Das, B.M., *Mekanika Tanah (Prinsip-prinsip Rekayasa Geoteknis)*, Jilid I. Jakarta: Penerbit Erlangga, 1995
[2] Dinas Perkebunan Provinsi Kalimantan Timur 2021. Diperoleh dari basis data Dinas Perkebunan Provinsi Kalimantan Timur https://disbun.kaltimprov.go.id/
[3] Direktorat Jenderal Bina Marga, 2018. Spesifikasi Umum 2018 untuk Pekerjaan Konstruksi Jalan dan Jembatan. Diakses pada 2 Agustus 2022. Tersedia di https://binamarga.pu.go.id/
[4] Fadillah, Y., Kamil, A., Suroso, P. "Pengaruh Penambahan Abu Cangkang Kelapa Sawit Terhadap Nilai Stabilitas Tanah Lempung Yang Ditinjau Dari Nilai CBR dan Kuat Tekan Bebas," *SNITT Politeknik Negeri Balikpapan, ISBN: 978-602-51450-3-2 P-19*, pp. 139-145, 2021
[5] Hardiyatmo, H.C., *Mekanika Tanah I*. 3th ed. Yogyakarta: Gadjah Mada University Press, pp. 20-97, 2002
[6] Hardiyatmo, H.C., *Mekanika Tanah II*. 3th ed. Yogyakarta: Gadjah Mada University Press, pp. 47-83, 2003
[7] Sarifah, J., Pasaribu, B. "Pengaruh Penggunaan Abu Cangkang Kelapa Sawit Guna Meningkatkan Stabilitas Tanah Lempung," *Buletin Utama Teknik*, vol. 13, no. 1, pp. 55-60, 2017

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