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Evaluation of the Compressive Strength of the Clay Soil Reinforced with the Column of Oil Palm Shell Concrete

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Abstract

Application of the concrete from palm oil waste for soil improvement has not yet investigated. In this paper, the concrete made of PKS, sand, cement, and POFA mixtures was applied to form a column-reinforce clay soil system. The objective of this paper was to evaluate the compressive strength of the OPS concrete column reinforce clay soil. The soil specimens were compacted in a cylindrical steel mold with an inside diameter of specimen size was 125.4 mm diameter and 108 mm in height. The water content was varied into three i.e. near OMC, below OMC (optimum-dry), and above OMC (optimum-wet). The hole of 50.8 mm in diameter and 108 mm in height was made and filled with OPS concrete to form a column. The composition of the concrete mixture was 125 g of cement, 215 g of sand, 130 g of OPS, and 10 g of POFA. Cement and POFA was the binder in the mixture. The water to binder ratio (*wbr*) was 0.80 which was determined by trivial. It was concluded that the compressive strength has a tendency to increase with increases in moisture content of the soil. The highest compressive strength was obtained at optimum-wet moisture content that is 1736 kPa. The compressive strength increases with increasing the age of specimen. The compressive strength increases from 348 kPa (at 1 day) to 1736 kPa after 28 days of curing.

Keywords: clay, unconfined compressive strength, OPS concrete column

1. Introduction

Indonesia is one of the countries that produce large enough palm oil. The palm oil production in the form crude palm oil (CPO) tends to increase with increasing acreage of oil palm plantations. According to the data recorded by The Ministry of Agriculture, the Republic of Indonesia, in 2009-2013 the productivity of oil palm plantations Indonesia has a range of 2.5-2.7 tons/ha [1]. This is a concern which is very important cause of the production of waste in the form of palm oil should be utilized optimally. The palm oil wastes, which are potentially for construction materials, are shell, and fuel ash. The oil palm shell (OPS) is a waste from the processing of palm oil, which has not been utilized optimally for construction materials. Some investigation in a laboratory scale has been performed to utilize OPS for lightweight concrete and compressed brick [2-7]. In this concrete mix, palm oil fuel ash (POFA) can be added in the concrete as admixture. POFA is a waste material of palm oil that resulted from the combustion of palm kernel shells. This material was used in concrete compositions wherein the addition of this material serves to reinforce strength of the concrete [8,9]. All the research on the OPS/POFA mixed-concrete indicated a promising uses for lightweight concrete.

In the point of view of palm oil waste materials, many studies focused on its application in concrete and building materials as explained in previous paragraph. The application in soil improvement has not yet investigated intensively. An exploratory the use of OPS and/or POFA in laboratory for soil admixture was discussed in a few references i.e. Khalid et al. [10], Pourakbar et al., [11], Gungat et al. [12]. The use of the concrete containing OPS/POFA for soil improvement is possible to be explored to enhance the bearing capacity of problematic soil. Mini pile or mini column made of concrete can be applied to reinforced clay soil to enhance the bearing capacity due to the vertical loading. In this paper, the concrete made of OPS, sand, cement, and POFA mixtures were applied to form a column-reinforce clay soil system. The objective of this paper was to evaluate the unconfined compressive strength (UCS) of the OPS concrete column reinforce clay soil. The effect of the molding water content was also studied in this paper.

2. Experimental Program

2.1 Materials Used

Soils

The soil was collected from the Kasihan area in Bantul, Yogyakarta. The soil predominantly consist of fines particle about 78%-92%. The properties of soil are presented in Table 1. The soil was classified as high-plasticity clay (CH) according to the Unified Soil Classification System. The soil has swelling potential ranging from 8% to 24%, thus it can be classified as medium to very high swelling. This type of soil is often too soft and weak to support the upper infrastructure of construction projects, which makes it an excellent and challenging type of host soil for soil stabilization

Table 1. Properties of the soil

Parameter	Value
Specific gravity, G_s	2,48 – 2.80
Consistency limits :	
Liquid Limit, LL (%)	68 – 73
Plastic Limit, PL (%)	26 – 29
Plasticity Index, PI (%)	40 – 47
Particle sizes :	
Silt/clay	78 – 92
Sand	8.0 – 22
Standard Proctor compaction:	
Maximum dry density, MDD (kN/m^3)	12,2 – 13.4
Optimum moisture content, OMC (%)	28 – 29

Cement

Portland pozzolan cement (PPC) manufactured by a national cement industry was used in accordance with SNI 15-7064-2004 [13]. The chemical composition of the cement is presented in Table 2. The fineness of the PPC was 325 m^2/kg, which was measured by Blaine air-permeability apparatus.

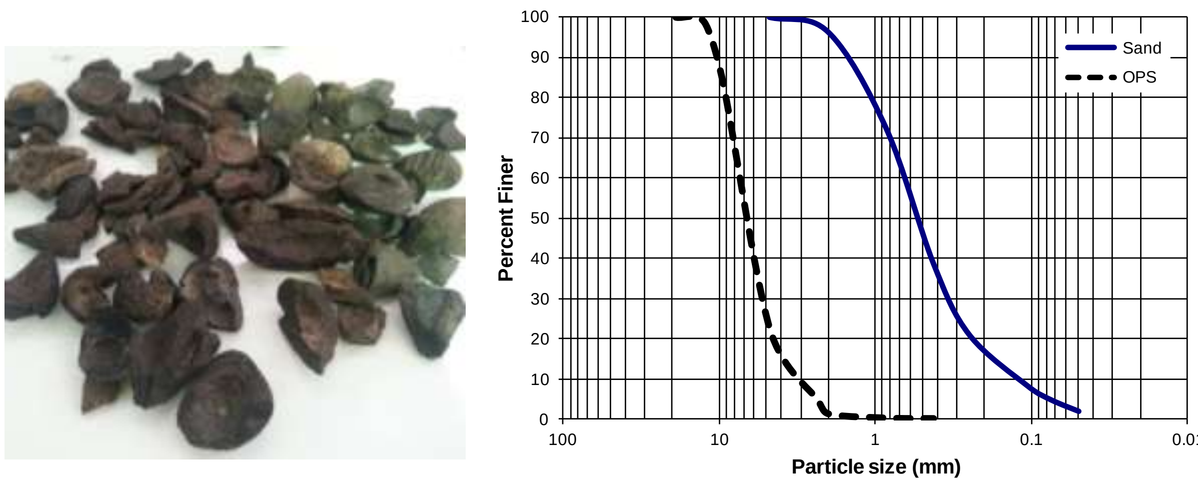
Table 2 Chemical composition of cement and POFA

Materials	Oxide composition (%)										
	Al_2O_3	CaO	Fe_2O_3	MgO	Na_2O	K_2O	MnO	SiO_2	P_2O_5	TiO_2	LOI
Cement	8.76	58.66	4.62	0.90				23.13			1.69
POFA	8.87	3.24	1.06	1.42	0.57	3.22	0.03	52.63	1.86	0.31	27.7

Palm oil shell and fuel ash

OPS and POFA were collected from a local crude palm oil producing mill, and comprised old discarded waste at the palm oil mill area in Riau in the Sumatera Island of Indonesia. The OPS were used as the coarse aggregate. The texture and particle size distribution of the OPS is shown in Figure 1. The OPS size ranges from 2 mm to 15 mm.The curve in Figure 1b indicated that the average particle size of the OPS is 7 mm; it means that the more than 50% OPS have a size greater than 7 mm.

The POFA was oven dried for 24 h, before used as admixture. The oven-dried ashes were sieved using a 75 μm (No. 200) sieve to remove nutshells and fibers which were incompletely combusted. The chemical composition of the POFA is presented in Table 2.



(a) (b)

Figure 1: (a) The texture of the OPS, (b) Particle size distribution o the collected OPS from the raw mills.

Sand

The fine aggregate for this research was river sand, which was collected from Progo river in Yogyakarta. The specific gravity of the sand is 2.65 and its particle size distribution is illustrated in Figure 1b.

Mix proportion of the OPS-concrete

The mini column was made of OPS concrete (OPS-crete). The column size was 50.8 mm (2 inch.) in diameter and 108 mm (4.25 inch.) in height. To form the column, the mix composition were 125 g of cement, 215 g of sand, 130 g of OPS, and 10 g of POFA. Cement and POFA was the binder in the mixture. The water to binder ratio (*wbr*) was 0.80 which was determined by trivial. This *wbr* produced a good workability of the concrete since the OPS and POFA tend to adsorb water.

Specimen Preparation and UCS Testing Procedure

The specimens shall have a minimum diameter of 50 mm (2 inch) [14]. The specimen size was 125.4 mm (6 inch) diameter and 108 mm (4.25 inch) in height. A 4 kg oven-dried soil was prepared and mixed with water thoroughly. The water content was varied into three i.e. near OMC, below OMC (optimum-dry), and above OMC (optimum-wet). The, the soil slurry was transferred into the mold and compacted using standard compaction energy [15]. The compacted soil was drilled by auger machine to make a column hole. The OPS-crete was prepared according the mix design as previous. The OPS-crete was poured into the hole and compacted gently to form a column. The OPS-crete column was left for about 24 hours to allow hardening in the mold by keeping the specimen and its mold in plastic bag. The specimen was extruded from the mold. The diameter, height, and weight of the specimen were measured subsequently. Finally, the specimen was kept in a sealed plastic bag to prevent moisture change and stored at a controlled room temperature about $28^{o}C \pm 2^{o}C$. The set of specimens was cured for 1 days, 3 days, 7 days, 14 days, and 28 days. Two specimens were prepared for each water content design. Figure 2 shows the specimen with OPS-crete column.

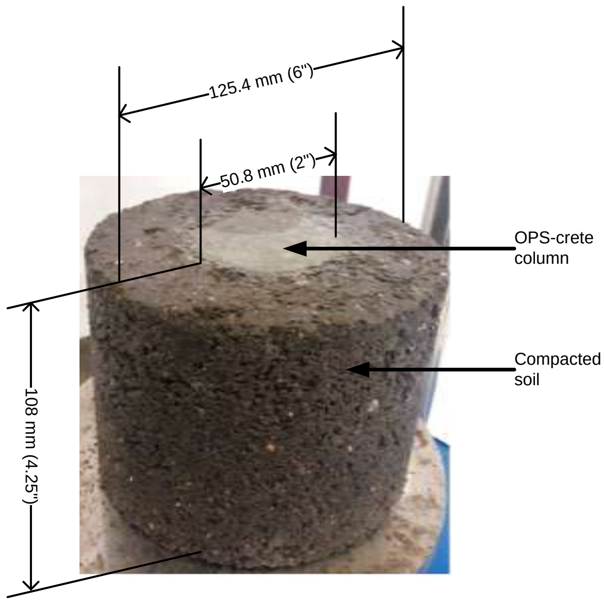


Figure 2: The compacted soil and OPS-crete column.

The UCS test was performed after 1 days, 3 days, 7 days, 14 days, and 28 days of curing. Before test, the dimension and mass of specimen were measured. The test followed the procedure as written in ASTM D2166 [14]. The specimen was placed in the loading device so it was centered on the bottom platen. The loading device was adjusted carefully so the upper platen just made contact with the specimen. The deformation indicator was set up to zero. The load was applied continuously to produce an axial deformation rate of approximately 1.0 % per min. The axial force, deformation, and time values at sufficient intervals were recorded to define the shape of the stress-strain curve. The maximum axial force applied to the specimen was recorded, along with its deformation. The specimen was continuously loaded until load values decrease with increasing strain or until 5 % strain was exceeded. Finally, the unconfined compressive strength for a given applied axial force was calculated by using Equation (1).

$$q_u = \frac{P_{\max}}{A_f} \tag{1}$$

which is,

$$A_f = \frac{A_o}{1-\varepsilon_f} \tag{2}$$

where,

P_{max} = maximum compression load,
A_f = cross section area of specimen at failure,
A_o = initial cross section area of specimen,
ε_f = axial strain at failure.

3. Results and Discussion

The axial stress and strain relationship of the specimens after 28 days of curing is illustrated in Figure 3. In general, the maximum axial stress obtained at 6-7% of its strain. After reaching the maximum stress, the residual stress was obtained until 20% strain. This behavior indicates that the soil-reinforced with OPS-crete column behave a brittle behavior. In this research, the highest compressive strength was obtained at optimum-wet moisture content that is 1736 kPa. It was observed that the soil surrounding columns experienced to fail at beginning for reaching the maximum stress, while the OPS-crete column remained support the load until reach a failure (Figure 4). However, this experiment did not investigate in detail its failure mechanism of the OPS-crete column and soil system.

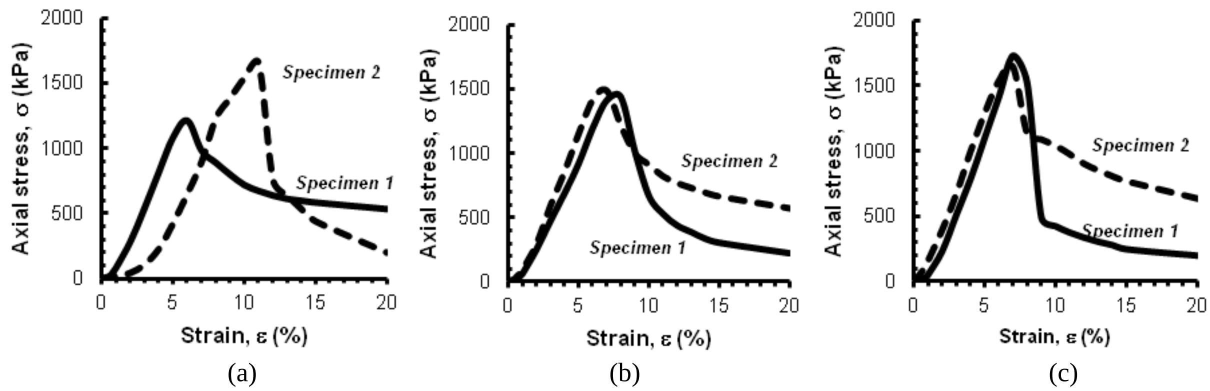


Figure 3: The typical axial stress and strain relationship of the OPS-crete column – soil composite (a) optimum-dry moisture content, (b) optimum moisture content, (c) optimum-wet moisture content

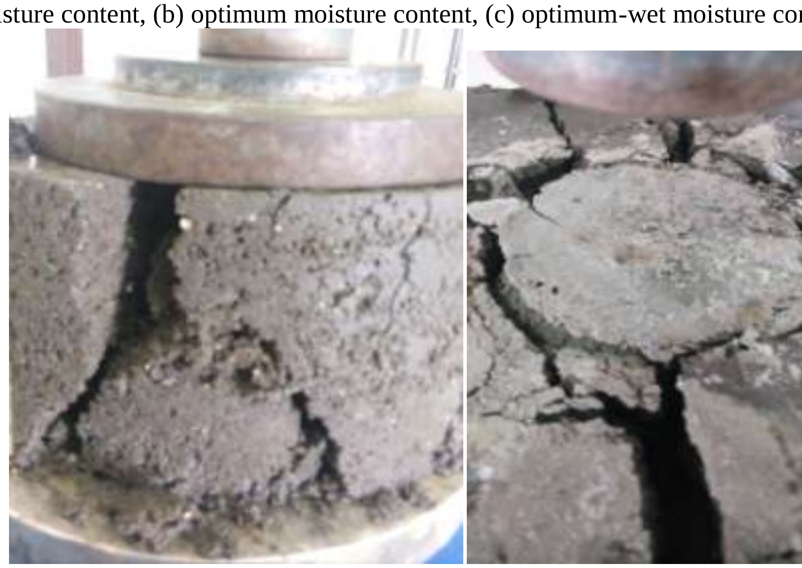


Figure 4: The typical failure of the specimen after test

It is observed that the compressive strength has a tendency to increase with increases in moisture content of the soil. This result might be true since the OPS-crete column needs water from surrounding soil to maintain the hydration and hardening process. The cement in the concrete needs water to hydrate and form Calcium-Silicate-Hydrate (C-S-H) which is the glue that holds the concrete together [16].

The previous discussion concluded that the highest compressive strength was reached at optimum-wet moisture content of soil. To study the effect of curing time, Figure 5 shows the relationship between the compressive strength test and the age of specimens. In general, it can be seen that the compressive strength increases with increasing the age of specimen. The compressive strength increases from 348 kPa (at 1 day) to 1736 kPa after 28 days of curing. It is general term that increasing compressive strength with time is the indicator of the hardening and pozzolanic reaction [16].

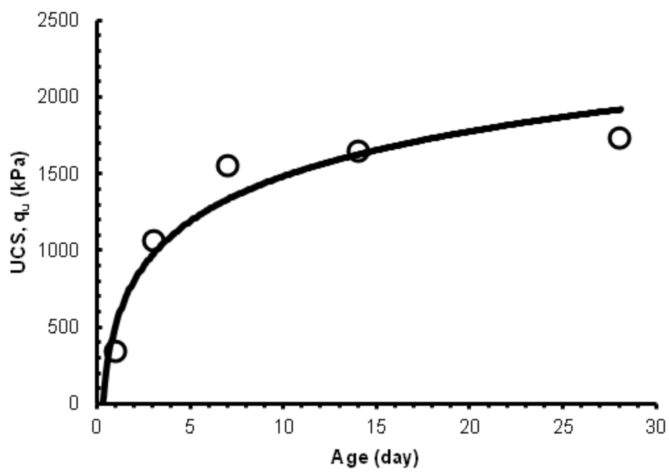


Figure 5. Relationship between age and maximum strength

4. Conclusions

The experimental works have been conducted to evaluate the unconfined compressive strength of the clay soil supported by OPS-crete column. The test was performed in three different soil moisture content conditions. It was concluded that the compressive strength has a tendency to increase with increases in moisture content of the soil. The highest compressive strength was obtained at optimum-wet moisture content that is 1736 kPa. The compressive strength increases with increasing the age of specimen. The compressive strength increases from 348 kPa (at 1 day) to 1736 kPa after 28 days of curing.

5. Acknowledgements

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