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Effectiveness of waste paper ash for stabilization on clay soil

Efectividad de las cenizas de papel usado para la estabilización en suelos arcillosos

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Abstract

Through this paper, three main approaches were adopted to evaluate the effectiveness of waste paper ash (WPA) for stabilization on clay soil. First, the physical properties of mixing soil were studied. Furthermore, the swelling potential of mixing soil with different percentage was also discussed. Finally, the compressive strength using unconfined compressive strength (UCS) apparatus was evaluated. It was found that after mixing with waste paper ash (WPA), the percentage of soil passing sieving number 200 and plasticity index reduces by increasing of the waste paper ash (WPA) percentage. It might be attributed to the bonding of the chemical content of waste paper ash (WPA) to the soil particles. In addition, the swelling potential slightly reduces by increasing of waste paper ash (WPA) percentage. Furthermore, the compressive strength increases with waste paper ash (WPA) 5% and 10%.

Keywords: Waste paper ash; clay soil; stabilization; swelling potential; compressive strength.

Resumen

A través de este documento, se adoptaron tres enfoques principales para evaluar la efectividad de la ceniza de papel usado (WPA) para la estabilización en suelos arcillosos. Primero, se estudiaron las propiedades físicas de la mezcla del suelo. Además, también se discutió el potencial de hinchamiento de mezclar suelo con diferentes porcentajes. Finalmente, se evaluó la resistencia a la compresión utilizando un aparato de resistencia a la compresión no confinada (UCS). Se encontró que después de mezclar con ceniza de papel usado (WPA), el porcentaje de suelo que pasa por tamizado número 200 y el índice de plasticidad se reduce al aumentar el porcentaje de ceniza de papel usado (WPA). Podría atribuirse a la unión del contenido químico de las cenizas de papel usado (WPA) a las partículas del suelo. Además, el potencial de hinchamiento se reduce ligeramente al aumentar el porcentaje de cenizas de papel usado (WPA). Además, la resistencia a la compresión aumenta con la ceniza de papel usado (WPA) 5% y 10%.

Palabras clave: Cenizas de papel usado; suelo arcilloso; estabilización; potencial de hinchazón; fuerza compresiva.

1. Introduction

Soil stabilization can be carried out by increasing the soil density, adding inactive materials to increase the soil shear strength (cohesion or friction angle), increasing materials for chemical and physical changes of the soil, reducing the groundwater level, and replacing poor soil or low bearing capacity. Generally, soil stabilization can be done in two ways, namely mechanical stabilization and chemical stabilization (Silitonga et al., 2010). It has been known that the mechanical stabilization is a method to increase the bearing capacity of soil by improving the structure and repairing the physical properties of soil with various mechanical equipment, such as rollers. On the other hand, the chemical stabilization is a method to increase the strength and bearing capacity of soil by reducing or eliminating the unfavorable physical properties of soil and mixing soil with chemicals (Das, 2014).

In recent years, researchers have conducted many studies about soil stabilization specially to find a solution for environmental problems. One of the most problem is waste paper materials in the development country like Indonesia. Usually, the waste paper produced from waste material of household, commercial, industrial or other human activities.

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Many researchers have been studied the utilization of waste paper ash (WPA) in the civil engineering field and still develop till now, like using it in mortars and concretes (Kinuthia et al., 2001) and (O'Farrel et al., 2002), supplementary cementing material (Frias et al., 2008), and bricks (Liaw et al.,1998), as well as using it as a binder to stabilize clayey soils (Segui et al., 2013) and (Khalid, 2012) or as a potential raw material for mesoporous silica synthesis.

Through this paper, three main approaches were adopted to evaluate the effectiveness of waste paper ash (WPA) for stabilization on clay soil. First, the physical properties of mixing soil were studied. Furthermore, the swelling potential of mixing soil with different percentage was also discussed. Finally, the compressive strength using unconfined compressive strength (UCS) apparatus was evaluated.

2. Methodology and materials

2.1 Materials and sampling location

The sampling points were located near the main road in the Padang City, Indonesia. In this road, it was observed that some problems occurred due to the subgrade soil properties. The physical properties and particle size distribution of the collected soils are listed in (Table 1) and (Figure 1).

Table 1. Physical properties of the collected soils

Physical Properties		
Water content	%	94.07
Specific gravity (Gs)	-	2.41
Liquid limit (LL)	%	86.00
Plastic limit (PL)	%	39.01
Plasticity Index (PI)	%	46.99
Classification by USCS		*CH (Clay with high plasticity)*

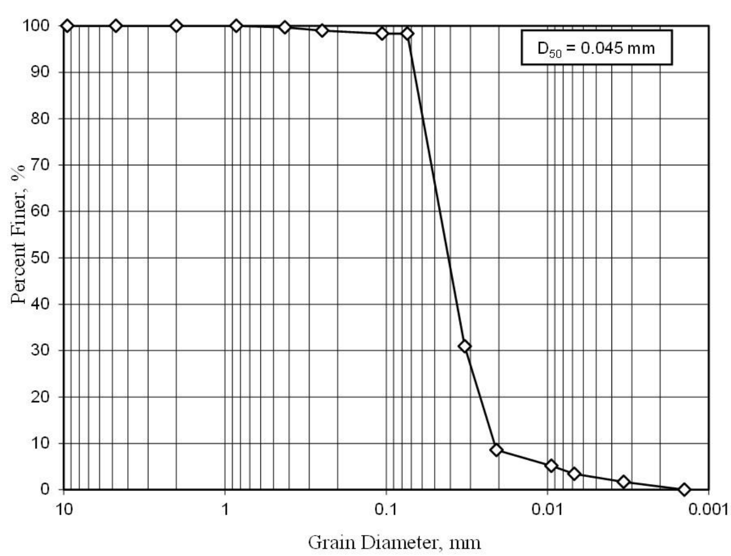

Figure 1. Particle size distribution

It can be seen that the natural water content is 94.07 %. The median grain size D50 is approximately 0.045 mm. On the other hand, the percentage of soil passing sieving number 200 is 98.36 % Consequently, the collected soils can be classified as clay with high plasticity (CH) according to the Unified Soil Classification System standards (USCS).

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2.2 Methodology

2.2.1 Waste paper ash (WPA)

The waste paper was collected from waste material of household, commercial, industrial or other human activities. In order to get the ash, the collected waste paper was burned with a constant temperature approximately 600o C in the laboratory. Furthermore, the waste paper ash (WPA) was sieved using sieving number 200.

According to (Balochi et al., 2020) the waste paper ash (WPA) from the X-ray Diffraction (XRD) results showed the presence of calcite, lime, portlandite, quartz, halite, calcium silicate, gehlenite, and aluminum. The chemical composition of the waste paper ash (WPA) is comprised mainly of CaO, SiO2, Al2O3, Fe2O3, Cl accounting for as high as about 84%.

2.2.2 Swelling test

(Figure 2) shows a schematic diagram of the swelling test apparatus. The swelling test was carried out with a curing time of sample after mixing about 3 days. The sample was prepared by compacting the soil based on the optimum moisture content obtained from the compaction test. A circular sample with 3 cm in height and 5 cm in diameter was adopted for testing. The standard of ASTM D4546-96 and D2435-96 were used in this test.

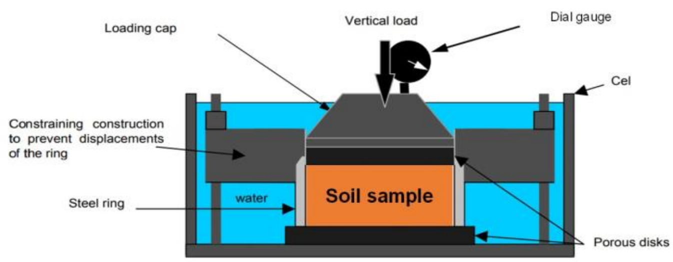

Figure 2. Swelling test apparatus

2.2.3 Compressive strength test

In order to get the compressive strength characteristics, the unconfined compressive strength (UCS) test considering both natural and mixing samples were tested. The unconfined compressive strength test (UCS) was carried out with a curing time of sample after mixing about 3 days. (Figure. 3) illustrates a schematic diagram of the used the unconfined compressive strength test (UCS) apparatus.

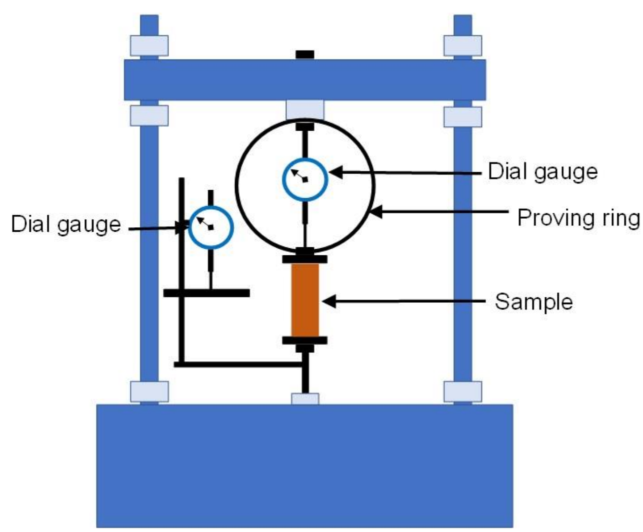

Figure 3. Unconfined compressive test (UCS) apparatus

A circular sample with 7.5 cm in height and 3.8 cm in diameter was prepared for testing. Then, the standard of ASTM D2166-06 were adopted.silicate, gehlenite, and aluminum. Furthermore, the testing program of swelling and unconfined compressive strength test (UCS) was illustrated in (Table 2).

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Table 2. Testing Program

Swelling test			
Sample ID	**WPA Percentage (%)**	**Initial Void Ratio (e_o)**	**Initial Water Content (%)**
SS01	0	0.97	22.00
SS02	5	0.89	19.00
SS03	10	0.79	17.50
SS04	15	0.81	17.51
Unconfined compression test			
Sample ID	**WPA Percentage (%)**	**Density (gr/cm^3)**	**Initial Water Content (%)**
SS01	0	1.58	22.00
SS02	5	1.52	19.00
SS03	10	1.59	17.50
SS04	15	1.56	17.51

3. Results and discussion

3.1 Physical properties

The particle size distribution characteristics for each soil sample is shown in (Figure 4). It can be seen that the percentage of soil passing sieving number 200 for natural soil was 98.56 %. After mixing with waste paper ash (WPA), the percentage of soil passing sieving number 200 reduces by increasing of the waste paper ash (WPA) percentage. It might be attributed to the bonding of the chemical content of waste paper ash (WPA) to the soil particles, thus the soil particles are getting coarser and the clay fraction in the soil is reduced.

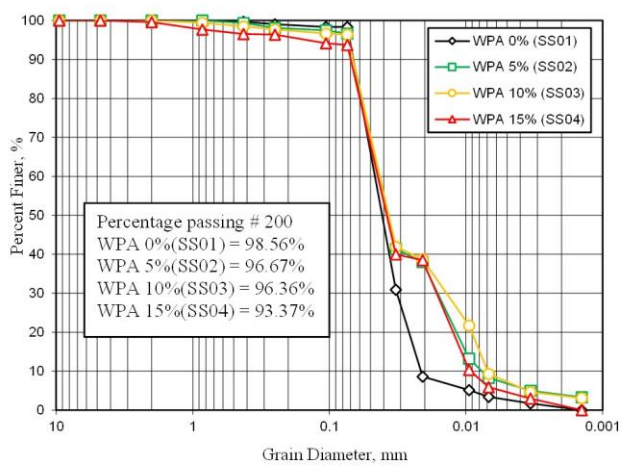

Figure 4. Unconfined compressive test (UCS) apparatus

Furthermore, the percentage of soil passing sieving number 200 also related to the plasticity index (PI) properties. (Figure 5) shows the plasticity index (PI) properties for each sample. It can be observed that the plasticity index (PI) significantly reduces. The plasticity index (PI) of natural soil (WPA 0%), WPA 5%, WPA 10% and WPA 15% was 46,99%, 35,67%, 30,00% and 28,70% respectively. It can be related to decrease of liquid limit (LL) due to the exchange of mineral composition between soil and waste paper ash (WPA). The pores surrounded by cementitious material which are more difficult to penetrate the water and make the waste paper ash (WPA) soil mixture more resistant to water absorption, therefore the reduction of plasticity occurred.

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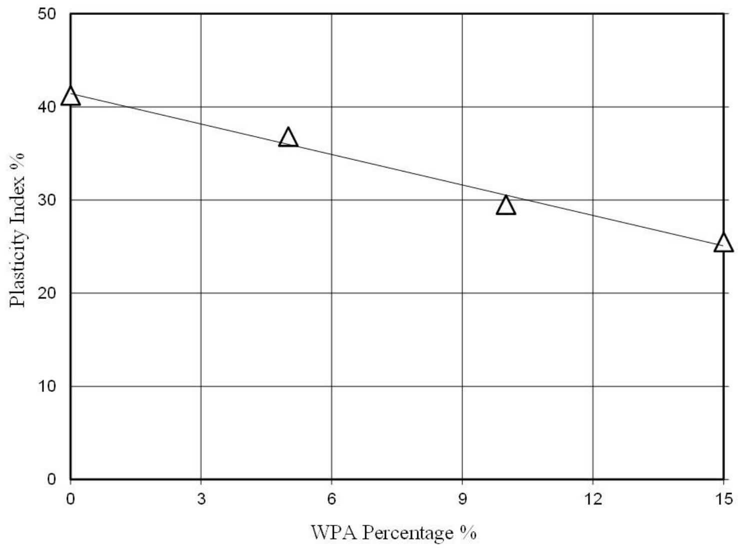

Figure 5. Relationship between plasticity index and WPA percentage

3.2 Swelling potential

The relationship between swelling potential and percentage of waste paper ash (WPA) are indicated in (Figure 6). The obtained results show that the swelling potential slightly reduces by increasing of waste paper ash (WPA) percentage. It can be attributed to increase of mineral composition of CaO, SiO_2, Al_2O_3, Fe_2O_3, Cl. Those minerals will replace H+ and Na+ ions in the natural soil. Therefore, the mixture soil more stable and the swelling potential reduces. In addition, the reduction in the percentage of swelling potential is also influenced by the hydration process where the substances present in the waste paper ash (WPA) reaction with water to become an adhesive medium and then form a hard mass.

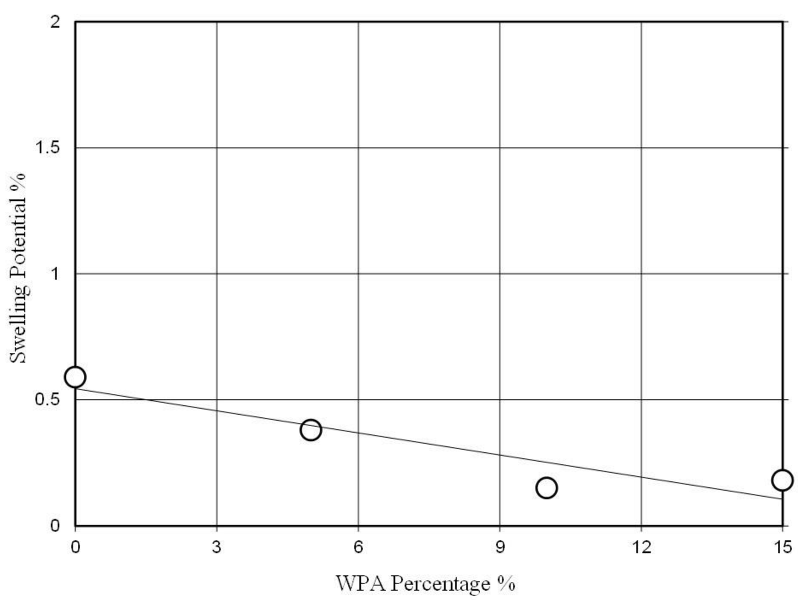

Figure 6. Relationship between plasticity index and WPA percentage

3.3 Compresive strength

The relationship between the compressive strength and axial strain is shown in (Figure 7). It was found that in the natural soil (WPA 0%), the maximum compressive strength was 100 kPa. Furthermore, the compressive strength increases for WPA 5% and 10% with the maximum value 105 kPa and 340 kPa. The increase in the value of compressive strength related to the chemical compounds contained in waste paper ash (WPA) successfully bonding with soil particles. The addition of waste paper ash (WPA) gave a sufficient contribution to the cementation process between a mixture of waste paper ash (WPA) and soil.

On the other hand, the compressive strength in WPA 15% slightly reduces to 250 kPa. It can be attributed to the reduction elasticity of soil, thus soil more brittle and will break easily due to the load. It can be said that the optimum of WPA percentage is 10% for the compressive strength characteristic.

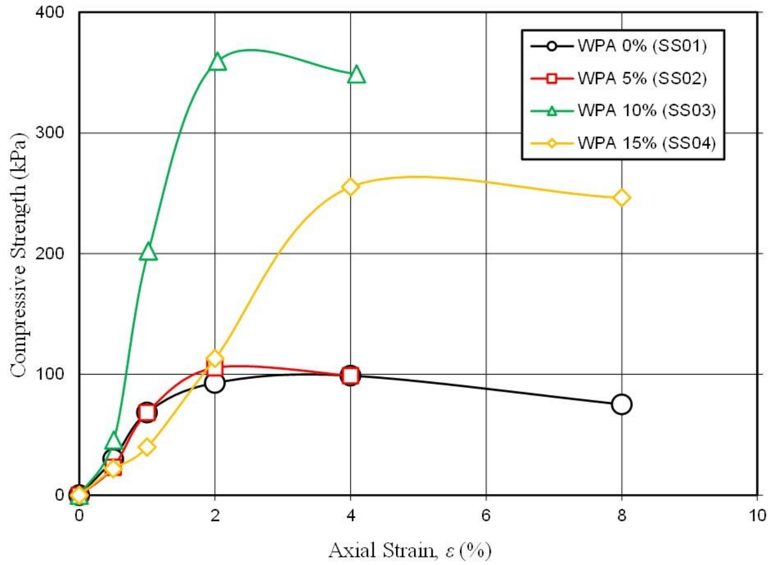

Figure 7. Relationship between compressive strebgth and axial strain

In order to evaluate the correlation of the compressive strength and the waste paper ash (WPA) ratio, the soil strength index (α) from each sample is plotted against the waste paper ash (WPA) percentage (Putra et al., 2020). The correlation for the whole soil samples as illustrated in (Figure 8). It can be observed that a waste paper ash (WPA) percentage give the impact to the soil strength index (α).

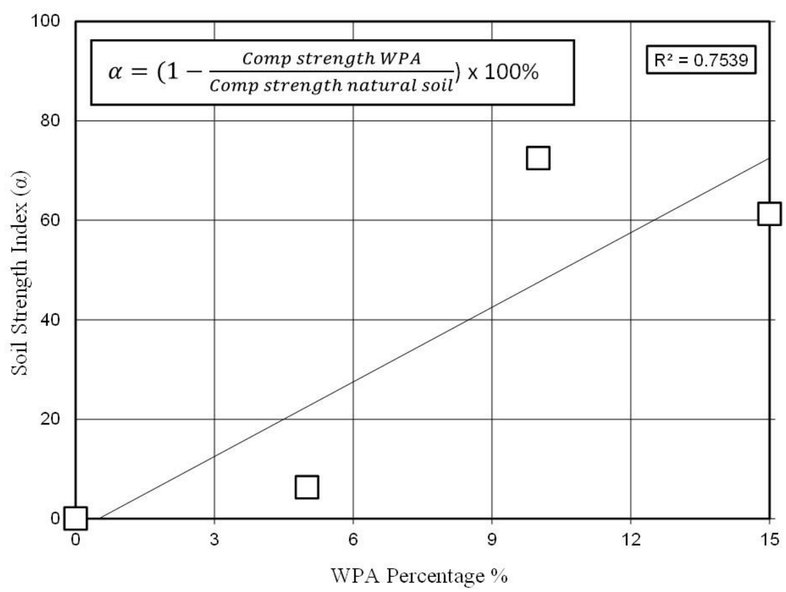

Figure 8. Relationship between soil strength index and WPA percentage

4. Conclusion

Through this paper, the effectiveness of waste paper ash (WPA) for soil stabilization was evaluated. The evaluation includes the physical properties, swelling potential and compressive strength. It was found that after mixing with waste paper ash (WPA), the percentage of soil passing sieving number 200 and plasticity index reduces by increasing of the waste paper ash (WPA) percentage. It might be attributed to the bonding of the chemical content of waste paper ash (WPA) to the soil particles. In addition, the swelling potential slightly reduces by increasing of waste paper ash (WPA) percentage. Furthermore, the compressive strength increases with waste paper ash (WPA) 5% and 10%.

Finally, a good correlation between the soil strength index (α) from each sample and the waste paper ash (WPA) percentage was obtained. A waste paper ash (WPA) percentage give the impact to the soil strength index (α).

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