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# EFFECT OF ORGANIC WASTE MATERIALS ON CLAYS SOIL PROPERTIES

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ABSTRACT

Clay soil has cohesive properties which cause the soil to be hard when dry and plastic when wet, which can cause damage to the construction of the building above it. One method of improving unstable soil is soil stabilization using additives. In this study, the mixed materials used were waste materials, namely rice husk ash, coconut shell ash, and sawdust ash with a proportion of 2%, 5%, and 8% respectively. Each of these materials is added with 5% sea shell powder as a substitute for lime. Soil sampling was carried out at the location of Koto Baru Nan XX Village, Padang City. The method used is the observation method, which is testing the physical and mechanical properties of the soil in the laboratory. The results showed that the value of the plasticity index was reduced the most by mixing coconut shell ash and sea shell powder to 87%. The optimum water content and dry unit weight of soil with added materials decreased during the compaction test. The optimum moisture content and dry unit weight dropped sharply when sawdust ash and shell powder were mixed by 57% and 9%, respectively, when viewed from their average values. Then followed by a mixture of coconut shell ash and sea shell powder of 47% and 15%. And the smallest decrease occurred in a mixture of rice husk ash and sea shell powder at 31% and 11%. The level of soil sensitivity is reduced the most in a mixture of sawdust ash and sea shell powder by 50% and continue by a mixture of coconut shell ash and sea shell powder by 43% and a mixture of rice husk ash and sea shell powder by 24%.


## 1. INTRODUCTION

Clay soil is classified as problematic soil in moisture content, permeability, bearing capacity, and consolidation. Improvement of soil properties and in-situ treatment of soil are gaining importance in the field of geotechnical engineering used for construction. Soil stabilization using waste materials, obtained from natural sources, is widely used as an alternative method in construction in recognition of the green concept. Large amounts of materials of natural resources are produced daily (Assam, 2020; Anoop et al., 2017; Widianti et al., 2021). Natural soils do not possess proper geotechnical properties to be used as embankment, subgrade stabilization, and foundation layers. In order to make them useful and have the requirements of geotechnical properties, researchers have concentrated the use of waste materials from agricultural wastes to improve the properties of soils and to reduce the cost of construction. The waste materials used are rice husk ash (RHA), saw dust ash (SDA), coconut shell powder (CSP), and sea shell powder (SSP).

## 2. LITERATURE REVIEW

Natural rice husk ash does not show obvious cementitious property. The material of RHA needs to be modified by some treatments, such as grinding, acid/alkali and calcium-based material excitation, so as to improve the physical and chemical properties effectively (Chen et al., 2021). The addition of lime will strengthen and accelerate the bond between soil minerals so that in terms of strength will be higher (Zaika & Suryo, 2020). Experiment study by Pushpakumara et al, (Pushpakumara & Mendis, 2022) indicated the effect of RHA and lime increasing the index properties of soil and a slight reduction in compaction properties. The addition of lime and RHA to soil increases the optimum moisture content and reduces the maximum dry density, it enhances the development of UCS of soil (Jha & Gill, 2006). Lakshmi et al. (2021) the optimal precentage of quick lime and RHA to clayey sand increasing the shear strength and CBR value. Rahman (Rahman & Paul, 2020) studied the effect of RHA and lime improving the CBR and UCS value in low strength cohesive soil.

Coconut shell as agricultural waste material, are collected and burnt in the open air to produce coconut shell ash (CSA), which in turn can be pozzolan in soil stabilization and in partial replacement of cement in concrete production (bade & Udo, 2020). Experiment by and Zava (Yusuf & Zava, 2019) showed that CHA-treated increasing the OMC, while the MDD decreased with increase in the CHA content of the soil and improve the strength of subgrade materials. If admixed with Portland cement or lime, it can be used for improvement of sub-base and base soil materials. The index of plasticity reduces with the addition of various percentage of CSA, indicating a reduction in swelling potential and increase in strength properties, was studied by Bade et al, (Bade et al., 2016).

Karim et al, (Karim et al., 2018) observed the SDA additive has an adverse effect on the property of soil indices by increasing LL and PI which implied by the increasing clay content. On compaction, test results show that SDA reduces the MDD and increases the OMC of soft clay soils. Experiment by (Butt et al., 2016; Ogunribido, 2012) showed the stabilized soils by adding SDA optimally improve liquid limit, plastic limit, plasticity index, specific gravity, MDD, un-soaked CBR and UCS value. Optimum reduction in LL, differential free swell, plasticity index as well as OMC increase in CBR when black cotton soil treated with 16% sawdust ash and 4 % lime (Ikeagwuani et al., 2019; Obeta et al., 2019). The addition of SDA improved the properties of the virgin soil, making it good for sub-base material whereas on addition of lime the plasticity index reduced drastically when compared with the soil stabilized with SDA alone (Kale et al., 2008).

The natural materials above are helpful in improving the geotechnical properties of soil due to their low cost and one of the alternative ways of stabilizing soil. In this research, each waste material above will be added the seashell powder as a substitute for lime.

## 3. METHOD

A series of laboratory tests were conducted on origin soil to find out the consistency limit, optimum moisture content, maximum dry density, unconfined strength test, and CBR.

### 3.1 Sample preparation

The clay soil was collected from Kelurahan Koto Baru Nan XX, Padang City. Proportion of each admixture (rice husk ash, coconut shell ash, saw dust ash, and seashell powder) is 2%, 5%, 8%, and a percentage of a seashell powder is 5% were added to the soil to find out the value for which above mentioned tests were conducted or this scenario in details as shown in Table 1.

**Table 1.** Scenario

| Scenario | Admixture |
|---|---|
| Scenario 1 | Clay Soil + 2% CSA + 5% SSP |
| Scenario 2 | Clay Soil + 5% CSA + 5% SSP |
| Scenario 3 | Clay Soil + 8% CSA + 5% SSP |
| Scenario 4 | Clay Soil + 2% RHA + 5% SSP |
| Scenario 5 | Clay Soil + 5% RHA + 5% SSP |
| Scenario 6 | Clay Soil + 8% RHA + 5% SSP |
| Scenario 7 | Clay Soil + 2% SDA + 5% SSP |
| Scenario 8 | Clay Soil + 5% SDA + 5% SSP |
| Scenario 9 | Clay Soil + 8% SDA + 5% SSP |

### 3.2 Atterberg Limit

The Atterberg's limits are a basic measure of the nature of a fine-grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behavior of a soil is different and thus so are its engineering properties. The boundary between each state can be defined based on the change in the soil behavior. The typical values of LL and PL and typical values for degree of expansion are shown in Table 2 and Table 3.

**Table 2.** Typical values of LL and PL (Bashir Ahmed, 2021)

| Soil Type | LL | PL |
|---|---|---|
| Silts | 24 – 27 | 16 – 20 |
| Clays | 80 – 100 | 45 – 54 |
| Kaolinite | 35 – 100 | 15 – 60 |
| Illite | 55 – 120 | 20 – 70 |
| Montmorillonite | 100 – 800 | 50 – 700 |

**Table 3.** Typical values for degree of expansion (Holtz et al., 2011)

| PI | Degree of Expansion |
|---|---|
| >35% | Very high |
| 25 – 41 | High |
| 15 – 28 | Medium |
| <18 | Low |

### 3.3 Unconfined Compressive Strength

Unconfined compressive strength test is an experiment that aims to determine the free compressive strength (without any horizontal pressure), $q_u$ in undisturbed or remoulded soil and also to determine the degree of soil sensitivity. With the addition of CSA, RHA, and SDA mixtures, it is expected that the strength of the soil can increase and the soil becomes better and the test is conducted based on ASTM D2166/D2166M-13 (*Standard Test Method for Unconfined Compressive Strength of Cohesive Soil 1*, n.d.).

### 3.4 Compaction Test

Compaction is the process of mechanically compacting soil grains that causes air to escape from the soil pore space, thereby increasing soil density. There are various mechanical methods used for soil compaction. While in the laboratory, pounding or beating is used using certain tools. Compaction experiments aim to determine the optimum dry density ($\gamma_{dry}$) and optimum moisture content ($W_{opt}$) of soil samples with a certain energy. The level of soil density can be determined from the optimum dry density of the soil. Compaction testing is b ased on ASTM D1557-12 (*Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 Ft-Lbf/Ft 3 (600 KN-m/m 3 )) 1*, n.d.). The Unconfined compression strength values are shown in Table 4.

**Table 4.** Unconfined compression strength values (Bashir Ahmed, 2021)

| Soil Consistency | $q_u$ (kPa) | $q_u$ (kg/cm$^2$) |
|---|---|---|
| Very soft | <25 | <0.25 |
| Soft | 25 – 50 | 0.25 – 0.50 |
| Medium | 50 – 100 | 0.50 – 1.00 |
| Stiff | 100 – 200 | 1.00 – 2.00 |
| Hard | 200 – 400 | 2.00 – 4.00 |
| Very hard | >400 | >4.00 |

## 4. RESULT AND DISCUSSION

The soil properties of original soil are shown in Table 5.

**Table 5.** Soil properties of sample

| Properties | Value | Standard |
|---|---|---|
| Water content (%) | 61.17 | ASTM D2216 |
| Specific gravity | 2.61 | ASTM D854 |
| Sieve analysis: | | |
| Passing #200 (%) | 97.15 | ASTM D422 |
| Retained #200 (%) | 2.85 | ASTM D422 |
| Liquid limit (%) | 73.75 | ASTM D4318 |
| Plastic limit (%) | 53.77 | ASTM D4318 |
| Plasticity index (%) | 19.98 | ASTM D4318 |
| Sensitivity | 2.14 | ASTM D2166 |
| Optimum Moisture Content (%) | 48.06 | ASTM D698 |
| Maximum Dry Density (g/cm$^3$) | 1.28 | ASTM D698 |
| California Bearing Ratio | 2.65 | ASTM D1883 |

Based on AASHTO, the soil is classified as A-7-5 (clay) with very poor *GI* value. This soil samples have low strength and are unsuitable for subgrade materials. While according to USCS, the soil is classified as sandy elastic silt. Changes in soil properties due to the inclusion of added materials are presented and discussed appropriately.

### 4.1 Atterberg Limit

Atterberg limit tests were carried out to compare the direct effect of CSA, RHA, SDA, and SSP on the consistency limit of clay soil. Figure 1 shows that the effect of CSA + SSP on consistency limits. It is observed that the addition of 2% CSA + 5% SSP decreases 71% in the value of the plasticity index. At the addition of 5% CSA + 5% SSP decreases 75% and at 8% CSA + 5% SSP the value of the plasticity index reduces by 87% from origin soil. Figure 2 shows that the value of plasticity index fluctuated due to addition of RHA + SSP to the soil. The addition of 2% RHA + 5% SSP to the soil reduces significantly the 56% plasticity index. At the addition of 5% RHA + 5% SSP climbed to 19.76 which is almost the same as the original soil. With the addition of 8% RHA + 5% SSP, the value declined by 34%. Figure 3 shows that the plasticity index by adding SDA + SSP to the soil there is reduction considerable, ranging from 61 – 65%. By adding 2% SDA + 5% SSP, 5% SDA + 5% SSP, and 8% SDA + 5% SSP the value of the plasticity index remained stable. The effect of CSA, RHA, SDA are shown in Table 6, Figure 1, Figure 2, and Figure 3.

**Table 6.** Effect of CSA, RHA, and SDA on consistency limits

| Admixture | LL (%) | PL (%) | PI (%) |
|---|---|---|---|
| Clay Soil + 2% CSA + 5% SSP | 51.54 | 45.71 | 5.82 |
| Clay Soil + 5% CSA + 5% SSP | 51.37 | 46.30 | 5.07 |
| Clay Soil + 8% CSA + 5% SSP | 52.21 | 49.54 | 2.67 |
| Clay Soil + 2% RHA + 5% SSP | 49.67 | 40.97 | 8.70 |
| Clay Soil + 5% RHA + 5% SSP | 49.63 | 29.86 | 19.76 |
| Clay Soil + 8% RHA + 5% SSP | 50.67 | 37.50 | 13.17 |
| Clay Soil + 2% SDA + 5% SSP | 50.04 | 42.96 | 7.08 |
| Clay Soil + 5% SDA + 5% SSP | 49.60 | 41.82 | 7.78 |
| Clay Soil + 8% SDA + 5% SSP | 50.20 | 43.30 | 6.90 |

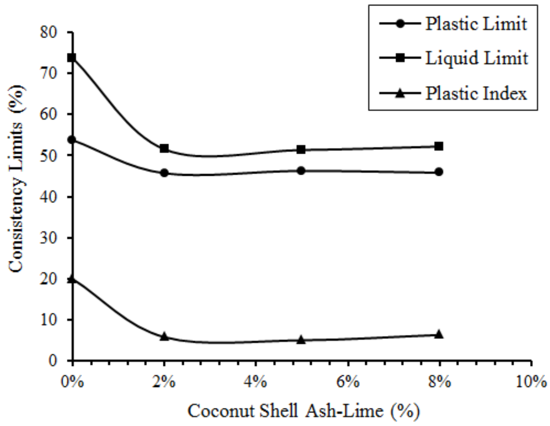


**Figure 1.** Effect of CSA + SSP on consistency limits

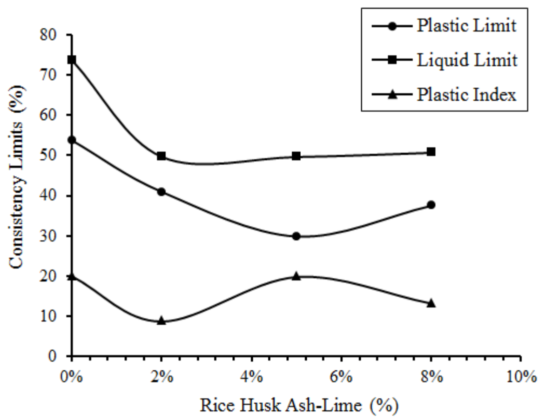


**Figure 2.** Effect of RHA + SSP on consistency limits

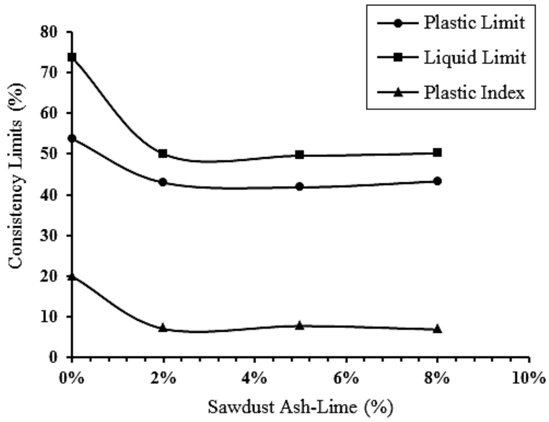


**Figure 3.** Effect of SDA + SSP on consistency limits

### 4.2 Unconfined Compressive Strength

Unconfined compressive strength tests were conducted on both undisturbed and remolded soils. The initial sensitivity value of the soil is 2.14. With the addition of 2% CSA + 5% SSP to the soil reduced to 1.55 and continued to reduce moderately to 1.25 in addition of 5% CSA + 5% SSP. By adding 8% CSA + 5% SSP to the soil increases markedly to 1.90. The addition of 2% RHA + 5% SSP declines the value of soil sensitivity moderately to 1.65. The addition of 5% RHA + 5% SSP the soil climbed slightly to 1.85 and continue by adding 8% RHA + 5% SSP to the soil increases significantly to 3.31. The addition of 2% SDA + 5% SSP the value of soil sensitivity decreases to 1.57 and continue to decreace but more moderately to 1.09 at 5% SDA + 5% SSP. By adding 8% SDA + 5% SSP increases swiftly to 1.27.

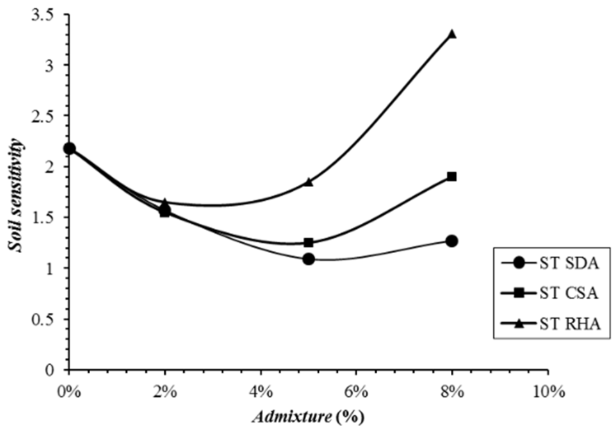


**Figure 4.** Sensitivity of at various percentages of CSA, RHA, SDA, SSP

Here it can be seen that the level of soil sensitivity has increased after the addition of 5% ash + 5% SSP. The effect of CSA, RHA, SDA, and SSP on the unconfined compressive strength for the stabilized soil samples are shown in Figure 4 and Table 7.

**Table 7.** Soil sensitivity of various percentages

| Admixture | ST |
|---|---|
| Clay Soil + 2% CSA + 5% SSP | 1.55 |
| Clay Soil + 5% CSA + 5% SSP | 1.25 |
| Clay Soil + 8% CSA + 5% SSP | 1.90 |
| Clay Soil + 2% RHA + 5% SSP | 1.65 |
| Clay Soil + 5% RHA + 5% SSP | 1.85 |
| Clay Soil + 8% RHA + 5% SSP | 3.31 |
| Clay Soil + 2% SDA + 5% SSP | 1.57 |
| Clay Soil + 5% SDA + 5% SSP | 1.09 |
| Clay Soil + 8% SDA + 5% SSP | 1.27 |

## 4.3 Compaction

The variation of MDD and OMC with CSA, RHA, SDA, and SSP content are shown in Table 8, Figures 5 and 6, respectively. It has been observed, generally, that MDD and OMC decrease with increasing addictive content. The addition of 2% CSA + 5% SSP to the soil decreases the MDD value to 10% and OMC 53%. The addition of 5% CSA + 5% SSP, MDD decline 16% and OMC 56% and continue to decline but more slightly to 18% MDD and 34% OMC by adding 8% CSA + 5% SSP. The MDD value by the addition of 2% RHA + 5% SSP, 5% RHA + 5% SSP, and 8% RHA + 5% SSP declines swiftly to 1.23, 1.11, 1.07, respectively. MDD value declined 4 - 16% while the value of OMC reduced 22 – 38%. Adding 2% SDA + 5% SSP to the soil reduces to 1.17 and remained stable at 5% SDA + 5% SSP and 8% SDA + 5% SSP. The value of OMC of the addition of CSA + SSP fuatuated around 20%.

**Table 8.** MDD and OMC at Various of CSA, RHA, and SDA

| Admixture | MDD | OMC |
|---|---|---|
| Clay Soil + 2% CSA + 5% SSP | 1.15 | 22.81 |
| Clay Soil + 5% CSA + 5% SSP | 1.08 | 21.20 |
| Clay Soil + 8% CSA + 5% SSP | 1.05 | 31.88 |
| Clay Soil + 2% RHA + 5% SSP | 1.23 | 37.33 |
| Clay Soil + 5% RHA + 5% SSP | 1.11 | 29.70 |
| Clay Soil + 8% RHA + 5% SSP | 1.07 | 32.44 |
| Clay Soil + 2% SDA + 5% SSP | 1.17 | 20.19 |
| Clay Soil + 5% SDA + 5% SSP | 1.17 | 20.40 |
| Clay Soil + 8% SDA + 5% SSP | 1.15 | 20.90 |

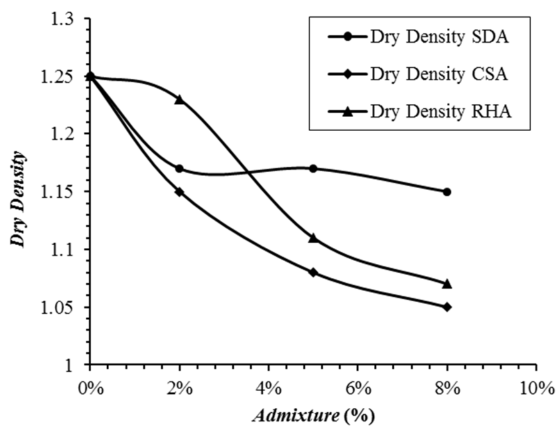

**Figure 5.** MDD at various percentages of CSA, RHA, SDA, and SSP

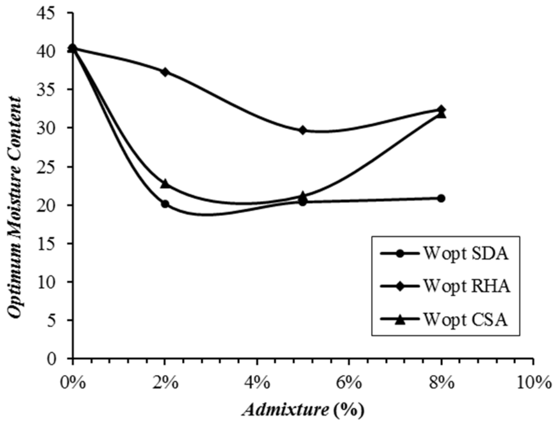


**Figure 6.** OMC at various percentages of CSA, RHA, and SDA

## 5. CONCLUSION

Testing of the physical and mechanical properties of the soil was carried out by adding CSA RHA, SDA, and SSP. On the addition of CSA and SSP, the value of the plasticity index decreased by a maximum of 87% from the original soil at the addition of 8% CSA + 5% SSP. MDD and OMC values experienced a maximum decrease in the combination of adding 5% CSA + 5% SSP. And the level of soil sensitivity decreased to a maximum of 43% at the addition of 5% CSA + 5% SSP.

On the addition of SDA and SSP, the value of the plasticity index decreased by a maximum of 65% in the combination of 8% SDA + 5% SSP. MDD and OMC values experienced a maximum decrease in the combination of adding 5% SDA + 5% SSP. And the level of soil sensitivity decreased to a maximum of 50% at the addition of 5% SDA + 5% SSP.

On the addition of RHA and SSP, the value of the plasticity index decreased by a maximum of 56% at the addition of 2% RHA + 5% SSP. MDD and OMC values experienced a maximum decrease in the combination of the addition of 5% RHA + 5% SSP. And the level of soil sensitivity decreased to a maximum of 50% at the addition of 2% SDA + 5% SSP.

From the tests that have been carried out, the addition of CSA and SSP lowers the value of the plasticity index, MDD, and OMC compared to other ingredients, seen in the combination of 8% CSA + 5% SSP. Meanwhile, the addition of SDA and SSP reduced the level of soil sensitivity significantly, namely the addition of 5% SDA + 5% SSP.

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