



The Effect of WHA and Lime for Shear Strength of Clay Stabilized by Cement

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Abstract. Cement, lime, and Rice Hush Ash (RHA) of high plasticity clay have all been used to reduce compressibility. With the use of the additive, the clay's shear strength and bearing capacity increased. Usage waste material, Wooden Hush Ash (WHA), is tiny. The silicate content of WHA is almost the same as RHA. This study aims to utilize ASK for a stabilization material of high plasticity clay to increase shear strength. Unconfined Compression Strength (UCS) tests were performed to compare the UCS value of clay; clay with 5% cement; clay with lime; clay-cement with WHA; clay-cement with lime and WHA; and clay with lime and WHA. Before the UCS test, the sample was separated into two groups: with and without curing for 28 days, and with and without soaking for 4 days. While in conditions unsoaked, the q_u value is uniform. Results show, without curing and soaked, q_u values of all variations have the same value in the range of 350 kPa to 380 kPa. In conditions with curing 28 days with and without soaked, q_u values range from 365 kPa to 485 kPa for mixtures with WHA and a combination of lime with ASK. While adding of 10% lime additive increases the q_u value to >1100 kPa UCS testing results prove, with and without curing and soaked, lime is more optimal to increase the value of UCS than WHA. Replacement lime with WHA by 4% to 6% increases the q_u value from 160 kPa to 465 kPa and 485 kPa and 110 kPa to 440 kPa to 475 kPa of soaked and unsoaked condition respectively. WHA can be used to reduce lime in soil stabilization.

Keywords: clay, cement, lime, stabilization, wooden hush ash

INTRODUCTION

Soil is a support for the foundation of a building. Therefore, it is necessary to study the basic properties of the soil, such as its origin, grain size distribution, water drainage ability, compressibility, shear strength, load-bearing capacity, and others [1]. Soils can be classified into three groups: coarse-grained soils (sand, gravel), fine-grained soils (silt, clay), and mixed soils [2].

Expansive clay is a clay with a unique property: expansive mineral content with a high ion exchange capacity, which means expansive clay has a high potential for shrinkage if water content changes. The expansive soil will expand as the water content increases, resulting in an increase in pore water pressure and the emergence of swelling pressure. When the water content is reduced to the limit of shrinkage, shrinkage will occur. Buildings can be damaged

by such swelling and shrinkage properties. [3]. Expansive clay has a high shrinkage value, meaning it expands as the water content increases and shrinks if the water content decreases. If a construction is built on high plasticity clay, it will experience damage due to the characteristic of expansive clay, such as the soil becoming soft when swelling and cracking when shrinking. Improvement of expansive clay soil can be done by adding lime [4]. Utilizing lime with percentages of 6%, 8%, 9%, 10% as a substitute for cement in stabilizing expansive clay soils with a long treatment time for soil bearing strength and development [5]. With a curing duration of 7 days, 14 days, and 28 days, adding 6% rice husk ash and 4% cement [6]. After the soil has been stabilized, the UCS, CBR, and swelling potential values can be evaluated to improve expansive clay. Samples can be treated in as little as 7, 14, or 28 days [7][8].

Waste of Wood processing, either in the form of skin wood, chips wood, or saw-dust is commonly thrown in the soil or burned. When wood waste (WHA) is buried in the soil, it decomposes. Wood ash has a chemical composition similar to rice husk ash (RHA), which has been utilized as an addition to replace pozzolanic materials like cement and lime.

Some of the findings of research using lime as a stabilizing agent can be explained as follows::

Research on the effect of adding lime with the length of curing time on strength and development [9] [10] [11] [12] found that the highest soil bearing capacity value was found in a mixture of 8% lime with a curing period of 28 days, compared to curing 0, 14 days, 7 days, and 4 days. There was a significant difference between the unsoaked CBR and the soaked CBR due to the sample treatment of soaked CBR soaked in water which resulted in the soil surface tending to be soft.

Research on the effect of cement stabilization on the swelling of expansive clay [13] [14]. Expansive clay stabilized with cement (0, 5, 10, 15, and 20%) increased the bearing capacity of the soil in the cement mixture by 20%, resulting in a 767.01 percent increase over the original soil's bearing capacity. The maximum dry soil density value increases as cement content increases, but the optimal soil moisture content value falls as cement content increases.

Subsequent research showed that the results of the mechanical properties test of soil mixed with 6% sawdust revealed that the swelling value reduced by 26.53 percent and the swelling pressure decreased by 47.31 percent the longer the treatment period. The result of the effective treatment period achieved is a treatment period of 4 days, however, because the treatment period is more than 4 days the results tend to be constant [15].

This research was conducted to determine the UCS value of expansive clay with a mixture of lime and wooden hush ash (WHA). Mix the soil with cement first, and then mix variations of lime and WHA.

METHODOLOGY

The soil samples examined came from the Muara Fajar area, Pekanbaru City. The cement used was of the PCC type, the lime used was quick lime purchased from the production of PT Brataco, and sawdust ash obtained from sawmill residues at the Somel factory in the Teratak Buluh area, Siak Hulu District, Kampar.

Preliminary testing includes soil properties test of physical and mechanical properties of clay. To determine the soil classification, soil consistency test was carried out with the atterberg limit and hydrometer test. As for the mechanical properties, compaction testing was carried out on the original soil to obtain the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). Samples mixing, for manufacture of UCS test samples, is done by mixed of the dry weight of clay, cement, lime, and wood husk ash (WHA) with water at OMC of clay. Variations of samples can be 95% clay + 5% cement (Cl-C); lime from 4 to 10% with clay; WHA 4 to 10% with clay; clay-cement (Cl-C) with lime or /and WHA (see **Figure 1**).

Unconfined Compressive Strength (UCS Test) This is done by mixing clay and cement which is locked at 90% condition, then 10% mixture of lime and WHA with different variations. The water content used in the mixture is the original optimum moisture content of clay. Samples are printed in UCS tubes sample (height=116mm, dia. 55mm) with compaction efforts according to standard proctor compaction energy. the curing of the test sample was carried out for 28 days and soaked for 4 days and given 4 treatments to the test sample, including:

1. Non curing and unsoaked, (NC-US)
2. Non curing and soaked, NC-S
3. Curing and unsoaked, C-US
4. Curing and soaked, C-S

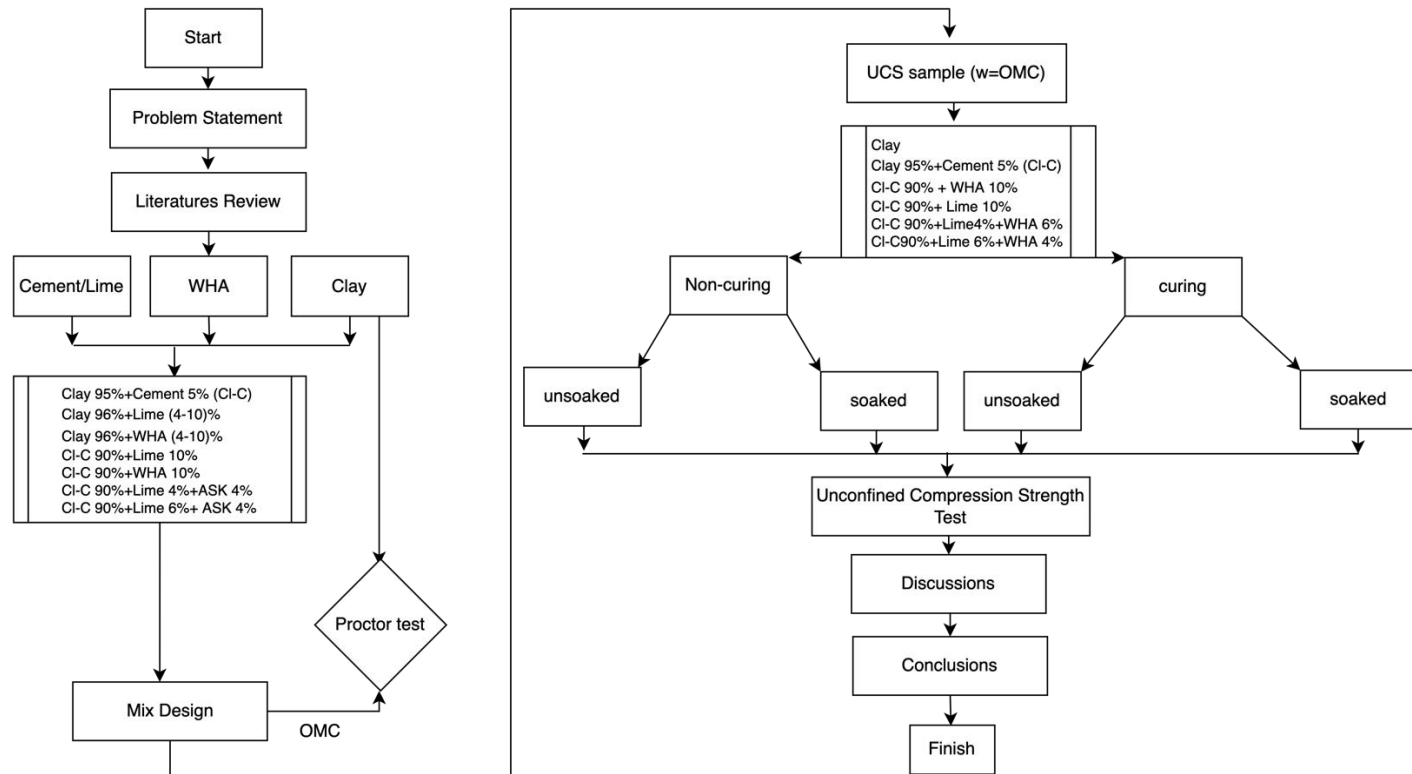


FIGURE 1. Flow Chart of Research

RESULT AND DISCUSSIONS

Result

The data collected for this study obtained from a number of laboratory tests, which were then organized and presented in a logical and understandable manner to allow for analysis. The atterberg limit, a compaction test using the standard Proctor method, and laboratory CBR values with four treatments were the results of the laboratory analysis.

The original soil in field conditions, which is fine grain soil, has a liquid limit (LL) value of 69.15% and a plastic limit (PL) 32.65 and a plasticity index value (IP) of 36. 50% is a high plasticity clay, according to the Atterberg plasticity curve, and the USCS classification with the symbol CH. The swelling potential level of the original soil is in the High category [15].

The Atterberg Limit test results on **Table 1** show that the addition of cement, lime, wood husk ash (WHA), or a combination of cement, lime and wood husk ash changes the soil classification from clay (CH) to silt (MH).

The laboratory compaction test using the Standard Proctor method obtained an optimum moisture content of 29.0% and a maximum dry density of 13.70 kN/m³. The water content of the optimum water content will be used as the water content for making samples for Unconfined Compression Strength (UCS) testing

TABLE 1. Atterberg Limit Test Results

| No | Mix Variation | LL (%) | PL (%) | Swelling Pot | USCS |
|----|----------------------|--------|--------|--------------|------|
| 1. | Clay 95% + Cement 5% | 63,15 | 37,92 | High | MH |
| 2. | Clay 96% + Lime 4% | 65,38 | 43,53 | High | MH |
| 3. | Clay 94% + Lime 6% | 62,51 | 42,17 | Medium | MH |

| | | | | | |
|-----|-----------------------------|-------|-------|--------|----|
| 4. | Clay 90% + Lime 10% | 57,86 | 41,00 | Medium | MH |
| 5. | Clay 96% + WHA 4% | 60,13 | 43,03 | Medium | MH |
| 6. | Clay 94% + WHA 6% | 58,36 | 41,07 | Medium | MH |
| 7. | Clay 90% + WHA 10% | 55,98 | 36,78 | Medium | MH |
| 8. | Cl-C 90% + Lime 10% | 63,26 | 51,01 | Low | MH |
| 9. | Cl-C 90% + WHA 10% | 54,47 | 30,47 | Medium | MH |
| 10. | Cl-C 90% + Lime 4% + WHA 6% | 58,76 | 40,74 | Medium | MH |
| 11. | Cl-C 90% + Lime 6% + WHA 4% | 60,31 | 45,27 | Medium | MH |

Note: WHA = Wooden Husk Ash Cl-C = Clay 95% + Cement 5%

According to **Table 1**, the addition of cement or lime of less than 5% has not changed the swelling potential class, but the addition of 6% lime or more reduces the swelling potential class to medium. The combination of adding soil and husk ash; cement, lime, husk ash (lime content <10%) were also shown to reduce the swelling rate to medium. On the other case, the addition of 10% lime to the clay and cement mixture makes the swelling potential low.

The results of UCS testing on samples treated with or without curing for 28 from and with or without soaking for 4 days are given in **Table 2**.

TABLE 2. Unconfined Compression Strength Test Results

| Mix Variation | qu (kN/m ²) | | | |
|------------------------------|-------------------------|--------|------------|--------|
| | Non-Curing (NC) | | Curing (C) | |
| | unsoaked | soaked | unsoaked | soaked |
| 1. Original Soil | 182,84 | 36,22 | 252,23 | 34,44 |
| 2. CC 90% + WHA 10% | 356,54 | 30,34 | 435,02 | 365,10 |
| 3. CC 90% + Lime 10% | 1133,20 | 276,46 | 1674,23 | 380,32 |
| 4. CC 90% + Lime 4% + WHA 6% | 364,78 | 96,20 | 465,64 | 441,69 |
| 5. CC 90% + Lime 6% + WHA 4% | 368,57 | 157,11 | 485,76 | 475,30 |

The results of UCS testing on samples treated with or without curing for 28 from and with or without soaking for 4 days are given in **Table 2**

Discussions

After testing the consistency limit, a standard proctor test was carried out and the data obtained from the test results were both used as reference data for mixing the test objects in the UCS test and an analysis of the effect of the mixture was obtained. During the curing time, The pozzolanic reaction caused the clay granules to react with cement and rice husk ash or cement and lime to form strong bonds, resulting in larger and denser granules. The strong bond formed is a function of time; the longer the duration, the stronger the bond formed. In addition, the bond strength to form dense granules is determined by the composition of the added material, such as cement and wood husk ash or cement and lime. The high content of cement, wood husk ash, and lime does not necessarily increase the strength of the mixture

In general, the unconfined compressive strength of the mixture cured at 28 days was higher than that of the uncured (Figure 2, Figure 3, Figure 4, Figure 5). In the clay-cement mixture (Cl-C) plus 10% WHA (**Figure 2**), the difference in the value of the unconfined compressive strength is relatively small. This means that the reaction between the mixture and WHA to form a pozzolanic bond is fast (<6 hours). Figure 2 shows a high difference between the value of the unconfined compressive strength of the cured and uncured mixture. So, the occurrence of a strong bond between the mixture with lime takes a longer time.

Soaking was aimed to make the sample saturated. During the saturation process, the sample pores filled with air was replaced with water. The entry of water into the pores of the soil can also make the bonds of the soil grains loose and the grains dissolve in water. Loosening or weakening of soil bonds decreases soil strength.

Looking at **Figure 3**, the difference in the unconfined compressive strength of the soaked and unsoaked samples is very large. When soaked, the bond between the clay and WHA loosens/weakenes when water enters the pores. The loose/weakening of the bond could be because the binding time has not been elapsed or because there is some wooden husk ash that does not react with the soil due to high concentration.

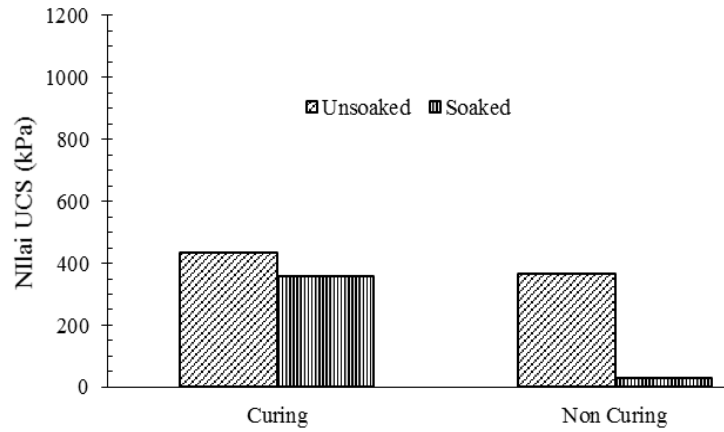


FIGURE 2. CI-C 90% + WHA 10%

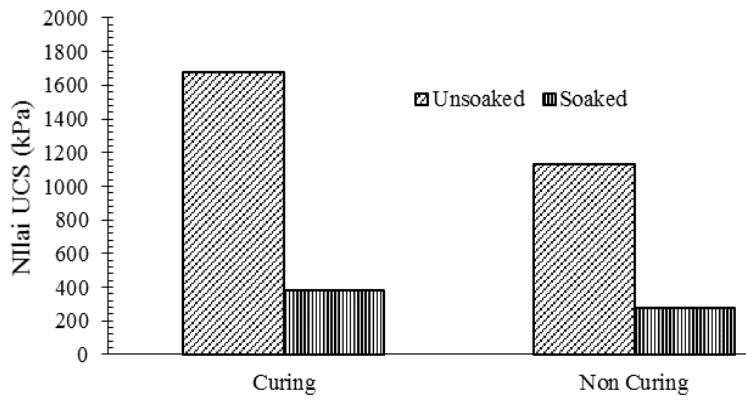


FIGURE 3. CI-C 90% + Lime 10%

The difference in the values of the unconfined compressive strength of the samples soaked with and without curing was around 100 kPa smaller in the soil with 10% lime mixture (Figure 4) than in the soil plus 10% WHA (335 kPa difference). Because there is still a bonding process between lime and soil during the soaking phase, or the composition of the mixture is better, there is a smaller difference in the mixture with 10% lime.

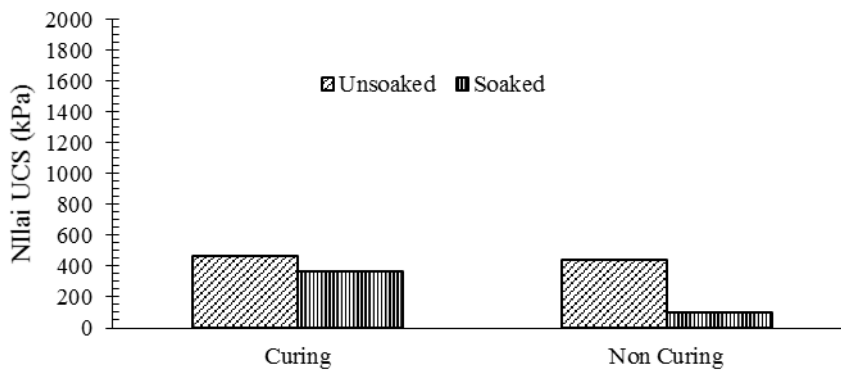


FIGURE 4. CI-C 90% + Lime 4% + WHA 6%

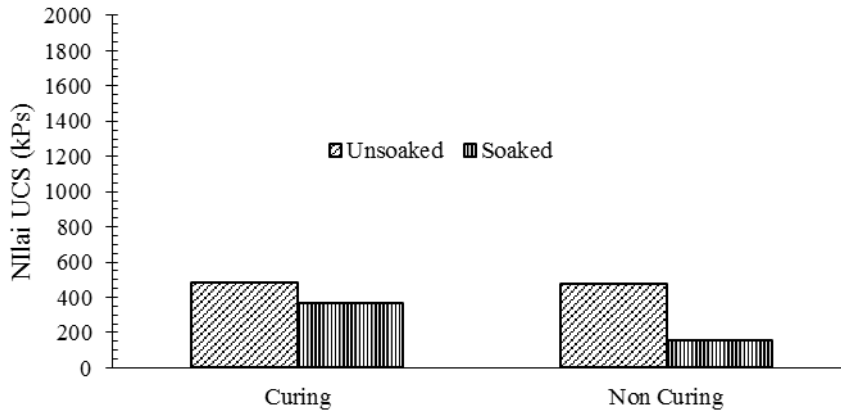


FIGURE 5. Cl-C 90% + Lime 6% + WHA 4%

Soil cement 90% + lime 10% has the greatest value for the UCS test results. The value of q_u obtained was 1674.23 kPa which was obtained based on soaking and unsoaked conditions. The increasing value of Unconfined compressive strength (UCS) was due to the pozzolanic process between calcium hydroxide (CaOH) from the soil reacting with silicate (SiO₂) and aluminate (Al₂O₃) from additives to form a soil binder material consisting of calcium silicate or aluminate silicate. The reaction of Ca²⁺ ions with silicates and aluminates from the surface of clay particles forms a cement paste (hydrated gel) so that it binds soil particles. [16]. Kazemian has opinion that the cementation reaction that occurs in the soil mixture with additives forms new, harder granules so that they are stronger to withstand the given load, in other words, the addition of lime will strengthen the original soil by increasing the CBR value.

The soil mixture of 90% Cl-C + 6% lime + 4% WHA had the second largest value in the UCS test with the condition of curing and not soaking. Each test value is 485.76 kPa for the value of q_u . The soil mixture of 90% cement + 4% lime + 6% WHA is a mixed variation that has the third largest value in the UCS test with a q_u value of 465.64% with the condition of the samples being cured without soaking.

Influence of Water Content

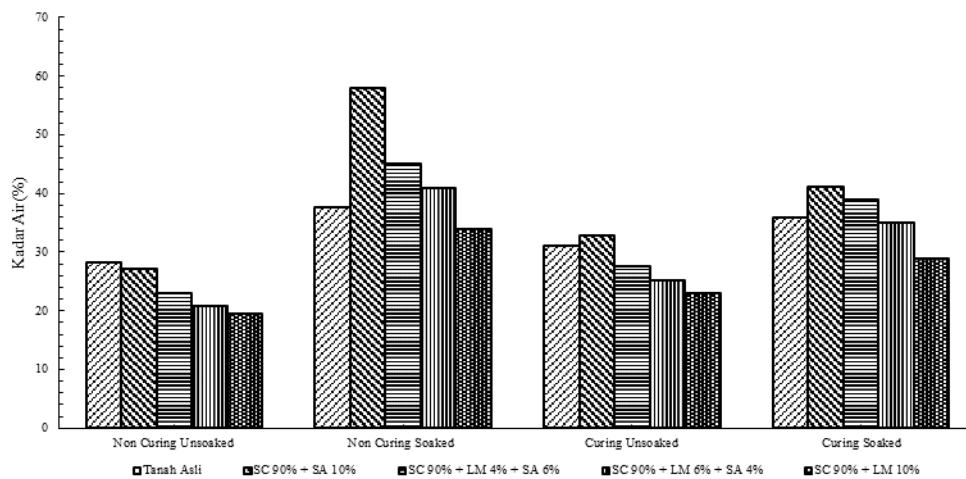


FIGURE 6. Water Content of UCS Samples on All Conditions

Figure 6 shows that the water content increased after being treated from conditions without curing and not soaking, curing and not soaking, curing and soaking, without curing and soaking. The highest water content value was found in the Cl-C 90% + WHA 10% test object with conditions without curing and soaking. This water content causes a

decrease in the q_u value in the CI-C 90% + WHA 10% test object, the high-water content reduces the bond between soil, cement, and sawdust ash. The greater use of sawdust ash during soaking conditions increases the water absorption capacity of the test object and reduce the value of q_u . For samples that are soaked without curing, the value of water content is greater when compared to samples that are cured only, due to the influence of the water content when the samples are soaked. The increased water content in the soaked test object decreases the value of q_u compared to the value of q_u in the samples that is only soaked

CONCLUSIONS

The addition of wood husk ash, lime, and cement was proven to increase the value of the unconfined compressive strength of clay with a high level of plasticity. The addition of 10% wood husk ash increased the unconfined compressive strength of more than 200% by curing, while without curing and soaking it decreased the value of q_u .

Addition of 10% lime increased the value of unconfined compressive strength, 100% without curing and 600% with 28 days curing for unsaturated sample conditions. The saturated sample test, because of 4 days of immersion, there was an increase in q_u greater than 800%. The addition of lime is proven to be effective in preventing the entry of water in the pores of the soil when the soil is soaked in water.

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