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THE DURABILITY OF LIME AND RICE HUSK ASH IMPROVED EXPANSIVE SOIL

*Yulvi Zaika[1] and Eko Andi Suryo[2]

[1,2]Engineering Faculty, University of Brawijaya, Indonesia

*Corresponding Author, Received: 30 June. 2019, Revised: 1 Jan. 2020, Accepted: 13 Jan. 2020

ABSTRACT: Rice husk is as waste farm material in Indonesia used as fuel for making bricks and similar materials. Rice husk ash (RHA), a combustion product that wasted previously, currently being investigated for use as a mixture of cement or soil stabilization material. This study aims to investigate the mixture of lime and RHA as a stabilizing agent. Due to minor contains of calcium in RHA, its utilization for stabilization materials needs to be combined with lime that can increase the stability of expansive soils and shorten the curing time as well since it is needed for binding of molecules from soil minerals. By determining the optimum mixture of 4% lime and 6% RHA expressed as the ratio of the dry weight of the material, it was found that the CBR of stabilized soil is greater than that of natural soil, a mixture of expansive soil with lime and expansive soil with RHA itself. The dry wet cycle is assumed as a change that occurs in the environment due to the season. The amount of water absorption which is indicated by an increase in weight and volume of soil shows the durability of additive to environment changes and have an effect on strength and swell potential of expansive soils.

Keywords: RHA, Lime, Durability, Dry Wet Cycle, Strength, Swelling

1. INTRODUCTION

Expansive soils are soils that have the potential to shrink and swell under changes in water content. Changes in water content of expansive soils due to the environment condition imposed at the ground surface, vegetation and groundwater fluctuations. An increase in moisture content may be due to precipitation while a decrease in water content may be due to elevated temperatures.

Indonesia is a country that has 2 seasons, namely dry season where temperatures can reach 35 C and rainy season with an average annual rainfall of 2000 - 30000 mm (2018). Changes in groundwater levels will be significantly influenced by season. Areas with expansive soil will have a change in moisture content in the season. The soil will shrink in the dry season and swell in the rainy season. Failure that occurs in the structure above it cannot be avoided.

The problems associated with the expansive soils are not yet widely appreciated outside the area of the occurrence. The amount of damage caused by expansive soil should be a warning. Several methods can be done to build a structure on it such as using deep foundations, remove the troublesome ground and replace it with suitable material, soil reinforcement [1], using additive material that is produced higher strength and lower compressibility than natural soil. Soil improvement methods are often used in road projects rather than using deep foundations because they cover a large area.

The most important binder are limes [2-4] because it can improve expansive soil properties with increasing strength and reduce the shrinkage properties although there are other materials that are also often used such as fly ash [5], gypsum [6] or combination of lime with cement[7], natural pozzolana[8], fly ash [9] and perlite [10]. Lime is often used in conjunction with other additives which have high silica but low calcium content. Calcium content in lime is high enough to improve the performance of other additives which are usually cheaper than lime or even waste material.

Waste material such as steel slag[11] or agricultural products such as bagasse ash[12], rice husk ash[13,14] can be used as a stabilizing material because they have a high silica content and other minerals that are useful for the cementation process of soil minerals.

The population in the country with the main food is rice, husk ash is the remaining material will be available in sufficient quantities. Rice husk ash is used as a concrete mixture, absorbent in wastewater treatment and others. Research on RHA for expansive soils has been carried out [15] where an increase in RHA content will increase the carrying capacity (CBR) with an optimum dosage of 6% and an increase in RHA content will decrease swell potential. Because the results of the addition of RHA reach less satisfactory results, some researchers tried to mix with other materials such as FA and lime [16].

A combination of bagasse and hydrated lime was studied [17] as a stabilization agent for the subgrade layer. The samples were prepared using different content of agents with portion 3:1 for bagasse and lime respectively. The result of this study gives a solution to facilitate to cope environment problems through the reduction of waste material.

Some considerations to choose the additives subtenant include:
1. Availability of materials
2. The influence of these materials on changes in soil properties
3. Workability
4. Costs
5. Durability

The aim of this study is to evaluate the remediation of RHA and lime as a stabilized substance. The durability of the treated material is a major concern in the pavement structure, due to wet and dry conditions. Investigated the occurrence of cracks in the soil due to environmental changes which is one of the factors in the occurrence of slope failure. How long the remediation of material is able to withstand environment change.

Durability is addressed to analyses the longevity of chemical stabilized expansive soil subjected to the environment such as freeze-thaw and wet/dry. The durability of the additive agent is extremely determined to mineralogical and microscopic stabilized soil [19] in which was influenced by additive agent, curing time, freeze-thaw or wet-dry cycle.

Previous studies on soil durability and additives were carried out by [18] which analyzed the effect of curing time on cohesive soil mixtures with lime and natural pozzolan on shear strength which showed that the effect of lime was more dominant than natural pozzolan on changes in friction angle and cohesion.

2. EXPERIMENTAL PROGRAM

The experimental program consists of physical and mechanical tests for natural and remediation soil. Short and long term performance combination lime and RHA compound stabilized soil were investigate in certain curing time. The wet and dry cycle performed as a reflection environment change.

2.1. Material and Method

Undisturbed samples were collected from Ngasem, Bojonegoro village, East Java, Indonesia for investigating the condition of natural soil. Physical and mechanical properties were performed to define the type of soil and potential of swelling of the samples. The experiment is soil plasticity, compaction and California Bearing Ration based on ASTM procedurals.

The disturbed samples were collected to perform the optimum dosage of additive and natural soil. It was the result of compaction and CBR test in unsubmerged and submerge condition.

2.2. Sample Preparation and Mix Design

The natural soil test result is presented in Table 1. Based on USCS and AASHTO classifications, the soil is classified as high plasticity clay and a poor soil type as a road subgrade layer in which the value of soil activity (A) is very high swell potential. The value of un-soaked California Bearing Ratio is 14.7% and soaked CBR is 4.6% at 21,9% moisture content and dry density of 0.82 gram/cm^3.

Table 1 Physical properties of expansive soil

No	Parameters	Value
1	Specific Gravity (Gs)	2,68
2	Liquid Limit (LL), %	104
3	Plastic Limit (PL), %	44.4
4	Shrinkage Limit (SL), %	2.8
5	Plasticity Index (PI), %	59.6

2.3. Natural Soil and RHA

Disturbed samples were prepared for compaction tests with difference RHA content (5%, 6 %, and 6.5%). Atterberg limit is a parameter that can be used to determine the level of the expansiveness of the soil. Fig. 1 shows the change in liquid limit value, plastic limit, shrinkage limit, and plasticity index for remediation of soil.

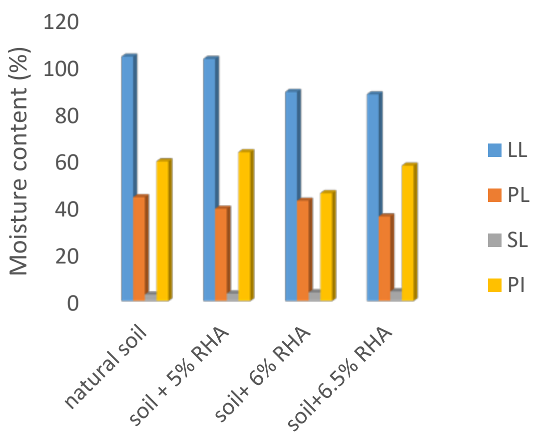

Fig. 1 Parameters of the plasticity of soil

The content of RHA caused an increase in liquid limit while the plastic limit did not change so much that it reduces the plasticity index of the material.

Fig. 2 shows the compaction parameters namely optimum water content (OMC) and maximum dry density (MDD) content of the mixture. Changes in OMC and MDD due to RHA content do not appear to show significant changes.

Investigation of soil strength based on CBR values on soils that have been stabilized with RHA without curing time shows results in Fig. 3. From Fig. 1 to 3 it can be concluded that the concentration of RHA that can give the best results is 6%.

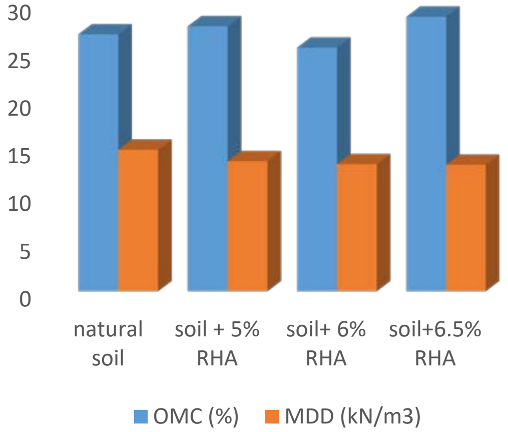

Fig. 2 Parameter of Compaction test for material

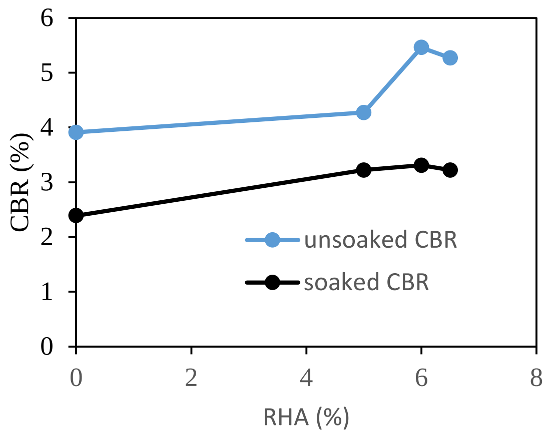

Fig. 3 Combination of lime and RHA without curing time

Harichane at.al.[20] investigated the effect of different curing time for lime improved soil on shear stress. The addition of lime has a significant effect on shear stress particularly beyond 28 days and in samples containing 8% lime for both grey and red soils tested. There is a significant difference in the strength of soil shear mixed with lime, natural pozzolana and a combination of lime-pozzolana. The difference in the content of additive material other than the characteristics of the natural soil will determine to cure time.

By providing sufficient time for curing, the unsoaked CBR will increase by around 13% but the soaked CBR does not show significant changes [15] so it is necessary to provide other additives to improve the performance of the mixture.

2.4. Natural Soil and Lime

Local lime was used in this study as an additive agent. Thus, five different lime content of 0, 6, 8, 9, 10% by soil weight were investigated the optimal lime content. Optimization of lime content is needed to determine the minimum amount of lime needed in stabilized soils to achieve adequate levels of strength to withstand environmental conditions and prevent solubility (Figure 4).

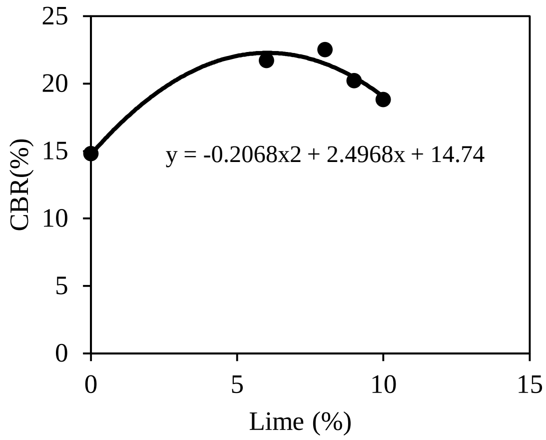

Fig. 4 Changes in CBR Value based on lime improved soil

The second set was tested for swell potential to analyze the changes due to differences in the dosage of lime mixed with the soil as shown in Fig 5. The swell potential could reach less than 0.5% at 4% lime.

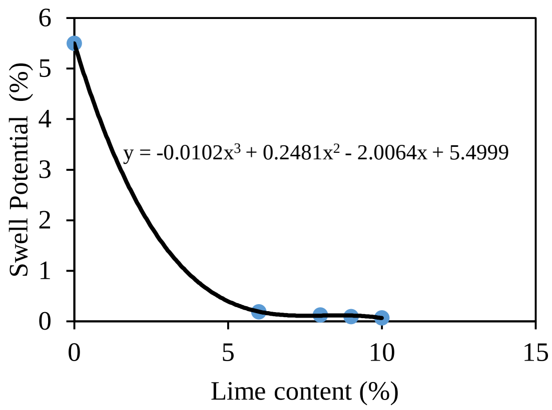

Fig. 5 Decrease in the swell potential of expansive soil due to lime

In this study soil mixtures and lime at a dosage of 4% have increased strength by 62% and reduced swell potential by 90%.

The first step is to find a combination of levels of expansive soil mixture with lime and RHA. With the spirit to use waste material, this research formulates a mixture for durability testing is 6% RHA and 4% lime.

The next step determines the right curing time to increase the durability of the mixture. Fig.6 shows that it takes curing time for 14 days to significantly increase strength.

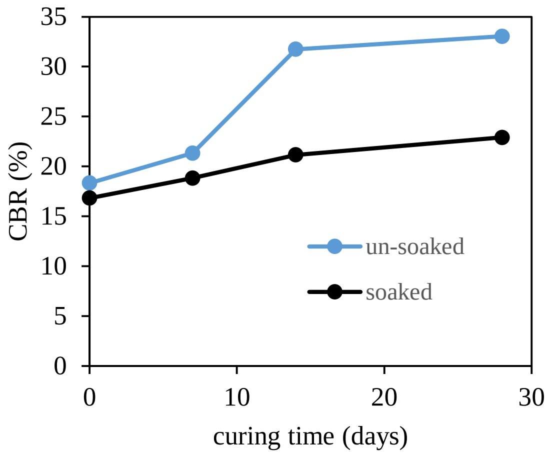

Fig 6. Effect curing time for RHA and lime improved soil

The results of previous studies note that to increase strength is strongly influenced by the strength of soil particles, soil gradation and the bond between the soil particles. For coarse-grained soil, the first and second factors are very dominant, while fine grained soil is largely determined by the second and third factors. Meanwhile, the nature of soil shrinkage which is only in clay soils with the high mineral content of montmorillonite is largely determined by the stability of its ionic bonds which will affect the bonding of soil particles. Things that can change the bonding of these particles include water as a bipolar molecule that easily binds cations from the soil.

3. WET AND DRY CYCLES

In order to know whether the results of the mixture of expansive soils with RHA and lime, reference is taken of the natural soil and a mixture of expansive soils with lime to determine whether the results are better or worse in maintaining their condition due to environmental changes.

Soil specimens are prepared by mix dry natural expansive soil and RHA with hydrated lime. For hydrated lime, additional water shall be added to the lime- soil mixture to facilitate mixing and uniform distribution of the hydrated lime in the soil layer. Durability test specified and compounds stabilized soil is specimens are compacted at optimum moisture content into molds using modified Proctor compaction effort immediately after mixing, placed in sealed containers, and then cured for 7 days. This phase is design as 0th cycles. One cycle will be started at the wet condition in 4 days and the following day the sample is in dry condition. Every cycle the CBR and swell potential will be measured.

After curing, specimens are then placed in a chamber that is subsequently evacuated to a pressure of 24 in. Hg (11.8 psi). After that, the chamber is flooded with distilled water and specimens are allowed to soak. The difference in sample height will be calculated as a change in volume and calculated as potential swell. The carrying capacity of the soil will be measured after dry conditions in one cycle.

The sample height increased rapidly on the first day and grew slowly the following day. Although the sample was air-dried for 4 days but could not evaporate the absorbed water when soaked so that the water content after drying was still higher than before soaking. CBR decline in the first cycle is very large as in Fig. 7. The dry-wet cycle shows a tendency to reduce the strength of the soil until 87%.

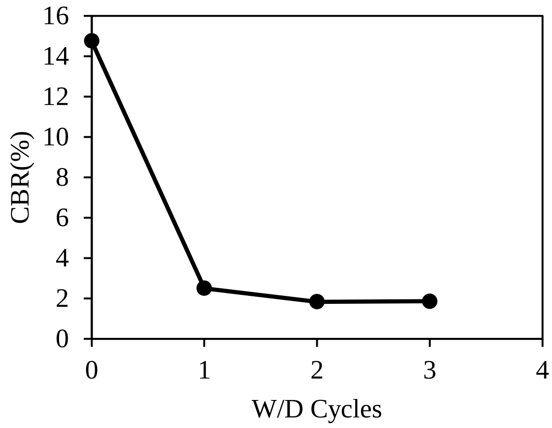

Fig. 7 Influence wetting-drying cycle of natural soil to CBR

The same phenomenon also occurs in the swell as shown in Fig. 8. Because the immersion on the first day is already very large (Figure 9), the binding of water to the next increment in cycles two and three becomes insignificant. This shows the soil during the first rainy season every year has decreased the ability to withstand the load and show corrugation on the road surface. If the swell potential test is obtained at a value of 5.5%, then the wet-dry cycle turns up to 7.1%.

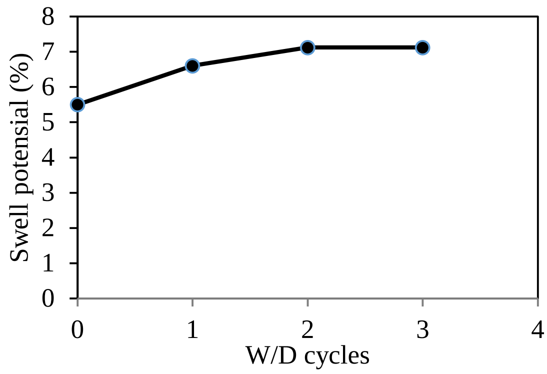

Fig.8 Influence wetting-draining cycle of natural soil to swell potential

Expansive soil is clay soil containing montmorillonite minerals. This mineral structure consists of one sheet of gibbsite, which is between the silica sheets. Because the inter-crystal bond by the Van Der Wall style between the silica sheets is weak and there is a shortage of negative ions in the octahedral so that water and other ions easily enter and release the bond. Montmorillonite crystals have very small size and a very large interest in water. This is the reason why this clay mineral is easy to swell and shrink due to changes in water content.

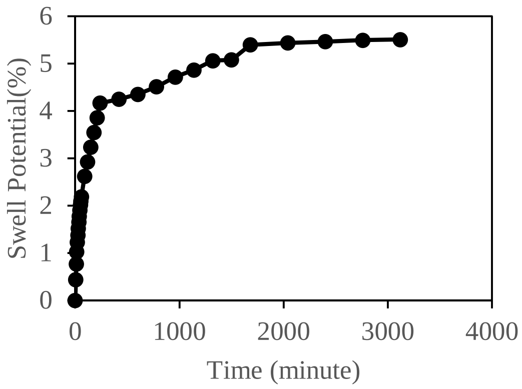

Fig. 9 Swell potential in the first cycle

Additive substances that are mixed with soil result in the process of exchanging alkali cations (Na^+ and K^+) from the soil replaced by cations from additives so that the size of the clay grains increases (flocculation). After the flocculation process occurred, the pozzolanic and hydration process follows in soil stabilization. The pozzolanic process occurs between calcium hydroxide from soil reacting with silicates (SiO_2) and aluminate (AlO_3) from additives to form a binding material consisting of calcium silicate or aluminate silicate. The reaction of Ca^{2+} ions with silicates and aluminate from the surface of clay particles forms a cemented (hydrated gel) paste that binds soil particles. The cementation reactions that occur in soil mixtures with additives form new grains that are harder so that they are more resistant to the load given.

In this study, curing time was also carried out in lime improved soil for seven days. During this time lime and soil are expected to undergo a process of flocculation, hydration, and cementation. However, improved soil has a limit of reliability to environmental changes. The time needed to produce a durable mixture is highly recommended by several factors such as the type of additive and the time needed to achieve maximum strength before being utilized, environmental changes that affect the mixture.

Based on the Chittoori BCS et al. [21] study, all the soils dominated by clay minerals will fail early in the lower additive content. The content of montmorillonite determines the technical characteristics of stabilized soil. Clay soils with the same plasticity will have different properties when given the same dose of additive. In this study, the dosage of lime was indeed under the optimum mixture so that only 3 cycles of strength degradation had occurred.

Wetting is defined as a process leading to an increase in water content of unsaturated soil upon ingress of soil. Drying has defined a process leading to a reduction in water content and degree of saturation of soil due to evaporation and evapotranspiration. In conducting the research the W / D cycle will focus on changes in volume and weight during the wet process and drying process at the same time as the wet process. Because the drying process requires a very long time to return to the initial conditions, the change in volume and weight is more focused on changing the wet conditions for each stage of the cycle. The results of W / D experiments on lime stabilized soils can be seen in Fig. 10 and 11.

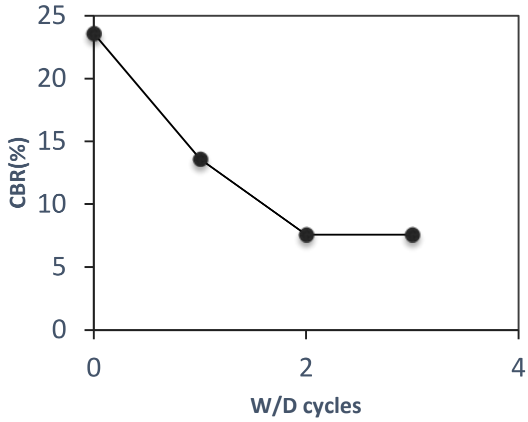

Fig. 10 CBR value in the wetting-drying cycle

Due to the subsequent dry-wet process, the soil strength has decreased, which shows that the lime bonding is not strong, so it is easily removed, so the CBR drops.

In the early stages of adding lime will cause the hydration process of quicklime.

$$CaO + H_2O \rightarrow Ca(OH)_2 + 12\ kJmol^{-1} \quad (1)$$

Mixing of soil and lime will increase Ca^{+2} and pH, cation exchange modification of clay particles that cause aggregation of clay particles. Short-term results are improvements in workability and reduced swell potential (also shrinkage).

Furthermore, the physic-chemical stabilization process depends on the time of treatment. The measure of acidity (pH) will cause the release of Si and Al so that the reaction will occur as follows:

Si + Al + Ca + OH → CAH + CSH + CASH (2)

This is the basic process of the hydro setting reaction where the clinker reaction with water will form a cementitious compound (CSH CASH, etc.). The presence of some chemicals can change the reaction settings:

- Sulfur lead the formation of ettringite which causes swelling
- Nitrate causes a decrease in USCS
- Phosphate can interfere with the hydration process
- Chloride accelerates hydration but leads to the salt formation and reduces the strength
- Other minerals (mica) prevent reactions and cause swelling of swelling

The treated soil is in the first submerging in water causes a potential swell increase of up to 0.5%, then increase until 3% in the first cycle. The following dry-wet cycle of two soil types showed insignificant changes after the first cycle.

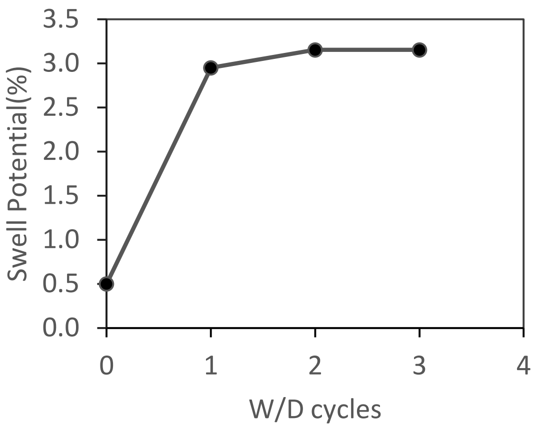

Fig. 11. Swell potential in the wetting-drying cycle of lime improved soil

Guney et al. [22] conducted a cyclic wetting-drying experiment to observe the effects of lime stabilization on the swell potential. In that study, both potential swelling tests and swell pressure were performed on soil specimens that were not treated and treated with lime, subject to cyclic wetting-drying. It observed that the main advance of lime stabilization disappeared after the first wetting-drying cycle, and the potential for swelling increased for the next cycle.

The addition of RHA material in expansive soils and lime gave better results as shown in Fig. 12 and 13. Changes in strength from initial conditions after treatment did not show significant changes until the second cycle and strength decreased very sharply in the third cycle reaching CBR which is 1.1%. Experiments carried out to test the potential for swelling in each cycle did not provide significant changes up to 3 times the dry-wet cycle. The nature of shrink and swell does not reappear even though the strength in the third cycle has decreased dramatically.

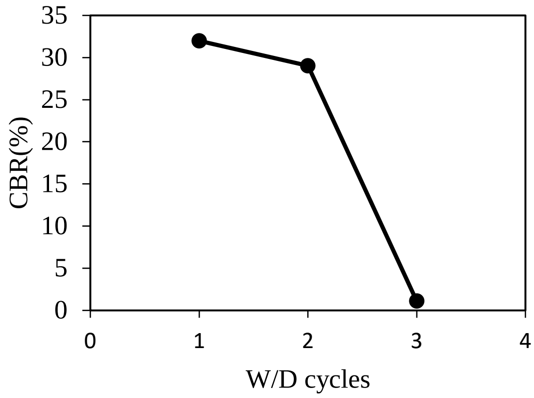

Fig.12. CBR of RHA and lime improved the soil in W/D cycles

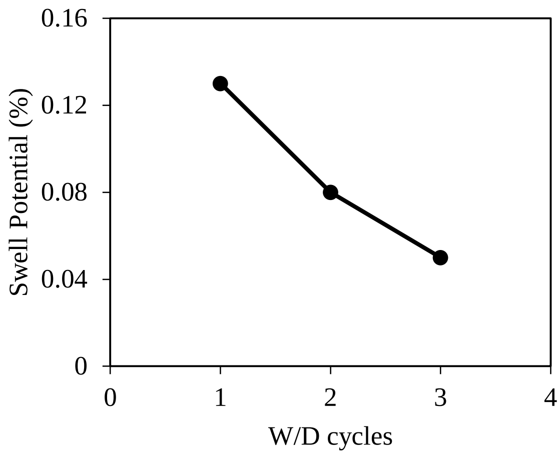

Fig. 13 Swell potential of RHA and lime improved soil

Table 2 Result CBR during cyclic wetting-drying cycles

Type of soil	Cycles	CBR (%)	Strength loss (%)
Natural soil	0	14.76	
	1	2.0	83.06
	2	1.84	87.51
	3	1.84	87.36
Soil +4% lime	1	13.60	7.93
	2	7.6	48.58
	3	7.6	48.58
Soil + 6% RHA	1	23.539	-58.26
	2	11.64	21.14
	3	8.758	40.66
Soil+4%lime+6 %RHA	1	32.0	-116,8
	2	29.04	-96.75
	3	1.108	92.49

The mixture of lime and RHA increases the ability of durability in 2 times the dry wet process where the mixture of lime soil and RHA alone only last one dry wet process. When investigated the effect of changes in weight due to the dry-wet cycle can be read in the following Figure

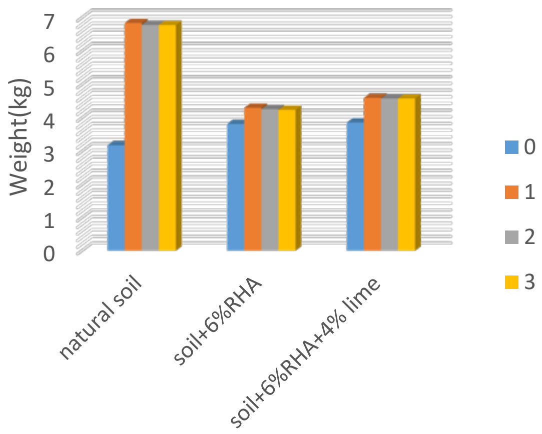

Table 14. Weight of material in every cycle

The increase in the weight of the natural soil in the first cycle reached 100% due to the soil absorbing water from the environment until the 3rd cycle. In soil mixtures with additives, the increase in weight in the first cycle is only about 12%. The RHA bulk density is quite low, ranging from 86 - 114 kg / m^3. At the same volume, the mixture of RHA and soil will have greater weight because of the small and light size of the RHA causing the pores of the mixed soil will become smaller because it is filled with RHA. Changes in weight gain are proportional to changes in strength and swell potential.

4. CONCLUSIONS

The existence of expansive soil has a bad influence on the structure above it where changes in soil volume due to water content due to seasonal changes will cause cracks and lead to instability. Utilization of waste materials such as RHA as expansive soil stabilization materials has a positive effect on the environment in addition to providing economic value without pollution because it does not contain harmful substances.

To get maximum results, RHA combined with lime can significantly increase CBR if done for 7 days in advance. The addition of lime will strengthen and accelerate the bond between soil minerals so that in terms of strength will be higher and so will the swell potential will be lower. In terms of durability, it also seems to be able to last longer than lime and RHA itself. Changes in the environment due to seasonal changes will have a negative influence on the third cycle where it can also be seen from changes in soil weight and volume at each stage of the cycle.

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