Improvement of Expansive Soils Stabilized with Rice Husk Ash (RHA)

Daryati and M A Ramadhan
Program of Vocational Education of Building Construction, Jakarta State University, Jakarta - Indonesia
Corresponding author: agphin@unj.ac.id

Abstract. This study aims to stabilize expansive soil with RHA by 0%, 3%, 6% and 9%. The index properties test with existing soil included lean clay (CL). The existing soil was repaired by adding stabilizing material in the form of RHA as an added material. Based on the specific gravity test, it can be concluded that the addition of RHA reduced the value of specific gravity, made the plastic limit (PL), liquid limit (LL) and plasticity index (IP) decrease, which means that it could improve the properties of the existing physical soil. Standard Proctor Compaction Test (SPCT) with unsoaked method was conducted by giving 3 different number of blows, i.e. 10, 25, and 56 blows in 3 layers. The results show that the optimum moisture content (OMC) was almost constant, while the maximum dry density (MDD) slightly increased and most were added to an additional 6% of RHA. CBR test results show that the existing soil was 0.053 and after adding RHA, increased to 130% in the addition of 6% of RHA.

Keywords: expansive clay, RHA, stabilization

1. Introduction
Road construction consists of several layers, namely surface course, base course, sub base course and subgrade. These layers serve as receivers of traffic loads and spread them to the layers below. Based on observations made in the Sukatani area of North Cikarang, currently most of the area have developed into a residential area and environmental roads often suffer damage in the form of cracks extending along these roads. There is also damage to house buildings that have cracked and part of the land that is descending. Damage to roads and houses can be caused by settlement of the land or can also be caused by depreciation and development of subgrade. Therefore, the technical nature related to subgrade needs attention.

Visually, the soil in the North Cikarang region, precisely in Sukatani Sub-district, Bekasi Regency, which is the sample of this study, has a tendency as an expansive clay because when it is exposed to water, the soil becomes slippery and sticky. Therefore it is necessary to do more in-depth research on the problem of soil behaviour which will be used as a subsoil of a road construction. Clay is soil that has a low carrying capacity, it has the potential to experience enormous development and shrinkage. If the water content increases, the clay will expand. If the water level drops to its shrinkage, then the clay will experience a fairly high shrinkage. These properties can cause damage to environmental roads such as houses experiencing cracks or roads that have decreased or cracked, dams that can easily burst and others.

Based on the above conditions, we need a special treatment to improve the condition of the expansive soil with stabilization methods. There are various methods of soil stabilization, for example
by mechanically using compaction or by mixing with other materials such as asphalt, cement, lime, husk, sand or other materials. The success of this stabilization effort depends on the methods, materials and tools used.

In this study, soil stabilization will be carried out by mixing expansive clay with Rice Husk Ash (RHA). The reason is that the rice fields in these locations are quite extensive. Rice crops are mostly found in many regions in Indonesia because rice is a staple food in Indonesia. However, the part of rice crops which is found and underused and only becomes waste is rice husk. RHA is the combustion residue from rice husk, so that in principle the rice husk ash is the residual combustion waste. However, based on previous studies, it has been shown that rice husk ash has a high SiO$_2$ chemical content and can be used for soil stabilization due to the pozzolan of the chemical. Therefore it is necessary to conduct research on the use of rice husk in this case rice husk is changed first to ashes and thus it is expected to stabilize and reduce the bad nature of clay.

Investigated the effect of RHA on some geotechnical [1]. The results obtained show that the increase in RHA content increased the OMC but decreased the MDD. It was also discovered that the increase in RHA content reduced plasticity and increased volume stability as well as the strength of the soil. Optimal content at 10% of RHA, says that RHA is used to introduce new material which can reduce the cost of chemical stabilization [2]. RHA may be used as chemical stabilizer as it contains high silica content. Blending lime-RHA together, you may enhance the engineering properties of clayey soils. This is advantageous for work construction in the civil engineering field [3]. Besides that, explains that RHA has a potential to improve the characteristics of black cotton soil [4]. Combination of lime and RHA can be used as the optimum consumption of materials for stabilization of sub-base layer in construction of forest roads [5]. An investigation into the effectiveness of RHA on expansive land has been carried out in Las Piñas City, Metro Manila, Philippines. An increase of the RHA content reduces the swelling potential of soil, other strength parameters such as the compaction behaviour and the unconfined compressive strength of the soil decline [6]. Based on this, this study will take the topic of the improvement of expansive soils stabilized with RHA.

2. Experimental setup

This research was conducted at the Soil Mechanics Laboratory, Faculty of Engineering, Jakarta State University. Sampling was carried out to a depth of 1.00 meters with Disturbed Sample and excavation. From the excavation, a number of samples to be tested were obtained. Soil Test aims to determine the physical and mechanical properties of the soil, for example soil moisture content and soil specific gravity. Next, the consistency limits was determined to determine the liquid limit, plastic limit, and the soil plasticity index. Furthermore, a soil grading test consisting of sieve analysis for coarse grained soil content and hydrometer analysis for finely grained soil content passed filter no. 200. Then the compaction test was carried out using the Standard Proctor Compaction Test (SPCT) with unsoaked method, then the California Bearing Ratio (CBR) laboratory test was performed to determine the carrying capacity of the soil and direct shear test of the soil to obtain the soil shear strength parameters.

States that RHA has a big potential as a pozzolanic material considering the silica content and porous structure [7]. According to, controlled burning of rice husk can produce amorphous rice husk ash (RHA) with high silica content [8]. During the process of burning rice husk to ashes, organic substances will be lost and leave a residue that is rich in silica. In addition, heat treatment on silica in rice husk produces structural changes that affect two things, namely the level of pozzolanic activity and the fineness of the ashes. Furthermore, rice husk is composed of roughly 32% cellulose, 21% hemicelluloses, 22% lignin, and 15% mineral ash. The mineral ash is composed of 55 to 97% SiO$_2$, with several other constituents such as K$_2$O, MgO, Fe$_2$O$_3$, CaO, and Al$_2$O$_3$ [9–11]

Demonstrates the effects of rice husk ash (RHA) on the geotechnical properties of soil in stabilized RHA with variation of 5%, 7.5%, 10% and 12.5% by weight of dry soil [12]. It shows that the soil can be made lighter which leads to decrease in dry density and increase in moisture content and reduced free swelling and compressibility due to the addition of RHA with the soil. Besides that, the unconfined compressive strength and shear strength of soil can be optimized with the addition of 10% RHA content. [13] states that the high angularity and friction angle (up to 530) of rice husk contribute to excellent stability and load bearing capacity. With specific gravities ranging from 2.8 to 3.8, rice husk aggregates
are decidedly heavier than conventional granular material. Rice husk aggregates tend to free drying and are not frost susceptible. The constituents of RHA are listed in Table 1.

| Constituent | Composition (%) |
|-------------|-----------------|
| SiO₂        | 67.3            |
| Al₂O₃       | 4.9             |
| Fe₂O₃       | 0.95            |
| CaO         | 1.36            |
| MgO         | 1.81            |
| Loss On Ignition (LOI) | 17.78 |

Table 1. Composition of RHA

In this study, clay stabilization will be carried out by adding RHA with mixing variations: 0%, 3%, 6% and 9%.

The results of testing the existing soil properties index are as follows:

| Physical and Mechanical Properties of Soil | Result |
|-------------------------------------------|--------|
| Soil water content (%)                    | 12.28  |
| Atterberg Limits :                        |        |
| 1. LL (%)                                 | 46.25  |
| 2. PL (%)                                 | 35.18  |
| Grain Size Distribution :                 |        |
| 1. Passing through the No. 200 sieve (%)  | 98.28  |
| 2. Percentage of clay (%)                 | 54.76  |
| 3. Percentage of silt (%)                 | 43.34  |
| 4. Percentage of sand (%)                 | 1.70   |
| Specific Gravity (Gs)                     | 2.669  |

For the California Bearing Ratio (CBR) Test:
1. 0.01”  0.053
2. 0.02”  0.051

Direct shear Test:
1. Ø  14°
2. C  0.92

Based on the data, identification of existing soil was carried out. For fine grains classified according to the A-line on the plasticity chart: PI = 0.73 (LL - 20) = 0.73 (46.25 - 20) = 19.16. With PL = 35.18 and PI = 19.16, from the Unified Soil Classification System (USCS), the existing soil is CL or clay with low plasticity. Based on Chen’s Table (1988) regarding the expansive characteristics of existing soil, including the category of expansive soils with low shrinkage potential. Likewise, if you use the Costet and Sanglerat tables (1981), the existing soil is expansive soils with weak shrinkage.

Furthermore, each variation of the addition of RHA was 0%, 3%, 6% and 9% of the weight of dry soil, was tested for physical properties which included: water content test, specific gravity test and Atterberg limit test and mechanical tests that direct shear test and CBR laboratory tests were carried out with reference to the Indonesian National Standards and with the following results:
Table 3. Laboratory test results

| Percentage of RHA | Water content (%) | Gs | Atterberg limit | Compaction Test | CBR | Direct Shear |
|-------------------|-------------------|----|-----------------|-----------------|-----|-------------|
|                   |                   |    | LL(%) PL(%) IP(%) | OMC gr/cm\(^3\) MDD (%) | 0.1” (%) | 0.2” (%) | C | Ø |
| 0%                | 12.28             | 2.669 | 46.25 35.18 11.07 | 1383 31.44 | 0.053 | 0.051 | 0.92 | 14° |
| 3%                | 6.99              | 2.516 | 40.02 34.38 5.64 | 1305 32.21 | 0.085 | 0.079 | 2.45 | 11° |
| 6%                | 5.87              | 2.411 | 39.18 33.05 6.13 | 1384 32.42 | 0.122 | 0.104 | 3.75 | 6°  |
| 9%                | 4.60              | 2.389 | 42.99 35.37 7.62 | 1406 33.25 | 0.105 | 0.092 | 4.15 | 5°  |

RHA is the residue of burning from rice husk, so that in principle the RHA is a combustion waste. However, based on previous studies showing that RHA has a chemical content that can be used for soil stabilization due to the pozzolan nature of the material. Burned husk has high pozzolanic properties which contain silicate elements, on average SiO\(_2\) is 91.72%. RHA is very rich in silica (Si) which in its oxide is known as silica dioxide. Burnt rice husk will produce silica content reaching >90%. From the research that has been done, the final conclusion is that RHA is very potential to be used in the geotechnical field, especially for soil improvement.

Table 4. Compositions of Mineral RHA

| Mineral                    | Composition (%) |
|----------------------------|-----------------|
| Silica Dioxide (SiO\(_2\)) | 84.16           |
| Aluminium Oxide (Al\(_2\)O\(_3\)) | 4.57         |
| Iron Oxide (Fe\(_2\)O\(_3\))   | 0.37            |
| Calcium Oxide (CaO)         | 3.99            |
| Magnesium Oxide (MgO)       | 3.53            |
| Carbon Dioxide (CO\(_2\))   | 0.51            |
| Loss on Ignition            | 3.8             |

3. Results and discussion

Research through testing conducted on existing soil as listed in Table 2 illustrates the characteristics of existing soil conditions. Judging from the grain distribution, it was found that 98.28% passing through no. 200 sieve. Plasticity Index (PI) of 11.07% and liquid limit (LL) of 46.5%. The results of this study indicate that the existing soil had a Plasticity Index of less than 35% and liquid limit below 55%. It can be concluded that the original soil of the North Cikarang Sukatani area was clay which has a low Plasticity Index. According to USCS, AASHTO and the relationship between PI and LL from the British Standard, existing soils are of low clay plasticity. Likewise, Chen (1988) states that existing soil is classified as expansive soils with low shrinkage potential.

The test results of the sieve analysis shows that the existing soil is a type of clay, it can be seen that the fine-grained soil passed filter No. 200 (0.075 mm) of 98.28%. Because the percentage passed filter No. 200 was more than 50%, it can be concluded that the original soil type was clay. From the identification of the properties of existing soil and analysis of the properties that are less good. This study tried to find alternatives to improve the existing soil by adding stabilization materials in the form of RHA. The results of the original soil mixing study with stabilization materials of RHA will be further explained.

Table 5. Effect of stabilization on specific gravity (Gs)

| Percentage of RHA | Specific gravity |
|-------------------|-----------------|
| 0                 | 2.669           |
| 3                 | 2.516           |
| 6                 | 2.411           |
| 9                 | 2.389           |
With the addition of RHA stabilization material, the specific gravity tends to decrease. From the specific gravity test, the addition of RHA reduces the value of specific gravity because the specific gravity of RHA is 1125 kg/m$^3$ which is much lighter than the soil specific gravity. Besides that, the nature of pozzolan owned by RHA will make the cementation process in the soil which causes the bonding between particles. Some pore cavities will be surrounded by cementation of RHA. That will increase the volume of the grains and further reduce the value of the specific gravity.

### Table 6. Effect of stability on soil consistency

| Percentage of RHA | LL(%) | PL(%) | IP(%) |
|-------------------|-------|-------|-------|
| 0%                | 46.25 | 35.18 | 11.07 |
| 3%                | 40.02 | 34.38 | 5.64  |
| 6%                | 39.18 | 33.05 | 6.13  |
| 9%                | 42.99 | 35.37 | 7.62  |

Mixing with an additional 3% of RHA results in a decrease in the liquid limit from 46.25 to 40.02, which means that the liquid limit value decreases to 6.23 or 13.5%. For blends with 6% added RHA, the liquid limit value dropped from 46.25 to 39.19 which means the liquid limit value dropped by 7.07 or 15.3%. Whereas with the addition of 9% RHA gets a liquid limit value of 3.26 which means there is a decrease of 7%. The biggest decrease occurred in stabilization with the addition of 6% RHA (15.3%).

The plastic limit also decreased by 2.3% for an additional 3% of RHA, 6.1% mixed with additional 6% RHA and by an additional 9% IP RHA decreased by 0.5%. The biggest decrease occurred in stabilization with the addition of 6% RHA (6.1%).

For the soil plasticity index with a mixture with an additional 3% of RHA with native soil resulted in a decrease in IP of 49% and for blends with an additional material of 6% RHA, the IP value decreased by 15.3%. Whereas with the addition of 9% RHA, the IP value decreased by 31.2%. The biggest decrease occurred in stabilization with the addition of 3% RHA (49%).

RHA added material made the plastic limit value (PL), liquid limit (LL) and plasticity index (IP) decrease. This shows that RHA as an added ingredient in improving soil properties cannot change the properties of expansive clay but only slightly improves the properties of the expansive soil.

### 3.1 Compaction test

The compacting test was carried out using the Standard Proctor Compaction Test (SPCT) with unsoaked method and incubation carried out for 3 days and made in 3 layers with variations of collision of 10, 25 and 56 times. The compacting test results obtained the optimum moisture content (OMC) value and the value of Maximum Dry Density (MDD) as follows:

### Table 7. The compacting test results

| Percentage of RHA | OMC (gr/cm$^3$) | MDD (%) |
|-------------------|-----------------|---------|
| 0%                | 1383            | 31.44   |
| 3%                | 1305            | 32.21   |
| 6%                | 1384            | 32.42   |
| 9%                | 1406            | 33.25   |

In an effort to stabilize soil with added material of RHA, the compacting test shows that the optimum water content was almost constant that only slightly increased with the addition of 9% RHA and the increase of not much change was only 1.7% of the optimum water content for existing soil. Whereas MDD increased by 2.5% for an additional 3% of RHA, increased by 3.1% for an additional 6% of RHA and increased by 5.8% for an additional 9% of RHA.

OMC only slightly increased with the addition of the volume of RHA. This was due to the gradation of RHA, which was probably almost the same as the existing soil. This was reinforced by the addition
of relatively few MDDs. This can be interpreted that to compact expansive clay required little additional water. It is also possible that RHA can function as a filler in existing soil particles.

Table 8. CBR test results:

| Percentage of RHA (%) | CBR 0.1" (%) | CBR 0.2" (%) |
|-----------------------|--------------|--------------|
| 0%                    | 0.053        | 0.051        |
| 3%                    | 0.085        | 0.079        |
| 6%                    | 0.122        | 0.104        |
| 9%                    | 0.105        | 0.092        |

Mixed with an additional 3% of RHA resulted in an increase in CBR from 0.053 to 0.085, which means that the CBR value rose by about 0.032 or 60.38%. For mixtures with an additional 6% of RHA, the CBR value rose 0.053 to 0.122, which means the CBR value rose 0.069 or 130%. Whereas with an additional 9% of RHA, a CBR of 0.105 was obtained which means there was an increase of 98%. The biggest increase occurred in stabilization with the addition of 6% of RHA (130%).

CBR of existing soil was 0.053 that was very small. And the increase of RHA could increase the CBR value to 130% which occurred in the addition of 6% RHA.

3.2 Direct shear test:

Table 9. The result of direct shear test:

| Load (Kg) | Normal Tension (kg/cm²) | Maximum Shear Tension (kg/cm²) | Cohesion (kg/cm²) | Ø |
|-----------|-------------------------|-------------------------------|-------------------|---|
|           | 5 10 15                 | 5 10 15                       |                   |   |
| 0%        | 0.154 0.310 0.461       | 0.108 1.521 2.042             | 0.92              | 14.2⁰ |
| 3%        | 0.152 0.310 0.458       | 2.695 3.231 3.688             | 2.45              | 11.1⁰ |
| 6%        | 0.153 0.310 0.471       | 3.952 4.266 4.559             | 3.75              | 6.3⁰ |
| 9%        | 0.152 0.310 0.452       | 4.240 4.521 4.802             | 4.15              | 5.2⁰ |

From the direct shear test results obtained by the value of the direct shear strength obtained from the relationship between the value of normal stress and earth shear stress. Furthermore, we will get the value of soil cohesion and soil shear angle. From various additional variations of RHA, it obtained an increase in the value of soil cohesion (C) and decrease in the soil shear angle. This happened because the mixing of clay and RHA formed a reaction which made the soil hard so that the shear resistance of the soil became stronger.

4. Conclusions

From the research that was carried out, it can be concluded: 1) The original soil is classified as CL, which is clay with low plasticity; 2) The addition of RHA tends to reduce the value of specific gravity; 3) RHA slightly increases OMC and MDD from the soil; 4) Increasing the use of RHA will reduce the soil plasticity index; 5) The addition of RHA can increase the CBR value to 130%, i.e. the composition to 6%; and 6) From various additional variations of RHA, it obtained an increase in the value of soil cohesion (C) and decrease in the soil shear angle.

5. References

[1] Okafor F O and Okonkwo U N 2009 Effects of Rice Husk Ash on Some Geotechnical Properties of Lateritic Soil Leonardo Electronic Journal of Practices and Technologies 15 67-74
[2] Prakash J, Kumari K, and Kumar V 2017 Thermal Convection in a Ferromagnetic Fluid Layer with Magnetic Field Dependent Viscosity: A Correction Applied International Journal of Innovative Research in Science, Engineering and Technology 39(3) 39-46
[3] Munthar AS and Hantoro G. (2000) Influence of Rice Husk Ash and Lime on Engineering Properties of a Clayey Subgrade. Electronic Journal of Geotechnical Engineering, 5 1-13.
[4] Shrivastava D, Singhai AK, and Yadav RK 2014 Effect of Lime and Rice Husk Ash on Index Properties of Black Cotton Soil *International Journal of Engineering Research and Science & Technology* **3**(4) 4030-4033

[5] Nasiri M, Lotfalian M, Modarres A, and Wu W 2016 Use of Rice Husk Ash as a Stabilizer to Reduce soil loss and Runoff Rates on Sub-base Material of Forest Roads from Rainfall Simulation tests *Croatian Journal of Forest Engineering* **150** 116-123

[6] Adajar MAQ, Aquino CJP, Cruz JDD, Martin CPH and Urieta DKG 2019 Investigating The Effectiveness of Rice Husk Ash as Stabilizing Agent of Expansive Soil *International Journal of GEOMATE* **16**(58) 33-40

[7] Hadipramana J, Riza F V, Rahman I A, Loon L Y, Adnan S H, and Zaidi A M A 2016 Pozzolanic Characterization Of Waste Rice Husk Ash (Rha) From Muar, Malaysia *Proc. Int. Engineering Research and Innovation Symposium* **160**(2) 574–583

[8] Rasoul B I 2018 Effect of incineration temperatures to time on the rice husk ash (RHA) silica structure: A comparative study to the literature with experimental work *School of Environment & Technology, University of Brighton, UK*

[9] Kim H S, Yang H S, Kim H J and Park H J 2004 Thermogravimetric Analysis of Rice Husk Flour Filled Thermoplastic Polymer Coposites *Journal of Thermal Analysis and Calorimetry* **76** 395-404

[10] Kumar A, Mohanta K, Kumar D and Parkash O 2012 Properties and Industrial Applications of Rice Husk: a review *International Journal of Emerging Technology and Advanced Emerging* **2**(10) 86–90

[11] Rout A K and Satapathy A 2012 Study on Mechanical and tribo-performance of Rice-husk Filled Glass-epoxy Hybrid Composite. *Material & Design* **41** 131-141

[12] Sarkar G, Islam M R, Alamgir M, and Rokonuzzaman M 2012 Interpretation of Rice Husk Ash on Geotechnical Properties of Cohesive Soil *Global Journal of Researches Engineering Civil and Structural Engineering* **12** 1–7

[13] Rajendran R, Banupriya S, and Dharani R 2016 Stabilization of Soil using Rice Husk Ash *International Journal of Computational Engineering Research* **6** 43–50

**Acknowledgments**

The authors would like to thank the Faculty of Engineering, Jakarta State University, for providing grant funds so that this research can be carried out properly. The author is extremely grateful to colleagues who have collaborated in completing this article.