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Fine-Grained Soil as Subgrades with Coconut Husk Ash

Kenneth Candido[1], Jener Braga, Rodel Gutierrez II, Jeffrey Tambal, Ronald L. Orale
College of Engineering, Samar State University
[1]kennethcandido@ssu.edu.ph

Abstract: The study evaluated the effects of Coconut Husk Ash (CHA) as a stabilizer of fine-grained soil for subgrade/subbase purposes. The CHA with size less than No. 200 sieve with a specific gravity of 0.66 was able to improve soil strength parameters; the effects, however, was sensitive. Maximum Dry Density which is also associated with higher CBR rating was achieved for clay and silt-clay soils at 5.0% CHA content, while silt soil gained its maximum MDD at 2.5% CHA. The data is, however, insufficient to conclude the range of quantity that results into better CBR rating. A similar study may be conducted with an improved number of trials.

Keywords: Soil stabilization, soil improvement, chemical stabilization, silica, pozzolana,

1. Introduction

There are about 36.5 million kilometers of road in the world, with the United States of America (18.06%), India (12.89%) and China (11.26%) having the longest total length of roads (CIA, nd). The durability of roads is not only dependent on the pavement wearing course but also its underlying subgrade and subbases (Schaefer et al., 2008;), the material wherein the road sits. All pavements derive their ultimate support from the underlying subgrade (Yoder and Witzack, 1975). A good subgrade will limit pavement deflections to acceptable limits, minimize differential movement due to shrinkage or swelling of soils and promote uniformity of support. Weaker subgrade essentially requires thicker layers whereas stronger sub grade may require thinner layers (Panchal and Avineshkumar, 2015). A subgrade performance depends on two interrelated characteristics; load carrying capacity and volume changes. (www.pavementinteractive.org/subgrade). The good subgrade must be able to carry the load from the pavement structure without excessive deformation. The carrying capacity is affected by the degree of compaction, moisture content and soil type (ibid). Soils that changes volume excessively due to its exposure to moisture or freezing conditions must be avoided (ibid).

Ideal subgrade and sub-bases are aggregates with a little amount of fines as filler materials. The proportion of soil having a size lower than 0.075 must not exceed 12%, and largest size of soil must be 50mm or smaller (DPWH, 2005). The fine-grained soil is not an ideal type of soil for subgrades, not even for embankment. Requirements for subgrades as stipulated in the Department of Public Works and Highways (DPWH) Blue Book (2005) requires that not more than 15% of the material used to pass the 0.075 mm (US No. 200) sieve. Unsuitable soils for subgrade are those materials containing organic matter, soils with liquid limit exceeding 80 and plasticity index exceeding 55%. The standards also discourage the use of soils with very low natural density (800 kg/cu.m. or lower) and soils that cannot be compacted properly.

In the past, when the bearing capacity of the soil is poor, the following are the options; (a) change the design to suit site condition, (b) remove and replace the in-situ soil and (c) abandon the site (Makusa, 2013). Abandonment of sites due to undesirable soil bearing capacities has dramatically increased, resulting in scarcity of land and higher demand of natural resources (ibid). Today, even the problematic soils such as soft clays and organic soils can be improved by modifying engineering properties of soils to meet strength requirements. Soil stabilization aims at improving soil strength and increasing resistance to softening by water by improving bonding between soil particles (Sherwood, 1993). There are two methods of soil stabilization; mechanical and chemical. The simplest form is compaction, a mechanical method. Chemical treatment consists of the addition of chemicals into the soil to modify the structure and properties of the soil with lime and cement as the two commonly used chemicals (Tao et al., 2016). Fly ash and ash from organic materials such as Rice Hull and other biomass were used to enhance engineering properties of soils. Several studies using organic ash have been presented, common of which is Rice Hull Ash (RHA) with varying effects (Rathan Raj. et.al., 2016; Choobbasti AJ et.al., 2010; Orale RL, 2008; Basha EA. et.al., 2005; Subrahmanyam MS et.al., 1981). The main component of RHA that reacts with chemicals and affect soil stabilization is its silica content which is about 90% (Huston, 1972).

Aside from rice hull, coconut *(cocos nucifera)* production in the Philippines is also voluminous. Despite its reported usefulness, the coconut husk goes to waste, and often rots on-site. Coconut production in the Philippines is about 4.05 million mt in 2015 (PSA, 2016) or about 2.8billion coconut. The husk of coconut is composed of 70 percent pith and 30 percent fiber on a dry weight basis (FAO, nd). Will coconut husk ash have a similar usefulness that of rice hull ash?

2. Objectives

This study aims to determine the impact of CHA to some of fine-grained soils' parameters, specifically it:

2.1 Determined the properties of CHA regarding
 - 2.1.1 Density
 - 2.1.2 Specific Gravity

2.2 Determined the properties of fine-grained soils regarding:
 - 2.2.1 Density
 - 2.2.2 Atterberg Limits
 - 2.2.3 Specific Gravity

2.3 Determined the impact of CHA to fine-grained soils regarding:
 - 2.3.1 Optimum Moisture Content (OMC)
 - 2.3.2 Maximum Dry Density (MDD)
 - 2.3.3 California Bearing Ratio (CBR)

3. Methodology

3.1 Research Design: The study is study is experimental, evaluating the effects to subgrade strength parameters by adding a fraction of coconut husk ash (CHA) into fine-grained soils; specifically clay, silt, and clay-silt mixture. In each group, a sample without CHA, and three samples with 2.5, 5.0 and 7.5% CHA was prepared and was tested at the Soils and Materials Testing Laboratory of Samar State University.

3.2 Raw material Sourcing and Preparation: The fine-grained soil samples (clay and silt) were obtained locally taking into grain size and Atteberg limits in the classification. All soils used were air dried until constant weight was attained and were stored in the laboratory.

The production of CHA was performed by burning a coconut husk using a makeshift kiln up to 150^{o}C for about 5 hours with whitish ash produced. The ash was allowed to cool down and was subjected to sieving using sieve no. 200. The ashes were stored in a tight container to prevent moisture gain and another form of adulteration.

3.3 Laboratory Tests: All tests used the standard procedures recommended by the American Society for Testing and Materials (ASTM) and the Association of American Society of Transportation Officials (AASHTO). There are four tests performed; Sieve analysis (ASTM D 422), Atteberg Limits with Liquid Limit (ASTM D4318-05), Specific gravity (ASTM D854-14), Compaction (ASTM D1557-12e1) and California Bearing Ratio Test (AASHTO T 193-99).

3.5 Statistical Analysis: The data was presented regarding frequency counts, relative frequency and mean. A line graph and regression curves were also used to present the soil behavior.

4. Results and Discussions

Coconut Husk Ash is categorized as pozzolana with 60-70% silica and approximately 4.9% and 0.95% of aluminum and iron oxides respectively (Oyetola & Abdullahi, 2006). Silica together with calcium and potassium are the main contributors to the stabilization of soil (ibid).
4.1 Properties of test materials

The specific gravity of fine-grained soil sample and coconut husk ash was analyzed using ASTM D854 standards. CHA used passed through sieve no. 200 while the sun-dried fine-grained soil samples used were passed through sieve no. 10. Shown in the table below is the specific gravity of CHA, silt, clay, clay-silt, and water.

Table 1. Specific gravity of test samples

CHA	Silt	Clay	Clay-Silt	Water
0.66	2.71	2.54	2.59	1.00

Many of these stabilizers are pozzolanic, thus making them upright stabilizers. Coconut Husk Ash has been categorized as Pozzolana, with about 60-70% Silica, and approximately 4.9% and 0.95% of Aluminum and Iron Oxides respectively (Oyetola and Abdullahi, 2006).

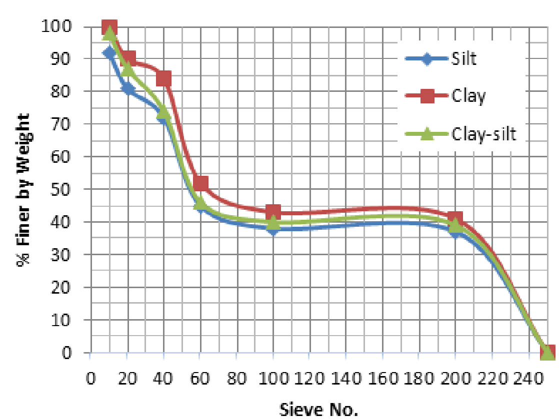

Figure 1. Grain-size distribution

After analyzing using ASTM D 422 standards, the result of grain analysis showed that more than 35% of the three samples passed the sieve no. 200. This indicates that all the samples are within silt-clay materials. Under the AASHTO classification system, they fell under the A-7-6 soil. This implies that they are fair to poor for road construction.

4.2 Effect of CHA to Atteberg Limit of Soils

Atteberg limits were analyzed using ASTM D4318. Figure 2 and 3 shows that the liquid limit and plastic limit increases as the CHA content increases; this indicates intermediate plasticity (R. Whitlow, 1995). Figure 3 shows that the minimum plasticity index of clay and clay-silt obtained at 5% CHA content while the silt soil is at 2.5%. Therefore, the addition of CHA content can reduce the swelling potential of silt, clay, and clay-silt at a particular CHA content (Amu and Owokade, 2011).

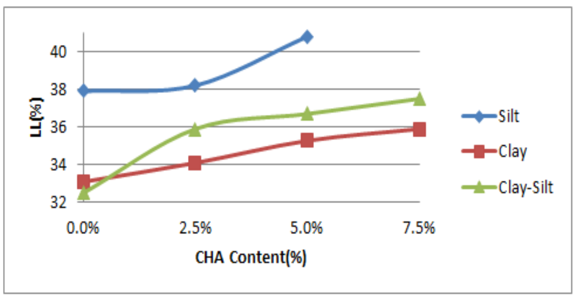

Figure 2. Relationship between Liquid Limit and CHA Content

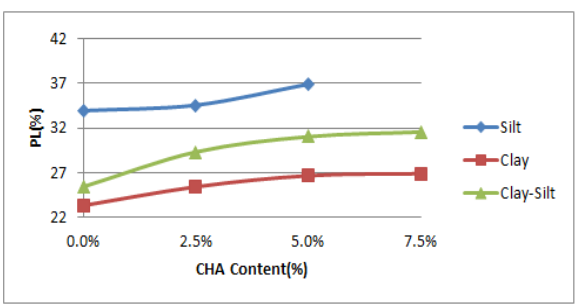

Figure 3. Relationship between Plastic Limit and CHA content

There was an increase in liquid and plastic with an increase in CHA content. The result is in agreement with the definition of liquid limit, which is the moisture content at which the soil exhibits dynamic shear strength. When an alteration occurs in the system of a soil existing in its liquid limit such that there is a relative decrease in the repulsive forces, its strength increase to a specific value such that more moisture will be needed to bring the soil to its dynamic shear strength (Olutaiwo & Adanikin Ariyo, 2016). Whereas the reduction in the PI by 2%, 8%, and 16% in silt, clay and clay-silt respectively may be because of the decrease in the amount of soil sized fraction owing to the flocculation and agglomeration of soil particles and also the formation of cementitious compounds of greater effective grain size as a result of pozzolanic action of CHA (Balarabe, 2013)

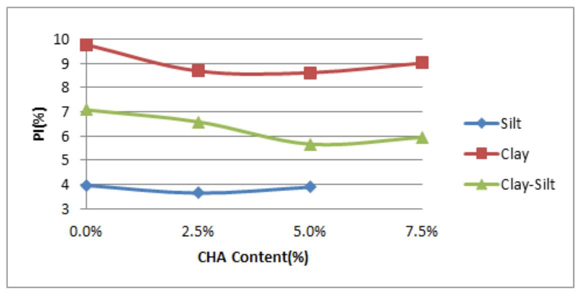

Figure 4. Relationship between Plasticity Index and CHA content

4.3 Effect of CHA to Compaction of Soils

Compaction was analyzed using ASTM D 1557. Figure 5 and 6 shows the summary of the compaction test results. The MDD of silt had increased from 1.16 to 1.38 g/cc at 2.5% CHA content while the MDD of clay and clay-silt have increased from 1.27 to 1.4 g/cc and 1.20 to 1.4 g/cc respectively at 5% CHA content. The optimum moisture content (OMC) also reduced correspondingly in all samples with addition of CHA. An increase in MDD is a good indication of improvement in soil property. The increase in density from the minimum attained value at no CHA content to 5% CHA contents could be due to molecular rearrangement in the formation of "transitional compounds" which have a high density at 5% CHA content (Osinubi, 1998a). Whereas the decrease could be as a result of the void within the soil sample being filled with CHA particles (Stephen & Osinubi, 2006). The reduction in OMC enhances the workability of a good soil (Olugbenga et al., 2011).

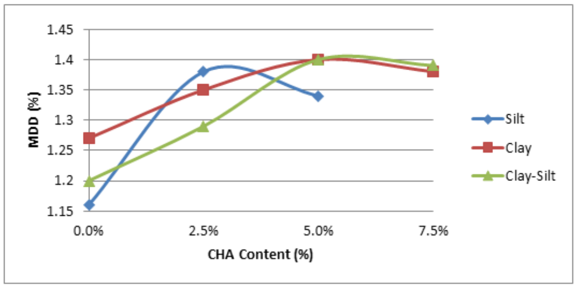

Figure 5. Relationship between Maximum Dry Density (MDD) and CHA content

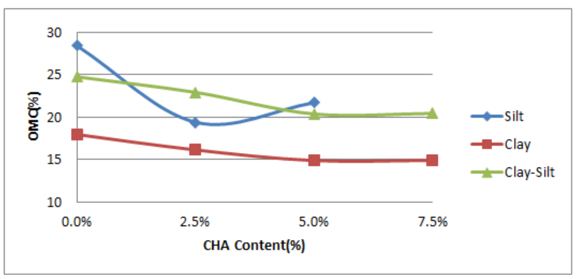

Figure 6. Relationship between Optimum Moisture Content (OMC) and CHA content

The increase in MDD by 19%, 10% and 17% for silt, clay, and clay-silt respectively is due to the flocculation and agglomeration leading to a volumetric decrease in density (Medubi, 1998). The decrease in MDD initially for compaction was due to the presence of large, low-density particles (Osula, 1984). At specific ash contents, the results indicate a decrease in MDD with increasing CHA contents. The initial decrease in the MDD can be attributed to the replacement of the soil by the CHA which has lower specific gravity compared to that of the soil (Moses, 2008; Osinubi et al., 2007). It may also be attributed to a coating of the soil by the ash content which results to large particles with larger voids and hence less density (Osula, 1984; and, Ola, 1983).

On the other hand, the decrease in OMC recorded at 2.5% and 5% CHA content was probably due to self – desiccation in which all the water was used, resulting in low hydration. When no water movement to or from cement – paste permitted, the water is used up in the hydration reaction, until too little is left to saturate the solid surfaces and hence the relative humidity within the paste decreases. The process described above might have affected the reaction mechanism of stabilized soil (Osinubi, 2000). The increment could have been as a result of increasing demand for water by various cations and the soil mineral particles to undergo hydration reaction (Moses, 2008; Osinubi, 1997; Osinubi & Stephen, 2006,)

4.4 California Bearing Ratio (CBR)

CBR was analyzed using ASTM D 1883. Results from Figure 7 reveal that CHA gradually increases the CBR value of clay and clay-silt, which shows that the higher the coconut husk ash addition, the higher the CBR. While the peak of CBR value for silt was obtained at 2.5% CHA content. The reason for increment in CBR may be because of the gradual formation of cementitious compounds in the soil by the reaction between the CHA and the soil. The decrease in CBR at RHA content of 5% may be due to extra CHA that could not be mobilized for the reaction which consequently occupies spaces within the sample. This reduced the bond in the soil-

CHA mixture. This claim, however, needs to be further evaluated. CBR values between 0-7 (OH, CH, MH, OL) have very poor to fair rating and can be used for subgrade only, while soils with CBR values of 7 to 20 are rated fair and can be used for sub-base purposes. This indicates that coconut husk ash increases the soil's CBR value for clay and clay-silt but the improvements made was very minimal because it remains fair for sub-base material.

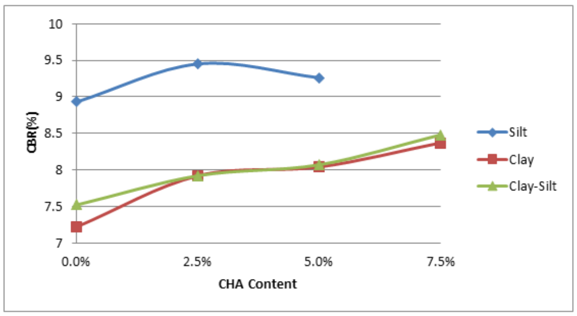

Figure 7. Relationship between California Bearing Ratio (CBR) and CHA content

The CBR value is increased by 16% and 13% for CHA content of 7.6% for clay and clay-silt respectively. Further, the CBR value is slightly decreased for CHA content of 7.5% in silt. The reason for increment in CBR may be because of the gradual formation of cementitious compounds in the soil by the reaction between the CHA and some amounts of CaOH present in the soil. The decrease in CBR at CHA content of 7.5% may be due to extra CHA that could not be mobilized for the reaction which consequently occupies spaces within the sample. This reduced the bond in the soil-CHA mixture (Aparna R., 2014)

5. Conclusions and Recommendations

From the tests performed, the following conclusions can be drawn.

1. The plasticity index of each sample is reduced with the addition of various percentages of coconut husk ash, indicating a reduction in swelling potential and hence an increase in strength properties.

2. The maximum dry density of silt increases from 0% to 2.5% addition of coconut husk ash while of that clay and clay-silt is same at 5% and reduces after. This indicates that at 2.5% CHA content for silt and 5% for clay and clay-silt are the effective optimum values because minimum OMC was also recorded at this value.

3. The CBR values increased gradually with increased percentages of CHA for clay and clay-silt within the maximum CHA content of 7.5%.

4. The improvement categories the soils treated with CHA for sub-base purposes only.

6. Bibliography

Amu OO & Owokade OS. (2011). Potentials of Coconut Shell and Husk Ash on the Geotechnical Properties of Lateritic Soil for Road Works.

Aparna Roy (2014). Soil Stabilization using Rice Husk Ash and Cement. International Journal of Civil Engineering Research, ISSN 2278-3652, Volume 5, Number 1 (2014), pp. 49-54

Balarabe W. (2013). Effect of Coconut Shell Ash on Properties of Fired Clay Brick. Journal of Civil Engineering and Environmental Technology, Print ISSN: 2349-8404; Online ISSN: 2349-879X; Volume 1, Number 6; August 2014 pp. 7-11

Basha EA, Hashim R, Mahmud HB & Muntohar AS. (2005). Stabilization of residual soil with rice husk ash and cement. Construction and Building Materials, 19(6).

Central Intelligence Agency of the USA (n.d.). The World Factbook: Field Listing: Roadways. https://www.cia.gov/library/publications/the-world-factbook/fields/2085.html (Accessed on April 4, 2016)

Choobasti AJ, Ghodat H, Vahdatirad MJ. (2010), Influence of using rice husk ash in soil stabilization method with lime. Frontiers of Earth Sciences in China 4(4).

Department of Public Works and Highways (2005). DPWH Blue Book; DPWH Standard Specifications for Public Works and Highways, 2004 Edition: Volume II, Highways, Bridges, and Airports

Food and Agriculture Organization of the United Nations-FAO (n.d.), Coconut – Tree of Life. http://www.fao.org/docrep/005/Y3612E/y3612e03.htm Accessed 1/2/16

Houston DF. Rice Hulls. In: Rice: Chemistry and Technology. American Association of Cereal Chemists; St. Paul, MN; 1972. pp. 301–340.

Makusa, G. P. (2013). Soil stabilization methods and materials in engineering practice: State of the art review. Lulea, Sweden: Lulea° University of Technology.

Medubi, A. (1998) Stabilization of Black Cotton Soil using Superphosphate Fertilizer Processing Residue as Admixture Unpublished M.Sc. Thesis Department of Civil Engineering, Ahmadu Bello University, Zaria.

Moses, G. (2008) "stabilization of black cotton soil with ordinary portland cement Using Bagasse ash as admixture" IRJI Journal of Research in Engrg. Vol.5 No.3, pp. 107-115

Ola, S.A.(1983). The geotechnical properties of black cotton soils of North Eastern Nigeria In: S.A. Ola(Editor). Tropical soils of Nigeria in Engineering Practice, A.A. Balkema, The Netherlands, Rotterdam,155-171.

Olutaiwo A.O., Adanikin Ariyo (2016). Evaluation of the Structural Performance of Lateritic Soil Stabilized with Cassava Peel Ash (CPA) and Cement. International Journal of Constructive Research in Civil Engineering (IJCRCE) Volume 2, Issue 2, 2016, PP 18-26 ISSN 2454-8693 (Online), www.arcjournals.org

Olugbenga O. Amu et al. / International Journal of Engineering and Technology Vol.3 (2), 2011, 87-94

Orale, RL. (2008). Impact of Rice Hull Ash to Soil Strength Parameters. Philippine Institute of Civil Engineers 2008 National Convention Technical Papers. Bacolod City Philippines.

Osinubi, K. J. (1997). Soil stabilization using phosphatic waste.' Proceedings 4th Regional Conference on Geotechnical Engineering, GEOTROPIKA '97, Johor Bahru, Malaysia, 11 - 12 November, 225 – 244.

Osinubi, K. J. (1998). Influence of compactive efforts and compaction delays on lime treated soils. Journal of Transportation Engineering, ASCE, Vol 124, No. 2, 149 – 155

Osinubi, K.J. (2000). Stabilization of tropical black clay with cement and pulverized coal bottom ash admixture. In: Advances in Unsaturated Geotechnics. Edited by Charles D. Shackelford, L. Houston, and Nien-Yui Chang. ASCE Geotechnical Special Publication, No.99, pp.289-302

Osinubi, K. J., Eberemu, A.O. and aliu, O.S. (2007) Stabilization of laterite with cement and bagasse ash admixture. Proceeding of the first International Conference on Environmental Research and Policy (ERTEP 2007) under the auspices of International Society of Environmental Geotechnology, Accra, Ghana, 16 – 19 July, Category B: Mining and Environment.

Osinubi, K.J., and Stephen, T.A. (2006). "Effect of curing period on bagasse ash stabilized black cotton soil." Book of Proc. Bi-monthly Meetings/Workshop, Material Society of Nigeria., Zaria. pp.1-8.

Osula D.OA, (1984) " Cement Stabilization Using Hydrated Lime as an Admixture" Unpublished MSc. Thesis Dept.of Civil Engineering Ahmadu Bello University Zaria.

Oyetola, E.B. and Abdullahi, M. (2006). The use of rice husk ash in low-cost sandcrete block production, Leonardo Electronic Journal of Practice and Technologies, 8, p. 58-70.

Panchal G. and Avineshkumar, (2015). Properties of Sub-Grade Soil Pavement Construction. International Journal of Innovative Research in Science, Engineering, and Technology, 4(9).

Philippine Statistics Authority (2016). Major Non-Food & Industrial Crops Quarterly Bulletin October-December 2015 9(4).

Schaefer, V., L. Stevens, D. White and H. Ceylan. (2008). Design Guide for Improved Quality of Roadway Subgrades and Subbases. Center for Transportation Research and Education, Iowa State University. Iowa Highway Research Board (IHRB Project TR-525)

Sherwood, P. (1993). Soil stabilization with cement and lime. State of the Art Review. London: Transport Research Laboratory, HMSO.

Rathan Raj R, Banupriya S, Dharani R. (2016). Stabilization of soil using Rice Husk Ash. International Journal of Computational Engineering Research, 6(2).

Yoder, E.J. and MW Witczac (1975). Principles of Pavement Design, 2nd ed., John Wily & Sons, New York.