International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Quick Lime Stabilization of Ferro Laterite Soil to Subgrade Material Implementation

Zubair Saing[1], Lawalenna Samang[2], Tri Harianto[3], Johannes Patanduk[4]

[1]Doctoral Program of Civil Engineering, Hasanuddin University, Makassar, Indonesia

[2]Professor of Civil Engineering, Hasanuddin University, Makassar, Indonesia

[3,4]Department of Civil Engineering, Hasanuddin University, Makassar, Indonesia

Abstract: ***This study aimed to determine and evaluate the strength characteristics of ferro laterite soil with lime stabilization on a particular mixture composition. Ferro laterite soil obtained from three different locations with conventional sampling process at 0-1 meters of depth, wrapped in the sample bag and labeled according to the location, namely LH1 for the Subaim location, LH2 for Buli location, and LH3 for Maba location. The sampling results were tested for physical properties of the soil according to ASTM and SNI standardization, involved testing; moisture content, particle size distribution, specific gravity, and the limits of Atterberg, as well as compaction test. Making of the soil test specimen is done by mixing the ferro laterite soil with the addition of lime in a composition of 3%, 5%, 7%, and 10% on the initial condition of maximum density and optimum moisture content standard Proctor test results. Cylindrical test specimen with dimensions H = 2D, then cured for 3, 7, 14, and 28 days before being tested for soil compressive strength with UCS testing. The test results showed that the ferro laterite soil stabilization with lime increases the compressive strength for the three types of ferro laterite soil that is significantly until the curing time of 28 days (72-254 kPa, 156-291 kPa, 80-272 kPa, respectively for LH1, LH2 and LH3), resulting with an increase in the percentage of lime addition. Similarly, the increase in curing time up to 28 days, resulting in an increase of soil compressive strength, in which the bond between grains of soil with lime increasingly stable. Based on these test results, the ferro laterite soil has the potential to be used as road base material and construction material, but it is necessary to test in detail the physical model (prototype) prior to implementation in the field.***

Keywords: Strength characteristic, ferro laterite soil, lime stabilization, curing time

1. Introduction

Indonesia is currently focusing on the development of infrastructure, particularly to support increased development investment. In line with this, the material needs for infrastructure development intended to increase, especially construction material and road material. Certain areas have limited resources to qualified material, especially material (grade) A and B. One such area is particularly the island of Halmahera in North Maluku, which has been buying material from other areas to be used as construction material and street. On the other hand, the material content of local potential to be developed as a replacement material for the use of road base layers and other construction materials, one of which is a ferro laterite soil.

This soil is a kind of laterite soil that contains a very large ferrous metal with a range between 40% -70%, depending on the origin of rock-forming minerals from the soil. Distribution of ferro laterite soil on the island of Halmahera in North Maluku province in eastern dominant. Halmahera ferro laterite soil is soil that forms in the tropics or sub-tropics with high levels of alkaline rocks weathering until ultramafic rocks dominated by ferrous metal content (Regional Geological Halmahera, East Halmahera RTRW 2010-2015).

Laterite soil (Portelinha, et.al., 2012) containing the clay minerals are relatively high mainly illite and montmorillonite, so the potential for damage is greater if carried out construction work on the ground like this. Clay minerals and metals are high, it can be used for various needs of both the construction, industry, and others. Laterite soil is soil groups result from weathering high, formed from the concentration of hydrated iron oxide and aluminum (Thagesen, 1996 from Olugbenga et.al, 2011), soil characteristics of this type have a hard, impenetrable, and very difficult to change if the conditions dry (Makasa, 2004 in Olugbenga et.al, 2011). Laterite have a wide variety of red, brown to yellow, fine grain sized residual soil with a granular texture have a mild form nodular and cemented well (Lambe and Whitman, 1979). Bridges (1970) state that the correct use of the term laterite is a compact rock formations vesicular iron (a massive vesicular or concretionary ironstone formation). Fookes (1997) named laterite based on hardening as "freeic" for hard soil rich in iron are cemented, "alcrete" or bauxite for hard soil rich in aluminum are cemented, "calcrete" for hard soil rich in calcium carbonate, and "silcrete" for the rich in silica. Other definitions are based on the ratio of silica ($SiO2$) to oxide ($Fe2O3$ + $Al2O3$), for laterit such comparisons between 1.33 and 2.0, while above 2.0 is not laterit.

Research on lateritic soil has been widely applied, especially in countries that there are many types of soil such as in Asia and Africa. Sree Danya, et. al (2010) showed that the higher the content of clay minerals in the soil causing laterite soil strength decreases. Olugbenga et.al, (2011) concluded that the laterite soil stabilization with lime will increase the strength of the soil becomes larger 2-3. Portelinha, et. al. (2012), suggests that the addition of a little lime and cement highly efficient, improve laterite soil by adding 3% only 2% of cement and lime. Aminaton, et. al. (2013), have tested the laterite soil stabilization using polymer solution (GKS), and concluded that the soil strength increases with increasing time ripened and ripened time of the increase occurred after 7 days. Amu, O.O., et al. (2011), has launched an investigation of the laterite soil stabilization using a cane and concluded that the ash cane fiber is very effective in stabilizing and strengthening the Geotechnical properties of soil laterite. Kiran, S.P., et. al. (2014), has launched an investigation of laterite soil stabilized with ash cane and cement and concluded that the ash cane fiber is very effective as a stabilizing agent in the content of 6% and 5% of the cement to reinforce the Geotechnical properties of laterite soil, and can be used for construction road as a sub base. Yinusa, A., et. al. (2014), conducted a study of laterite soil stabilization using corn cob ash (CCA), and concluded that the maximum dry density decrease in ash content of 1.5% CCA, optimum water content increased in the binder content of 0 to 7.5%. CBR value increased at the CCA content of 1.5%, and then decreased with the addition of CCA. Unconfined compression strength also increased the CCA content of 1.5%, and decreased with the addition of CCA. Liu Yangshen, et.al. (2004), conducted a study of the behavior of bentonite is used to strengthen the laterite soil and concluded that the bentonite can enhance the performance of hydraulic and mechanical laterite soil. Lativi, et al, (2014) have done a laterite soil stabilization using sodium silicate liquid, and the results indicate that the addition of sodium silicate over 9% decrease the compressive strength of the soil. Wisley, M.F., et. al. (2014) has conducted testing laterite soil characteristics as a coating material that is fed gasoline, hydraulic conductivity increase in line with the increase in the hydraulic gradient.

The growing research on the utilization of laterite soil, indicating that the soil is very potential to be used in various constructions. However, still not much research on soil laterite iron metal content is very high (ferro laterite soil). The potential of East Halmahera laterite soil as a local asset (local content) that has been attempted to be used as the subgrade material of the road, as the first phase has been carried out laboratory tests on the characteristic of soil strength which has been stabilized with lime (CaO) to curing up to 28 days.

2. Material and Method

The material used in this study is ferro laterite soil originating from the eastern Halmahera Island, with three different sampling locations. That location is the area with coordinates Subaim 1°3'46,24"N and 128°8'28,56"E, Buli to coordinate 0°55'13,29"N and 128°21'5,15"E, and the area with the coordinates Maba 0°40 ' 17.80'N and 128°16'51,20 "E. Soil sampling by extracting conventionally using a pick and shovel, then the soil sample was placed in a sack sample and wrapped in plastic to maintain the moisture content of the original, and labeled initials correspond to the location of the sample that is LH1 to samples from locations 1, LH2 for a sample of 2 locations, and LH3 to samples from three locations (Figure 1).

This study is an experimental research conducted in the laboratory to test the characteristics of laterite soil stabilization with lime as subgrade material. Some stages will be carried out as follows; first, conduct a literature review and a preliminary survey to identify the problem and identification of the sampling location; second, pre-testing of samples that have been taken to determine the characteristics of laterite soil. Laboratory tests to know the physical properties which include water content, limits of consistency, and specific gravity, while testing the mechanical properties include compaction test, compressive strength test, and test the carrying capacity. While, testing the mechanical properties include compaction test, compressive strength test, and test the carrying capacity. Soil consistency using the Atterberg limit tests, compaction tests then conducted using standard Proctor compaction test, the result of compaction test that used as a basis for sample preparation, sample was cured for 3, 7, 14, and 28 days before testing. Soil strength used unconfined compression test, while the soil bearing capacity tested using CBR test. Standardized testing of basic soil properties (physical and mechanical) which is used as in Table 1.

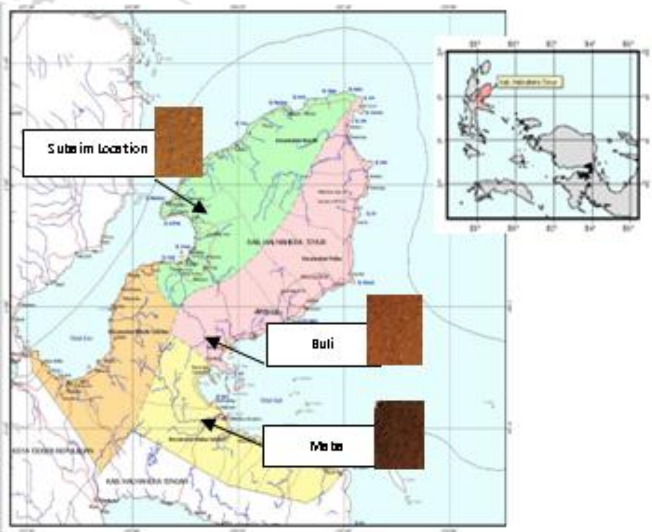

Figure 1: Location of ferro laterite soil sampling and soil type

Table 1: The standard test used

Type of Testing	Standard Number	
	ASTM	SNI (Indonesian Standard)
Grain Size Analisys	C-136-06	SNI 03-1968-1990
Liquid Limit (LL)	D-423-66	SNI 03-1967-1990
Plastic Limit (PL)	D-424-74	SNI 03-1966-1990
Plasticity Index (IP)	D-4318-10	SNI 03-1966-2008
Spesific Gravity (Gs)	D-162	SNI 03-1964-1990
Water Content (Wc)	D-2216-98	SNI 03-1965-1990
Uniconfined Compression Test (qu)	D-633-1994	SNI 03-6887-2002
Compaction Test	D-698	SNI 03-1742-1989
CBR Laboratory Test	D-1833	SNI 03-6796-2002

The ferro laterite soil, lime (CaO) and water was weighed with the composition of the plan to produce a mixture of material test specimens in accordance with the established (the composition of the addition of lime 0, 3, 5, 7, and 10%), the mixing is done thoroughly and cured for 24 hours until achieving equilibrium conditions prior to the tests. Test object which used a cylinder with dimensions H = 2D, in conditions of optimum moisture content, Proctor. Entered in the mold that has been smeared lubricating oil, further pulverization every third with 25 times the number of collisions. The test object and then cured for 7, 14, 21, and 28 days, were tested and determined the water content (Figure 2). The test data is processed to generate a relationship between the strength of the soil with the percentage of lime and its relation to the curing time is analyzed descriptively qualitatively.

Figure 2: The stage of testing: a) the manufacture of the test object, b) curing process, c) testing of compressive strength (UCS test), d) weighing the specimen after testing, e) drying in an oven

3. Results and Discussion

Testing of the basic properties of the soil covering; specific gravity, moisture content, soil volume weight, the limits of Atterberg, and grain size analysis. Tests carried out on the laterite soil for three types with three different locations using a standard test such as Table 1. Results of laboratory tests for physical properties and mechanical properties as well as chemical and mineral properties as shown in Table 2, Table 3 and Table 4.

Table 2: Physical properties of ferro laterite soil

Physical and Mechanical Properties	Ferro Laterite Soil		
	LH1	LH2	LH3
Water content (%)	20,26	22,25	18,86
Specific gravity	2.73	2.62	2.66
% Passing #200	92.32	94.89	91.75
Liquid limit (%)	65.98	68.73	67.77
Plastic limit (%)	47,92	41,96	48,86
Plasticity index (%)	18,06	26,77	18,91
AASTHO soil classification	A-7-6	A-7-6	A-7-6
USCS soil classification	CH	CH	CH
Optimum moisture content (%)	19,45	20,7	20.50
Maximum dry density (ton/m3)	1.769	1.773	1.780
CBR (%) – unsoaked	11,24	21,02	12,33
UCS (kPa)	71,44	128,88	75,61

Table 3: Chemical properties of ferro laterite soil

Element (%)	Ferro Laterite Soil		
	LH1	LH2	LH3
MgO	2,33	0,83	1,28
Al_2O_3	4,41	5,73	8,45
SiO_2	12,58	2,28	3,71
K_2O	0,1		
TiO_2	0,08		
FeO	80,5	86,55	84,88
SO_3		1,05	
CaO		0,25	
MnO		0,24	
NiO		2,78	1,38

Table 4: Mineral content of ferro laterite soil

Mineral Content (%)	Ferro Laterite Soil		
	LH1	LH2	LH3
Hematite HP, iron(III) oxide	13	7	1
Kaolinite	20	8	67
Illite-montmorillonite (NR)	60	80	18
rutile HP	1	2	11
Magnesium Silicate	6	3	3

Based on the test results in Table 2, it appears that the grain size of the land is dominated by clay minerals in the range of 91.75% to 94.89% and the soil, water content between 18.86% to 22.25%, while the specific gravity of between 2.62 to 2.66, with a plastic index between 18.06 to 26.77. These results, using AASHTO and USCS classification, the ferro laterite soil in a class of clay with high plasticity. The unconfined compression test (UCT) result of ferro laterite soil LH1, LH2, and LH3 to a mixture of 3%, 5%, 7%, and 10% lime (CaO) with curing time of 3, 7, 14, and 28 days as shown in Figure 3, 4, and 5.

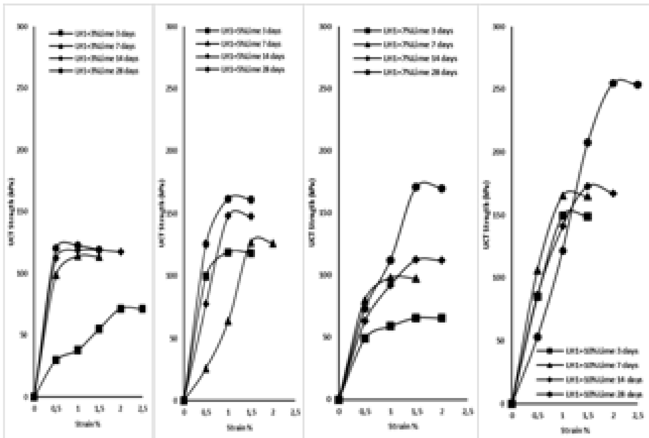

Figure 3: Unconfined compression strength for LH1 soil laterite with 3%, 5%, 7%, and 10% lime (CaO) to 3, 7, 14, and 28 days curing time

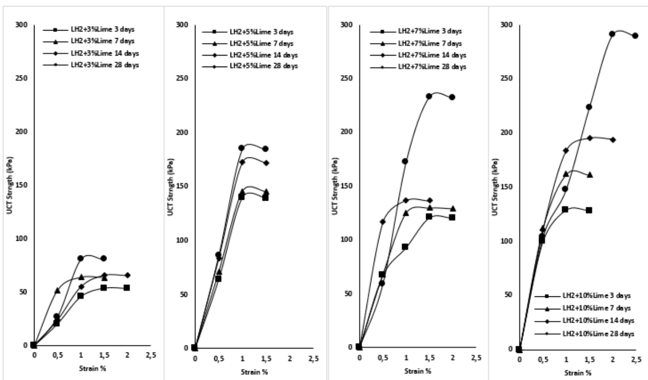

Figure 4: Unconfined compression strength for LH2 soil laterite with 3%, 5%, 7%, and 10% lime (CaO) to 3, 7, 14, and 28 days curing time

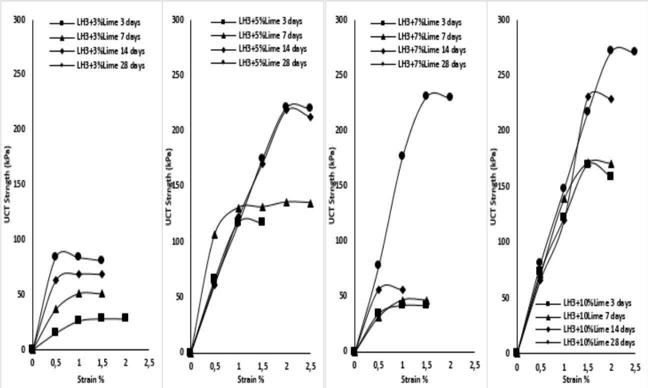

Figure 5: Unconfined compression strength for LH3 soil laterite with 3%, 5%, 7%, and 10% lime (CaO) to 3, 7, 14, and 28 days curing time

Based on Figure 3, 4, and 5, it appears that the unconfined compression strength changes during curing time. The curve shape of stress-strain relationship of laterite soil mix with lime (CaO), indicating that the soil is hard and rigid (stiff). Increasing load was given, soil strength increased to the extent of collapse and failure without any residual stresses, in this condition the soil becomes very fragile, that is in accordance with Olugbenga et. al, (2011) and Portelinha et. al, (2012) which states that the addition of lime to the soil will increase the strength of laterite soil becomes 2 times as large.

The more detail overview that showing the relationship between the soil strength and the percentage addition of lime and time cured from strength testing results of laterite LH1, LH2, and LH3 to the mixture composition of lime (CaO) 0%, 3%, 5%, 7%, and 10% with curing time 3, 7, 14, and 28 days are shown in Figure 6.

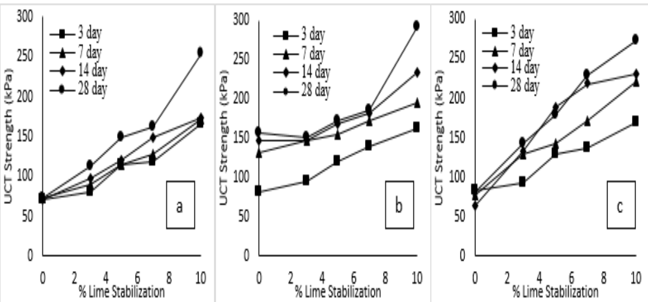

Figure 6: Relationship of soil compressive strength to the percentage of a mixture of lime (CaO) with a curing time; a) ferro laterite soil LH 1, b) ferro laterite soil LH2, c) ferro laterite soil LH3

Figure 6 shows the relationship between soil strength and percent addition of lime with curing time. The figure show that, the increase of percentage lime (CaO) addition and increased curing time lead to increased soil strength. In a mixture of 10% lime (CaO) with 28 days curing time, an increase of soil strength 72kPa-254 kPa for LH1, 156 kPa-291 kPa for LH2, and 80 kPa - 272 kPa for LH3, shows that ferro laterite soil LH2 better than LH1 and LH3. This represents an increase of soil strength is almost three times greater than the strength of the native soil. Increased curing time up to 28 days also increase the strength of the soil, increase soil strength not significantly to LH1 and LH3, but LH2 increased significantly to 91%. Increased curing time not significantly affected on native ferro laterite soil. While on the mixture of soil with lime in particular with 5%, 7%, and 10% lime, increase soil strength average of 65% to 10% lime, 43% to 7% lime, 38% to 5% lime and 50% to 3% lime. It is seen that the condition of a mixture of 10% lime to time ripened 28 days to produce the highest soil strength. These test results are very consistent with the results of testing that has been done by Olugbenga et. al, (2011) and Portelinha et. al, (2012).

Increasing the strength of ferro laterite soil is strongly influenced by the content of elements and minerals present in the soil. Laterite soil dominated by clay minerals that have a high plasticity such as mineral montmorillonite (smectite) and illite, can swell when in contact with water in liquid or vapor. This is related to the composition of the base layer mineralogy or the mineral montmorillonite unit structure. The structure of the mineral montmorillonite is an element that is formed of alumina octahedral sheet between two sheets of silica tetrahedra. An alumina octahedral structure composed of one atom of aluminum and 6 hydroxyl in the which the silica tetrahedral octahedral shape consisting of a silicon atom and four oxygen atoms in a tetrahedral shape (Mitchell, 1993). Most of the clay minerals have a sheet or layered structures, have them several elongate tubular or fibrous structures. Clay particles behave like colloids, it is a specific whose particle surface is so high that its behavior is controlled by the surface energy rater than mass energy. From the viewpoints of interparticle forces, reviews these characteristics of colloidal clay particles are similarly charged (Hamzah et al, 2012). In microstructure, on the condition of maximum density ferro laterite soil, bonding clay mineral particles are increasingly unstable, the addition of lime resulting condition is getting smaller micropores, thereby reducing the weak areas. The metal element content of iron in ferrous minerals in the soil also resulted in a ferro laterite particle bond is getting stronger, so that the conditions of 28 days cured the bond is more stable, it is this which causes increased soil strength.

4. Conclusion

In this paper, three different ferro laterite soils related to the mechanical and microstructural characteristics for subbase material utilization was studied. The main aim was to determine and evaluated the strength characteristics of ferro laterite soil with lime stabilization on a particular mixture composition to be used as subgrade material. Based on physical properties, sample of the fare laterite soil was A-7-6 for AASHTO soil classification system and CH for USCS soil classification system. An increasing percentage of the lime addition (CaO) and increased curing time lead to increased strength of the soil, on 10% lime mixture and 28 days curing time to produce the highest soil strength for all types of soil (254 kPa, 291 kPa, 272 kPa, respectively for LH1, LH2 and LH3). Based on these test results, the ferro laterite soil LH2 more than LH1 and LH3 potential to be used as road base material and construction material, but it is necessary to test in detail the physical model (prototype) prior to implementation in the field.

References

[1] Aminaton Marto, Nima Lativi, Houman Souhaei, 2013, Stabilization of Laterite Soil using GKS Soil Stabilizer, EJGE Journal, Volume 18, Bund. C, pp 521-532.

[2] Amu, O.O., Ogunniyi, S.A. and Oladeji, O.O., 2011, Geotechnical properties of lateritic soil stabilized with sugarcane straw Ash, American Journal Of Scientific And Industrial Research © 2011, Science Huβ, http://www.scihub.org/AJSIR ISSN: 2153-649X doi:10.5251/ajsir.2011.2.2.323.331, pp 323-331.

[3] B. Thagesen, 1996, Tropical rocks and soils, In: Highway and traffic engineering in developing countries: B, Thagesen, ed. Chapman and Hall, London.

[4] B. Makasa, 2004, Utilisation and improvement of lateritic gravels in road bases, International Institute for Aerospace survey and Earth Sciences, Delft.

[5] Bridges E.M., 1970, World soils Cambridge, University Press, London, 25.

[6] G. Fookes, 1997, Tropical residual soils, a geological society engineering group working party revised report, The Geological Society, London

[7] Hamzah Yusuf, Muh.Saleh Pallu , Lawalenna Samang and M.Wihardi Tjaronge, 2012, Characteristical Analysis of Unconfined Compressive Strength and CBR Laboratory on Dredging Sediment Stabilized With Portland Cement, International Journal of Civil & Environmental Engineering IJCEE-IJENS Vol:12 No:04, pp 25-31.

[8] Kiran.S.P, A.N Ramakrishna, Shrinivas.H.R, 2014, Stabilization of Lateritic Soil by using Sugarcane Straw Ash and Cement, Journal of Civil Engineering Technology and Research Volume 2, Number 1 (2014), pp.615-620

[9] Liu Yangshen, BAI Qingzhong, NIE Yongfeng, 2004, Properties of Bentonite enhanced Loess and Laterite, Cinese Journal Chemical Engineering, 12-1, pp 37-41.

[10] Nima Latifi, Amin Eisazadeh, Aminaton Marto, 2014, Strength behavior and microstructural characteristics of tropical laterite soil treated with sodium silicate-based liquid stabilizer, Environ Earth Sci 72:91–98 DOI 10.1007/s12665-013-2939-1, Springer-Verlag Berlin Heidelberg.

[11] Olugbenga O Amu, Oluwole F.B., dan Iyiola A.K., 2011, The Suitability and Lime Stabilization Requirement of Some Lateritic Soil Samples as Pavemen, Int. J. Pure Appl. Sci. Technol., 2(1), pp. 29-46

[12] F.H.M. Portelinha, D.C. Lima, M.P.F. Fontes, C.A.B. Carvalho, 2012, Modification of a Lateritic Soil with Lime and Cement: An Economical Alternative for Flexible Pavement Layers, Soils and Rocks, São Paulo, 35(1): 51-63, January-April, 2012, pp 51-63.

[13] Sree Danya, Ajitha, A.R, Evangeline, Y. Sheela., 2010, Study on Amended Soil Liner Using Lateritic Soil, Indian Geotechnical Conference – 2010, GEO*trendz* December 16–18, 2010 IGS Mumbai Chapter & IIT Bombay, pp 381-284.

[14] T. W. Lambe and V. R. Whitman, 1979, Soil mechanics, SI version, John Wiley and SonsInc., New York

[15] Wisley Moreira Farias, Geraldo Resende Boaventura, Éder de Souza Martins, Fabrício Bueno da Fonseca Cardoso, José Camapum de Carvalho and Edi Mendes Guimarães., 2014, Chemical and Hydraulic Behavior of a Tropical Soil Compacted Submitted to the Flow of Gasoline Hydrocarbons, Environmental Risk Assessment of Soil Contamination, Intech, http://dx.doi.org/10.5772/57234, pp 638-655

[16] Yinusa A. Jimoh , O. Ahmed Apampa, 2014, An Evaluation of the Influence of Corn Cob Ash on the Strength Parameters of Lateritic Soils, Civil and Environmental Research www.iiste.org ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online) Vol.6, No.5, 2014