International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 1450-1457 www.ijaem.net ISSN: 2395-5252

The Effect of Ceramic Dust on Engineering Properties of Cassava Peel Ash Modified Clay Soils

[1]Otunola Oluwaseun Olatunji and [2]Komolafe Temidayo Florence

[1,2]*Department of Civil Engineering, Federal Polytechnic Offa*

Submitted: 15-08-2022 Revised: 27-08-2022 Accepted: 30-08-2022

ABSTRACT: Most clay soils sometimes suffer geotechnical engineering problems such as high swelling and shrinkage due to high fine content. Several studies have used numerous conventional materials such as cement, lime and industrial materials to mitigate the adverse effect of clay soils in construction. Despite the economic and engineering benefits of these materials, there is still issue of their availability at a relative cheap cost. Thus, there is the need for cheap and readily available stabilizing material such as agricultural waste. This research evaluates the effect of ceramic dust (CD) on engineering properties of cassava peels ash (CPA) modified clay soil. A specific test such as chemical composition and scanning electron microscopes test was conducted on the clay soil, ceramic dust and cassava peel ash to ascertain their chemical constituents and morphology. While tests such as Atterberg limit, specific gravity, compaction and soaked California bearing ratio (CBR) were conducted on the clay soil and modified clay soil to ascertain their engineering properties. The results show that ceramic dust and cassava peels ash can be classified as a type C- Fly Ash. Also, the results show that as the CPA percentages increases, the liquid limit, plastic limit, plasticity index and optimum moisture content decreases. While maximum dry density, soaked CBR increased. The results show that inclusion of 5% ceramic dust as additives further improves the geotechnical properties of CPA modified clay soil. In Conclusion, both materials can serve as suitable alternatives to modify and stabilize problematic clay soils and hence help reduce construction costs, environmental hazards and ultimately bring about clay soils with improved geotechnical properties.

Keywords: Ceramic Dust, cassava peels ash, clay soil, maximum dry density, fly-ash.

I. INTRODUCTION

Clay soils are mostly encountered during road construction in many developing countries like Nigeria. Clay soil despite its vast availability, it is rarely use in construction industries because of it low bearing capacity and low strength due to high clay content (Amu, Ogunniyi and Oladeyi, 2016). Nigerian highways have been a commonplace to highway pavements failure due to the plasticity of these clay soils (Onakunle, Omole and Ogbiye, 2019). The exorbitant fee of transporting standardized construction materials and deficiency in its supply has make it imperative to seek out techniques of enhancing the properties of onsite unsuitable clay soils (Oyediran and Fadamoro, 2015).

Recent policy to augment Nigeria economy with the agricultural sector has led to exponential increase in agricultural produce, consequently increasing generation of agricultural wastes. (Afolayan, Olofinade and Akinwumi, 2019). However most of these agricultural wastes get dispose indiscriminately into our environment. To ensure proper waste management while ensuring sustainable low cost materials, the agricultural waste can be used to improve the properties of clay soils. Typical agricultural wastes that have been used are rice husk ash (Alhassan, 2008; Bashal, Hashim, Mahmud and Muntohar, 2005; Mittal, 2021; Nguyen and Nu 2020; Okafor and Okonkwo, 2009), Bagasse ash (Dabal, Patel and Dalal, 2017), coconut shell ash (Hamza and Paul, 2019), Palm kernel shell ash (Adetoro and Adekanmi, 2015, Ekeocha and Agwuncha,2014), Palm oil fuel ash (Pourakbar, Asadi, Huat, and Fasihnikou, 2015), Sugar cane straw ash (Ogunribido, 2012).

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 1450-1457 www.ijaem.net ISSN: 2395-5252

Thus, the readily available materials that can be used to improve clay soil without economic implications are agricultural by-products (Anthony and Akangee, 2015). Cassava peels and ceramics are major waste generated within our domestic environment and processing industry located areas, indiscriminate disposal of these wastes due to gross under utilization as well as lack of appropriate technology to recycle them is a major challenge, which results in environmental problem. Thus, there is need to search for alternative methods to recycle them.
This research work shall be based on effect of ceramic dust (CD) on cassava peels ash (CPA) modified clay soils.

II. MATERIALS

Clay Soil

The clay soil samples were obtained at a depth of 1m from the ground surface at opposite Erin-ile General Hospital, along Ajasse-ipo-Osogbo road, Erin-ile, Kwara State, Nigeria. The clay soil was reddish brown in color and has moderate moisture content when it was excavated from the ground. The clay soil was very sticky and fine to touch. The geotechnical properties of the clay soil was tested in the laboratory and the results are summarized in Table 1 and Figure 1

Cassava Peels Ash (CPA)

Cassava peels used in this research were obtained from a local garri processing factory at Afelele area within Offa metropolis. The peels were then sun dried and later burnt in to ashes by open air burning and then calcinated up to 700℃ in an electric furnace. Fig. 1 shows the dried and calcinated samples of the cassava peels. The calcinated peels were grinded to fine powder and sieved through 425µm, then later packed in bags and stored in a cool dried place.

(a) (b)

Figure 1: shows samples of (a) dried cassava peels (b) cassava peels ash

Ceramic Dust (CD)

Broken ceramic tiles were obtained from construction sites within Offa metropolis. Debris was removed from the ceramic tiles, grinded into powder form and sieved through a 425µm sieve so as to obtain a fine and uniform ceramic dust. Figure 2 shows the ceramic tiles and the powder form of the ceramic tiles.

(a) b)

Figure 2: shows samples of (a) ceramic tiles (b) ceramic dust.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 1450-1457 www.ijaem.net ISSN: 2395-5252

III. METHODS

Morphology and Chemical Composition

The morphology and chemical composition of the soil only and stabilized soil sample was determined using X-ray fluorescence (XRF) spectrophotometer and scanning electron microscopy (SEM) at Rolab Research and Diagnostics Laboratory Services, Ibadan, Nigeria.

Sample Preparation

The clay samples were sun dried for 2 weeks in replacement of conventional oven drying to avoid any irreversible modification in its clay mineral properties which may results from oven drying the soil above temperature of 100-110℃ (Oyediran and Fadamoro, 2015). The clay soil was modified by adding varying quantities of 2, 4, 6, 8, 10% of cassava peels ash (CPA) (by weight) separately to the clay soil and are then bagged and stored. After which, an additive ceramic dust of 5% (by weight) was added to the earlier prepared CPA modified clay and mixed thoroughly to allow for intimate mixing. The mixed samples were left for 48 h to cure and subsequently remixed to achieve a homogenous mix prior to testing.

The Sample used for California Bearing Ratio (CBR) test was prepared by static compaction in three layers at their respective Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).

Experimental Test

The laboratory tests carried out on the soils include Particle size distribution (sieve analysis), Specific gravity, Atterberg limits, Compaction and California Bearing Ratio (CBR). Stabilization of the clay soil with cassava peels ash and ceramic dust was conducted in accordance with BS 1924.

The geotechnical properties on the clays soils and stabilized clay soils were performed in accordance to BS 1377.

IV. RESULTS AND DISCUSSION

Preliminary Test On Soil

The result of the preliminary geotechnical test such as natural moisture content, specific gravity, Atterberg limits, compaction and soaked CBR carried out on the clay soil only is summarised in Table 1.

Table 1: Results of Preliminary Test on Soil Sample.

Index Properties	Values
Natural Water Quantity	36.57
Liquid Limit	52
Plastic Limit	25.40
Plastic Index	26.60
Maximum Dry Density (kN/m^3)	17.01
Optimum Moisture Content (%)	18.44
Specific Gravity	2.62
California Bearing Ratio (CBR) Soaked	2.8
AASHTO Classification	A-7-6
UCSC Classification	CH

According to AASHTO and UCSC soil classification system, based on the grain size and plasticity characteristics, the clay soil can be classified as A-7-6 and CH respectively as shown in Table 1. The soil is classified as having a high degree of severity and plasticity. Based on this classification, the clay soil sample are inadequate for use in most geotechnical construction because it fall below the recommended standards by AASHTO. Therefore, the clay soil samples would require stabilization.

Chemical Compositions

The results of the investigation carried out on the chemical composition of clay soil, ceramic dust (CD) and cassava peels ash (CPA) are shown in Table 2.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 1450-1457 www.ijaem.net ISSN: 2395-5252

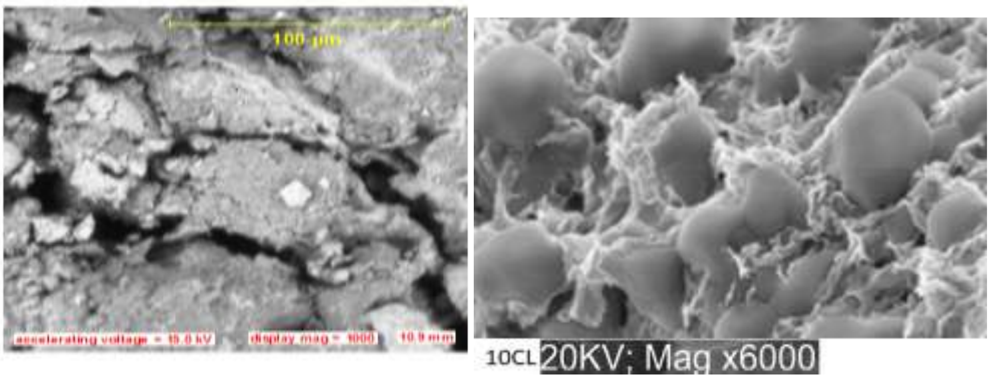
Table 2: Chemical Compositions.

Sample	SiO_2	AI_2O_3	Fe_2O_3	Na_2O	CaO	P_2O_5	K_2O	TiO_2	MgO	LOI	SiO_2+ AI_2O_3+ Fe_2O_3
Clay soil	43.03	22.34	15.3	-	-0.78	-	-	1.14	-0.66	-	-
Ceramic dust (CD)	42.50	15.70	6.35	1.12	0.86	0.59	1.01	0.04	0.81	6.20	64.55
Cassava Peels Ash (CPA)	52.94	7.48	8.71	1.8	7.26	0.55	12.78	0.05	4.39	7.28	63.13

The clay soil is found to be rich in silica content (43%), Aluminia content (22.34%) and Iron oxide (35.3%) as shown in Figure 2. According to Oyediran and Fadamoro (2015), the high values of Iron oxide in the clay samples can be accounted for by possibility of ferruginized materials overlaying the clay soils.
The chemical composition of CD and CPA indicates that they are mainly composed of silica content. According to ASTM C618 classification, a fly ash can be classified as type C or type F if the content of SiO_2+ Al_2O_3 +Fe_2O_3 is greater than the 50% or 70% respectively. From Table 2, the pozzolan content (i.e. combination of SiO_2+ Al_2O_3 +Fe_2O_3) of CD and CPA are 64.55 and 63.13. Thus, the CD and CPA meet the requirement for Class C pozzolan.

Morphology Study

Figure 3(a) and 3(b) show the SEM image of un-modified clay soil at 1000x magnification and stabilized clay soil with 5% by weight of CD and 5% by weight of CPA at 6000x Magnification respectively. The SEM image in Figure 3(a), the microstructure of the un-modified clay soil particles are platy, which are clustered into lumps and cemented together. From the SEM image in Figure 3(b), a considerable change was observed in the structure of the clay soil. The structure portray a foil like leafy structure with large cemented clusters. This could be accounted for by the pozzolanic activity taking place due to the addition of ceramic dust and cassava peels ash. The platy structure found in the clay soil can no longer be found in the stabilized clay soil. Similar trends was observed by Bhuvaneshwari, Robinson and Gandhi (2013) and Sante, Fratalocchi, Mazzieri, & Pasqualini (2014) in their research of stabilizing clay soils with lime.



(a) (b)

Figure 3: SEMs Image showing Microstructure of (a) un-modified clay soil particles (b) Modified clay soil.

Specific Gravity

The specific gravity of the CPA and CPA are 2.05 and 2.59 respectively. The specific gravity of the mixes of clay soil with the pozzolans are shown in Table 3. There was reduction in specific gravity of mixes of clay soils +CPA from 2.69 to 2.628. Similarly there was reduction in the specific gravity of the mixes of Clay soils + 5% by wt. of

CD + CPA from 2.69 – 2.681. It was observed that significant reduction in the specific gravity was observed in clay soils mixed with CPA compared to when CD was added.

Table 3: Specific Gravity of Clay soil mixes with pozzolan

Sample	Specific Gravity					
	0%	2%	4%	6%	8%	10%
Clay Soils + CPA%	2.69	2..677	2.664	2.652	2.639	2.628
Clay Soils + CPA% + 5% CD	2.69	2.688	2.687	2.684	2.683	2.681

Atterberg Limits
In determining the liquid Limit (LL), plastic Limit (PL) and plasticity Index (PI), the Atterberg limit test was performed on the clay soils and modified clay soils in accordance with ASTM D 4318. The results of the average value of LL, PL and PI are shown in Table 4 and Figure 4.

Table 4: Atterberg Limit States

Atterberg Limits (%)	Clay soil + CPA						Clay soil + 5% CD +CPA					
	0%	2%	4%	6%	8%	10%	0%	2%	4%	6%	8%	10%
Liquid Limit (LL) %	52	51.4	48.4	46.4	42.4	40.6	52.0	50.4	47.6	41.8	40.9	39.8
Plastic Limit (PL) %	25.40	25.1	23.4	22.2	21.3	19.40	25.40	24.9	22.8	20.6	19.4	19.5
Plasticity Index (PI) %	26.6	26.3	25.0	24.2	21.1	21.2	26.6	25.5	24.8	21.2	21.5	20.3

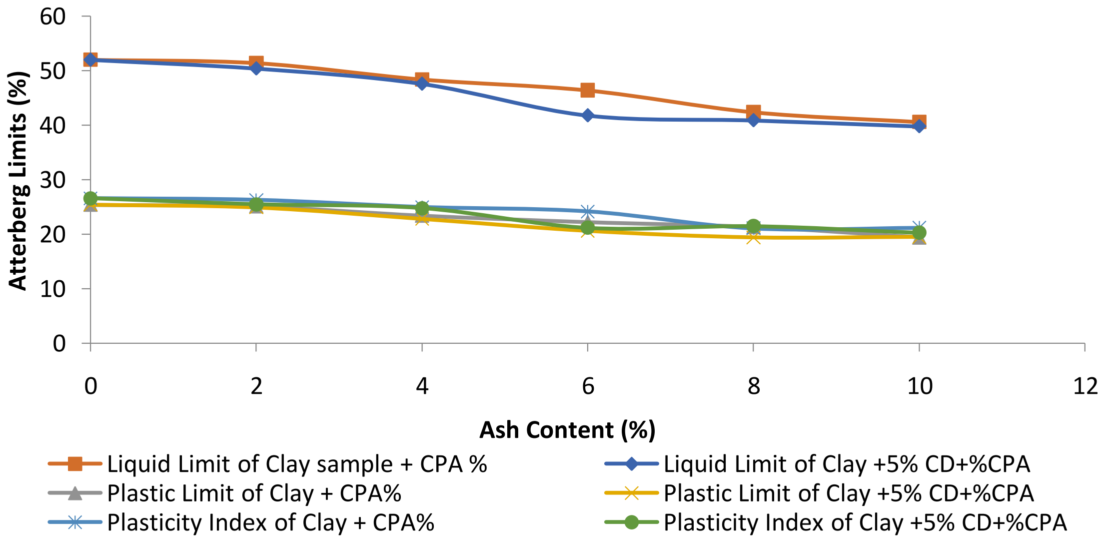


Figure 4: Atterberg Limit States

CPA changes the Atterberg limits of the soils. An increase in CPA from 0% - 10%, the liquid limit, plastic limit and plasticity index reduces from 52% to 40.6%, 25.40% to 19.40% and 26.6% to 21.2% (Figure 4). A similar trend was observed for addition of CD as additives, the liquid limit, plastic limit and plasticity index reduces from 52% to 39.8%, 25.40% to 19.50% and 26.6% to 20.3% (Figure 4). The values of Atterberg limit obtain from addition of CD are lower compared to values of Atterberg limits of clay soil +CPA only.. The reduction in plastic

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 8 Aug. 2022, pp: 1450-1457 www.ijaem.net ISSN: 2395-5252

index is expected because cassava peels ash and ceramic dust are cohesion-less material.
Thus an inclusion of CPA and CD reduces the Atterberg limits of the clay soils. Thus, this is an indication there is an improvement in the consistency of the soil.

Compaction

In determining the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD), the compaction test was performed on the clay soils and modified clay soils using the Standard Proctor test compaction method. The average value of the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) are shown in Table 5 and presented in Figure 5 and Figure 6 respectively.

Table 5: Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) Results

CPA Variation(%)	OMC and MDD of Clay Soils +CPA (%)		OMC and MDD of Clay Soils +5% CD+CPA (%)	
	OMC(%)	**MDD (kN/m^3)**	**OMC(%)**	**MDD** (kN/m^3)
0	18.44	17.01	18.44	17.01
2	18.07	17.05	17.23	17.52
4	17.95	17.09	16.82	17.76
6	17.22	17.56	16.62	18.02
8	16.64	17..87	16.45	18.13
10	16.57	17.75	16.46	18.26

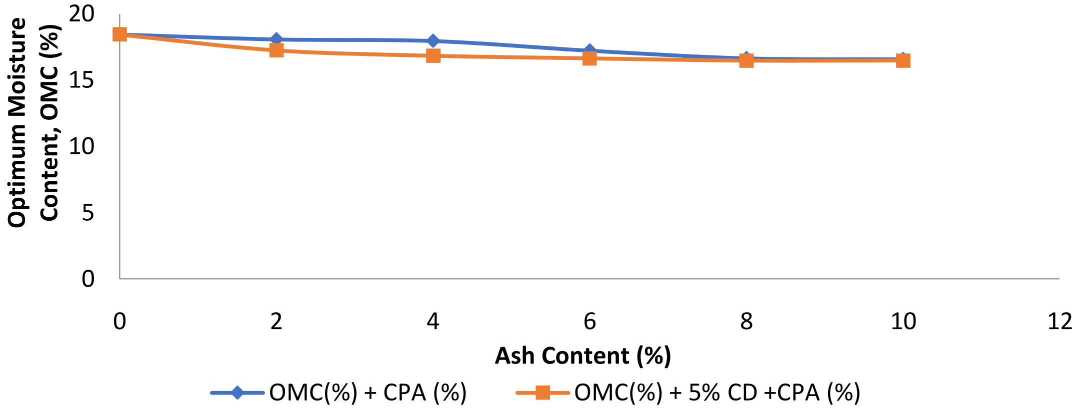


Figure 5: Optimum Moisture Content (%) of modified clay soils

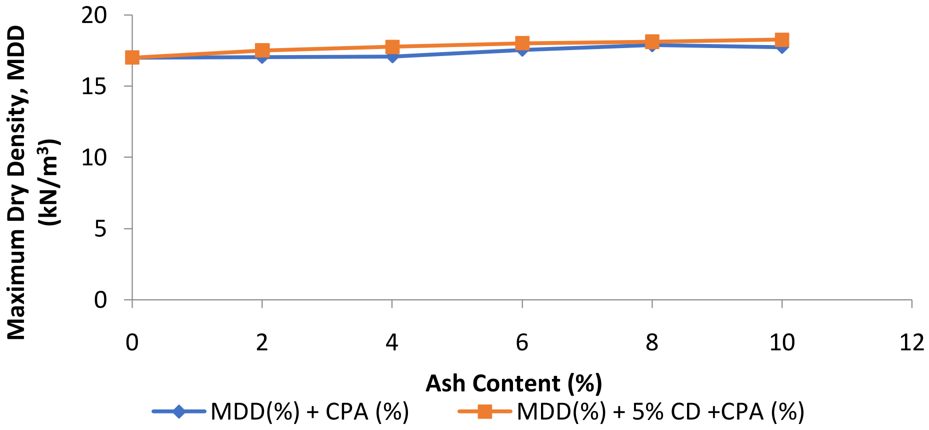


Figure 6: Maximum Dry Density (kN/m^3) of modified clay soils

The CPA and CD changes the optimum moisture content (OMC) and maximum dry density (MDD) of the clay soil. An increase in CPA from 0% - 10%, the optimum moisture content (OMC) decreases from 18.44% to 16.57% as shown in Figure 5, while the maximum dry density (MDD) increases from 17.01kN/m^3 to 17.75 kN/m^3 as shown in Figure 6. An addition of CD as additives, the optimum moisture content (OMC) further decreases from 18.44% to 16.46% (Figure 5), while the maximum dry density (MDD) decreases from 17.01kN/m^3 to 18.26 kN/m^3 (Figure 6).

It was observed that the addition of CD further increase maximum dry density (MDD) of the CPA modified clay soil. This is as a result of the CD having high specific gravity compared to the CPA. Also, the addition of CPA and CD reduces the optimum moisture content (OMC) because the surface area and the water absorption rate of the clay soil were diminished.

Thus, increase in the maximum dry density (MDD) and reduction in the optimum moisture content (OMC) is a pointer there is an improvement in the mechanical properties of the modified clay soil.

California Bearing Ratio

The average value of the soaked California Bearing Ratio (CBR) test results are shown in Table 6 and presented in Figure 7.

Table 6: California Bearing Ratio (CBR) Test Results

Sample	CBR (%)					
	0%	2%	4%	6%	8%	10%
Clay Soil + CPA(%)	2.8	3.2	4.1	4.3	5.2	5.5
Clay Soil + CPA (%)+ 5% CD	2.8	3.8	4.5	5.4	5.8	6.2

From Figure 7, it was observe that as CPA increases from 0% - 10%, the soaked CBR values increases from 2.8% to 5.5%. Similarly, addition of ceramic dust as additives to the CPA modified clay, the soaked CBR increases from 2.8% to 6.2% (Figure 7). It is observed that the addition of CD further increases the CBR values of the CPA modified clay soil. This is a result of the CD having coarser particles and more pozzolanic reactions.

V. CONCLUSION

This research work evaluates the effect of ceramic dust on geotechnical properties of CPA modified clay soil. The clay soil used in this research was classified as A-7-6 and CH AASHTO and USCS soil classification system respectively. This is a silt-clay material of high plasticity under general classification. The chemical composition test results reveal that both CD and CPA are Fly-Ash type C based on ASTM C618. The result shows that the CD will likely have high pozzolanic reactions compared to CPA. Also, it was shown that the addition of CPA - CD admixture improved the engineering properties of the clay soils. The plasticity index such as liquid limits, plastic limits and plastic index reduces. The reduction in the plasticity index is a pointer that the soil properties and its workability were improved. The OMC reduces to 16.57% at 10% CPA and 16.46% at 10% CPA + 5% CD, while the MDD increases to 17.75 kN/m^3 at 10% CPA and 18.46 kN/m^3 10% CPA + 5% CD. The soaked CBR values increases to 5.5% at 10% CPA and 6.2% at 10% CPA + 5% CD. The addition of CD further improves the geotechnical properties of the CPA modified clay soil.

Conclusively, the materials can serve as suitable alternatives to modify and stabilize problematic clay soils and hence help reduce construction costs, environmental hazards and ultimately bring about clay soils with improved geotechnical properties.

ACKNOWLEDGEMENT

The Research work was made possible through the financial support from Tertiary Education Trust Fund (TETFUND) Institution Based Research Fund.

REFERENCES

[1]. Adetoro, A. E; and Adekanmi, S. J., 2015, "Potentials Of Palm Kernel Shell and Sawdust Ashes For Stabilization Of Gbonyin Local Government Area Soil, Nigeria," Journal of Multidisciplinary Engineering Science and Technology (JMEST), 2(8), 2315-2319.

[2]. Afolayan, O. D; Olofinade, O. M; and Akinwumi, I. I., 2019, "Use Of Some Agricultural Wastes To Modify The Engineering Properties Of Subgrade Soils, A Review," Journal of Physics: Conference Series, 1378(2) (p. P.022050), IOP Publishing.

[3]. Alhassan, M., 2008, "Potential Of Rice Husk Ash For Soil Stabilization," Assumption University Journal of Technology, 11(4) , 246-250.

[4]. ASTM C 618 – 91, 2005, "Standard Specification For Coal Fly Ash and Raw Or Calicinated Pozzolan For Use As Mineral Admixture In Portland Cement Concrete," Annual Book of American Society for Testing and Material Standards, West Conshohocken, USA.

[5]. ASTM D 4318, 2003, "Standard Test Methods For Liquid Limit, Plastic Limit And Plasticity Index Of Soils," Annual Book of American Society for Testing and Material Standards, West Conshohocken, USA.

[6]. Amu, O.; Ogunniyi, S.; and Oladeji, O., 2016, "Geotechnical Properties of Lateritic Soil Stabilized With Sugarcane Straw Ash," FUOYE Journal of Engineering and Technology, 1(1), 116-119. doi: 10.5251/ajsir.2011.2.2.323.331.

[7]. Anthony, E.; and Akangee N. C., 2015, "Evaluation Of The Properties Of Rice Husk As A Partial Replacement For Ordinary Portland Cement," International Journal of Scientific Research Engineering and Technology (IJSRET), 4(7), 806-808.

[8]. Bashal, E.; Hashim, R.; Mahmud, H.; and Muntohar, A., 2005, "Stabilization Of Residual Soil With Rice Husk Ash and Cement," Construction Building Material, 19, 448-453.

[9]. Bhuvaneshwari, S.; Robinson, R. G.; and Gandhi, S. R., 2013, "Behaviour of Lime Treated Cured Expansive Soil Composites," Indian Geotechnical Journal, 44(3), 278–293. http://doi.org/10.1007/s40098-013-0081-3.

[10]. BS 1377, 1990, "Methods of Testing Soil for Civil Engineering Purposes," British Standards Institute, London.

[11]. BS 1924, 1990, "Methods of Test for Stabilized Soils," British Standards Institute, London.

[12]. Dabal, S.; Patel, R.; and Dalal, P., 2017, "Effect On Engineering Properties of Black Cotton Soil Treated With Agricultural And Industrial Waste," Material Today: Science-Direct, Proceedings, 4, 9640-9644.

[13]. Ekeocha, N. E.; and Agwuncha, F. N., 2014, "Evaluation of Palm Kernel Shells For Use as Stabilizing Agents of Lateritic Soils," Asian Transactions on Basic and Applied Sciences, 4(2), 1-7.

[14]. Hamza, M.; and Paul, S., 2019, "Effect of Polyurethane And Coconut Charcoal Ash In Soil Stabilization: A Review," International Journal of Technical Innovation in Modern Engineering and Science (IJTIMES), 5(4), 124-127.

[15]. Mittal, A., 2021, "Effect of Rice Husk Ash and Stone Dust on Selecting Engineering Properties of Poor Subgrade Soil," Jordan Journal of Civil Engineering, 15(1) , 133-141.

[16]. Nguyen, D. T.; and Nu, N. T., 2020, "Effect Of Different Types of Rice Husk Ash on Some Geotechnical Properties of Cement-Admixed Soil," The Iraqi Geological Journal, 53(2c) , 1-12.

[17]. Ogunribido, T. H. T., 2012, "Potentials of Sugar Cane Straw Ash For Lateritic Soil Stabilization in Road Construction," International Journal of Science Emerging Technology, 3(5), 102-106.

[18]. Okafor, E. O.; and Okonkwo, U. N., 2009, "Effect of Rice Husk Ash on Some Geotechnical Properties of Lateritic Soil," Nigerian Journal of Technology, 28(1) , 46-52.

[19]. Onakunle, O.; Omole, D. O.; and Ogbiye, A. S., 2019, "Stabilization of Laterite Soils From Agbara Nigeria With Ceramic Waste Dust," Congent Engineering, 6(1), 1710087 , 1-10.

[20]. Oyediran, I. A. and Fadamoro, O. F., 2015, "Strength Characteristics of Genetically Different Rice and Coconut Husk Ash Compacted Shales," International Journal of Geo-engineering, 6(1) , 1-14.

[21]. Pourakbar, S.; Asadi, A.; Huat, B. B. K.; and Fasihnikoutalab, M. H., 2015, "Stabilization of Clayey Soil Using Ultrafine Palm Oil Fuel Ash (POFA) and Cement ," Transportation Geotechnics, 3, 24-35.

[22]. Sante, M. D.; Fratalocchi, E.; Mazzieri, F.; and Pasqualini, E., 2014, "Time of Reactions in a Lime Treated Clayey Soil and Influence Of Curing Conditions on Its Microstructure and Behaviour," Applied Clay Science, 99, 100–109. http://doi.org/10.1016/j.clay.2014.06.018.