Article no. 27

THE CIVIL ENGINEERING JOURNAL 3-2020

SUGARCANE STRAW ASH EFFECTS ON LIME STABILIZED LATERITIC SOIL FOR STRUCTURAL WORKS

Olugbenga Oludolapo Amu[1], Christopher Ajiboye Fapohunda[1], Oluwaseun Adedapo Adetayo[1], Moronfolu Festus Ilesanmi[2]

1. *Federal University Oye Ekiti, Faculty of Engineering, Department of Civil Engineering, Ekiti State, Nigeria; oluwaseun.adetayo@fuoye.edu.ng*
2. *Obafemi Awolowo University, Faculty of Technology, Department of Civil Engineering, Ile-Ife, Osun State, Nigeria*

ABSTRACT

The research examined the appropriateness of sugarcane straw ash (SSA) as a modifier in lime stabilized lateritic soil with a view of improving the Geotechnical considerations of the soil structures. Elementary and Geotechnical investigations were performed on the lime stabilized soil samples and also when varying percentages of SSA were introduced. The elementary tests incorporated the moisture content, specific gravity, molecule size examination, and Atterberg's limits, while the Geotechnical were: compaction, California Bearing Ratio (CBR), and unconfined compression test. The lateritic samples were stabilized with 7% optimum of lime by weight, while SSA contents were gradually introduced at optimum lime up to 12.5% bulk of the soil. The addition of the SSA to the lime stabilized lateritic soil diminished the plastic indices from 25.09 to 21.98%, 24.76 to 21.09% and 19.43 to 15.37%; increased the unsoaked CBR values from 6 to 12%, 6 to 10% and 8 to 10 % and the unconfined compressive strengths from 88.10 to 126.13 kPa, 73.8 to 114.1 kPa and 52.17 to 127.85 kPa for tests A, B and C respectively. Concluding, the expansion of sugarcane straw debris improved the Geotechnical considerations of the lime stabilized lateritic soil tests for structural works.

KEYWORDS

Lateritic soil, Lime-stabilized soil, Sugarcane Straw Ash (SSA)

INTRODUCTION

Stability of civil infrastructures such as buildings, highways, and so on requires that they are found on firm and strong soil strata. However, it is not unusual to encounter on new sites, especially in the establishment of new built environment, soils that are not suitable for founding building and highway infrastructures. Removal of such soil and replacement with better soil from borrowing pit may prove expensive [1]. More often, it is more economical to employ one of the soil improvement methods on such soil, with a view to improving its Geotechnical properties before it is used as foundation material. The most widely recognized technique for soil improvement is soil sturdiness. Soil sturdiness includes the treatment of soils so as to improve their building properties with the end goal that they become progressively reasonable for development [2]. Although, many techniques of soil stabilization exist, a synthetic admixture adjustment which depends on the utilization of an admixture to change the compound properties of the soil to accomplish the ideal impact of improved Geotechnical performance has gained ascendancy in recent years. Notable materials that have been used or found by researchers to be suitable as a soil stabilizer includes: lime [3-7]; cement [8]; eggshell powder [9]; blast furnace slag [10]; fly ash [11]; marble dust [12];

stone dust [13]; used lubrication oil [14]; sugar cane bagasse ash [15-17], rice husk ash [16], saw dust ash [18], ground nut ash [19] and sugar cane straw ash [20]. These materials are either used singly or in combination, and for different types of soil. The present work investigates the effects of sugarcane straw ash (SSA) on the Geotechnical considerations of lime-stabilized lateritic soil for structural works. Lateritic soils are the most abundant materials in Nigeria, and indeed all over the world, especially in humid tropical and subtropical zones [21] on which most civil infrastructures (roads, buildings, and so on) are founded. In its regular state, lateritic soils for the most parts have a low bearing limit and low quality because of high mud content. According to [22], the quality and steadiness of lateritic soils cannot be ensured under burden within the sight of dampness. According to [21], the difficulties encountered when laterites are used include: (i) poor compaction because of high dampness content, (ii) affect ability to vacillations in dampness, where quality might be fundamentally decreased with a slight increment in water substance, and (iii) genuine agglomeration and trouble in compaction in the field. It is along these lines basic, consequently, to improve the Geotechnical considerations of laterite to make it fit for founding civil engineering infrastructures. Some admixtures that have been found in stabilizing laterite include: banana leaf ash [22]; cassava peel ash [23]; lime-cement mix [24]; palm piece shell debris [19], saw dust debris [18], lime [21], groundnut husk ash [19]. Many of these admixtures are waste materials, and as such, their use in soil stabilization is an innovative solution to the problems associated with waste disposal. The present work investigates the possibility of using sugarcane straw ash as a stabilizing agent of lime-stabilized lateritic soil. Though [25] researched the impact of SSA on the Geotechnical considerations of concrete balanced out lateritic soil, where the results showed improved Geotechnical properties. Similarly, an investigation conducted by [5] on lateritic soil using lime-sugarcane bagasse (SB) yielded improved geotechnical properties of optimum lime-SB of 4:1. Also, [2] experimented with the possible use of SSA as a stabilizing agent for lateritic soil. However, literature is scarce on the use of lime and sugarcane straw ash (SSA) together as balancing out specialist. Along these lines, the point of this work is to evaluate the impact of SSA on the Geotechnical properties of lime-settled lateritic soil for structural works.

RESEARCH QUESTION

Lime is created by consuming limestone. It responds promptly on contact with water in the soil to frame slaked lime or calcium hydroxide ($Ca(OH)_2$). This response produces heat and the pH esteem increments to roughly 12.5 [26]. It is a condition for the ensuing pozzolanic responses, in which mud particles in the soil respond with the calcium hydroxide to frame the quality improving response items. Knowing that sugarcane straw, from which the sugarcane ash (SSA) is derived, being a waste, presently has no value and also constitutes an environmental nuisance, will its presence enhance pozzolanic activities of lateritic soil, and thus becomes a valuable material? What will be the impacts of SSA on lime balanced out lateritic soil, in relation to the sustenance condition for pozzolanic response for improved Geotechnical properties? This is the fundamental research question about this investigation.

METHODOLOGY

The materials utilized in this investigation are, lateritic soil, hydrated lime, sugarcane straw ash, and portable water. The lateritic soil utilized was gathered from three distinct areas (tests A, B, C). The global positioning of the locations of tests A, B, and C are separately, 70 31' 02.51" N, 40 30' 48.74" E; 70 31' 02.94" N, 40 30' 48.48" E; and 70 31' 04.70" N, 40 30' 46.01" E. The samples were kept dry inside jute bags marked to indicate description, area and date of examining. The different soil samples were spread independently for air drying, to permit incomplete disposal of characteristic water which may influence investigation. After the drying time frame, irregularities in the samples were somewhat pounded with negligible weight and from there on sieved with strainer

No. 4 (4.76mm opening) to get the last samples for the tests. Hydrated lime was used because it does not set by reaction with water like hydraulic lime. The hydrated lime was kept in a safe bag under room temperature to forestall any contact with dampness or potentially whatever other outer elements that can influence its property. The sugarcane straw was gathered from a sugarcane farm in Igboya Ile-Ife, Nigeria. The straws were spread out on the ground and air dried to encourage simple consuming. After air drying, the sugarcane straws were singed straightforwardly into debris and gathered in polythene sacks, put away under room temperature until utilized. The sugarcane straw ash (SSA) was sieved through the BS sifter 212 μm to get fine debris.

Experimental investigations

Both preliminary and Geotechnical tests were completed on the soil samples A, B and C. The preliminary tests did on soil samples were, moisture content, specific gravity, molecule size examination, and Atterberg's limits, while, the Geotechnical investigations were, compaction, California Bearing Ratio (CBR), and unconfined compression test. All these were done as per relevant universal standard systems as stipulated in [27]. All the soil samples were stabilized with optimum 7% lime by weight. The lime-stabilized samples were then treated with SSA in varying percentages of 6%, 8%, 10% and 12.5% bulk of soil samples, in order to determine the optimum prerequisite of SSA required for the modification of the different samples. At the point when the samples were stabilized with 7% lime, the Geotechnical properties were determined and these were utilized as a control against which the Geotechnical considerations of the lime stabilized soil changed with sugarcane straw ash (SSA) were compared.

RESULTS AND DISCUSSION

Preliminary results of the soil samples

The results of the preliminary properties of the soil samples appear in Table 1. It can be observed in the Table 1 that soil samples A, B and C are delegated as A-7-6, A-7-5, and A-7-5 separately.

Tab. 1 - Preliminary results of soil tests

Property	Sample A	Sample B	Sample C
Natural Moisture Content	8.49	12.63	10.55
Specific Gravity	2.44	2.38	2.94
AASHTO Arragement	A-7-6	A-7-5	A-7-5
Liquid Limit	73.88	65.95	60.40
Plastic limit	27.27	33.72	30.83
Plasticity Index	46.61	32.23	29.57
Maximum Dry Density (kg/m^3)	1466	13881	1431
Optimum Moisture Content (%)	23.50	29.40	27.40
CBR (%)	6	3	5
UCS (kg/m^2)	81.25	68.10	52.77

DOI 10.14311/CEJ.2020.03.0027

All the soil samples have their liquid limits more noteworthy than 41% and plasticity indices more prominent than 11%. As per the AASHTO table for classification, soils having a place with this class are viewed as reasonable for poor material and are not appropriate as subgrade material. Therefore, soil stabilization becomes very relevant. The poor quality of the samples is further reinforced by high liquid limit and plasticity indices, thus necessitating application of soil improvement measures, as per soils used for similar research work by [28-29].

Atterberg limits characteristics

The Atterberg limits characteristics of lime-stabilized lateritic soil containing SSA are shown in Table 2. In relation to the Atterberg limit traits of the soil as shown in Table 1, it can be observed that the use of SSA caused a decrease in the plasticity record of the lime-balanced out lateritic soil at some points along the process.

The watched decline of the plasticity record of soil tests with SSA upgrades its qualification for use as construction materials. According to [30] and [29] a decrease in P.I gives a sign of a progressively steady soil with checked expanded usefulness.

Tab. 2 - Summary of Atterberg's limits

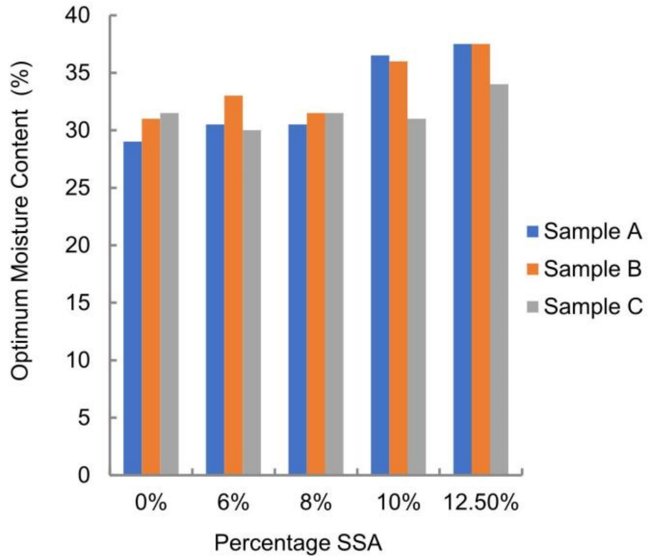
Samples	Percentage SCSA (%)	Liquid Limit, LL (%)	Plastic Limit, PL (%)	Plasticity Index, PI (%)
A	0	67.63	42.54	25.09
	6	70.4	44.35	26.05
	8	66.59	44.61	21.98
	10	66.4	43.59	22.81
	12.50	66.60	41.30	25.30
B	0	60.68	35.92	24.76
	6	62.8	38.26	24.54
	8	63.53	40.35	23.18
	10	63.93	42.15	21.78
	12.50	62.25	41.16	21.09
C	0	60.35	40.92	19.43
	6	56.46	41.09	15.37
	8	59.5	40.73	18.77
	10	59.18	42.99	16.19
	12.50	56.62	40.27	16.35

Results of the compaction tests

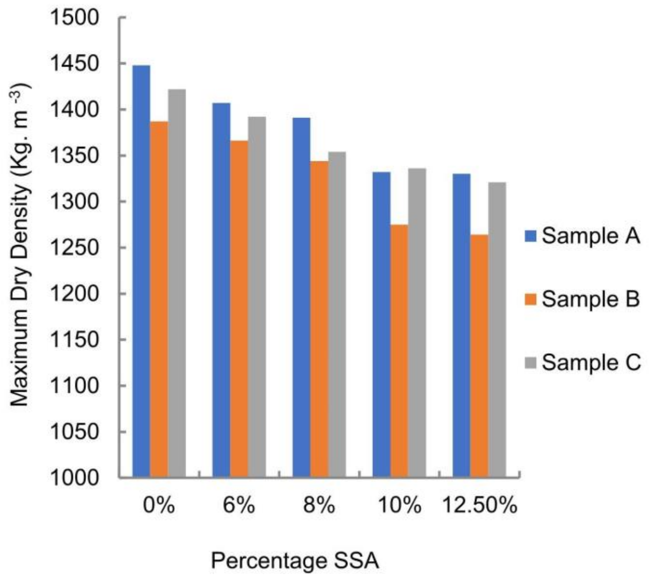
The compaction qualities of the lime-stabilized soil modified with sugarcane straw ash (SSA) as far as characteristics, moisture content and the maximum dry density are presented in Figure 1. From Figure 1, all the samples dynamically display higher moisture content with expanding substance of SSA. The expansion in moisture content is presumably because of the extra water held inside the flocculated soil structure coming about because of lime cooperation for the pozzolanic responses to occur [28-29]. The extra water held in the muddled soil structure because of the permeable property of sugarcane straw ash which could likewise bring about higher

---

moisture content in the soils [3]. The figure additionally shows decreases in the maximum dry densities of the treated soils with expanding SSA.



(a) Effect of SSA on the Optimum Moisture Content



(b) Effect of SSA on the Maximum Dry Density

Fig. 1 - Characteristics of Lime-stabilized Soil Modified by SSA

The decrease in dry density is an impression of the expanded obstruction offered by the muddled soil structure to the compactive exertion [31]. Likewise, adding to the decrease in the dry density is the specific gravity of the sugarcane straw ash, which is lower than that of the normal soil tests, in this manner the less heavy and smaller particles fill the voids of the muddled soil network to give a less thick lattice [32]. According to [33], a reduction in dry density shows that a low compactive vitality is required than the regular soil to accomplish its greatest dry density and accordingly, the expense of compaction will be diminished. The compactive attributes of lime-

DOI 10.14311/CEJ.2020.03.0027

stabilized soil modified with SSA of higher optimum moisture content and lower density can be used to reduce or eliminate volumetric changes in soil, caused by alternate wetting and drying [34].

GEOTECHNICAL CHARACTERISTICS

CBR Test Results

The CBR method, according to [18], is a solid handy method for finding the quality of the sub-level (bearing limit of soil) and assessing the necessary thickness of pavement to fulfil a given stacking. The consequences of the unsoaked CBR tests, suggested for tropical soil [1], to evaluate the bearing capacity of lime-stabilized lateritic soil containing SSA, are plotted and appeared in Figure 2. For all the samples, there is a typical pattern that can be observed, which is, increment in CBR values with SSA followed by decrease upon consistent expansion of SSA. An expansion in CBR esteem means that improved Geotechnical properties [1]. The expansion in the CBR estimation of the samples can be credited to improved conditions for pozzolanic exercises, by guaranteeing that the pH value is maintained at around 12.5 [26]. The pozzolanic activities will result in the strength-forming C-S-H gel hydration products. The CBR values of the normal soil tests are 6, 3 and 5% of tests A, B and C separately. The CBR estimations of 6, 6 and 8% were recorded on expansion of 7% lime to tests A, B and C individually.

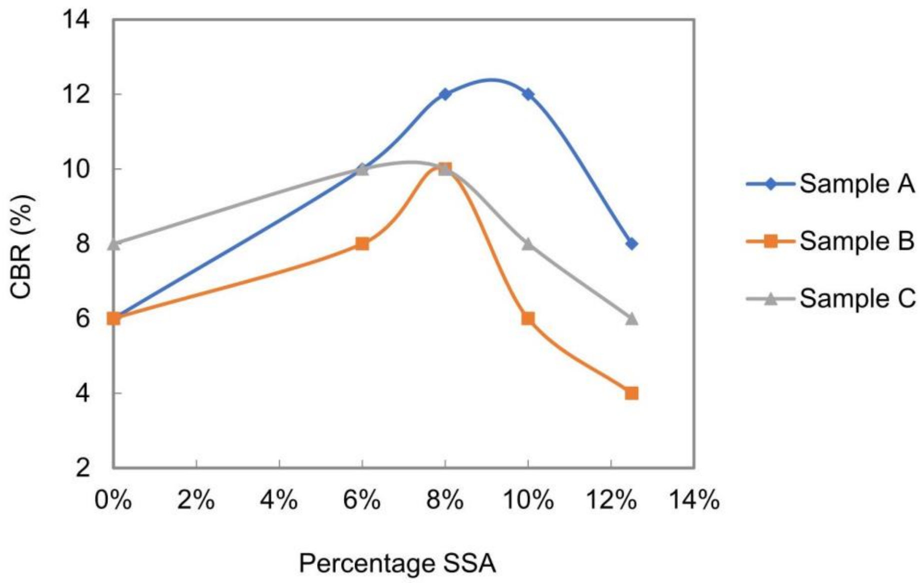


Fig. 2 - Effects of SSA on the Unsoaked CBR of the Tests Samples

The highest CBR values of 12%, 10% and 10% were recorded at 8% SSA and 7% lime combinations of tests A, B and C individually. The expansion in CBR esteem after expansion of lime is most likely because of the development of different solidifying specialists due to pozzolanic response between the silica present in soil and lime. As indicated by [35], a CBR estimation of 7–20 % is suggested for Highway sub-base and 0–7 % of the sub-level materials. It is obvious that the CBR values of lime-stabilized lateritic soil containing SSA up to 8%, can be used as highway subbase and subbase materials.

Unconfined compression test

The unconfined compression strength (UCS) test is the principle test prescribed for the assurance of the necessary measure of added substances to be utilized in modification of the soils [18]. The general guideline for a given kind of modification is that the higher the compressive quality, the better is the nature of the settled material. The results of the unconfined compression tests on lime-stabilized lateritic soil samples containing SSA are shown in Figure 3.

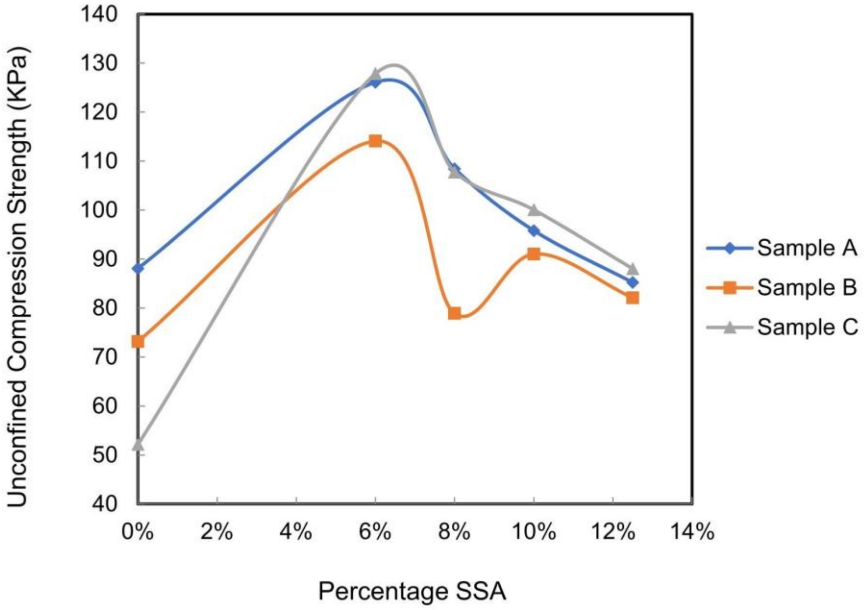


Fig. 3 - Effects of SSA on the Unconfined Compression Strength of the Soil Samples

It may be very well seen from Figure 3 that the unconfined compressive quality, increased with the expansion of SSA up to 6% and then decreased for all the samples. It can be explained that beyond 6%, the necessary condition for pozzolanic activities, in lime-based medium, which is a pH of about 12.5 [26] is disrupted. However, comparing the numerical values of UCS obtained for the samples; the unconfined compressive strength of the natural soil samples rose respectively, for samples A, B and C from 81.25, 68.10 and 52.27 KN/m^2 to 88.1, 73.18 and 52.37 KN/m^2 when lime was added. The compressive strength further increased with the addition of SSA, but the optimum values at 6% were 126.13, 114.1 and 127.85 KPa respectively, for tests A, B and C. It is likewise notable that UCS is the principal determinant for consistency of soil [32]. Additionally, according to [33], the UCS esteems between 0-25 kN/m^2 demonstrates exceptionally delicate soil, between 25-50 kN/m^2 shows delicate soil, between 50-100 kN/m^2 shows medium soil, between 100-200 kN/m^2 shows firm soil, between 200-400 kN/m^2 shows extremely hardened soil and more noteworthy than 400 kN/m^2 demonstrates hard earth. It may be very well seen that the unconfined compression quality of the samples A, B and C transformed from the underlying state medium consistency to hardened consistency at 6% SSA and optimum lime stabilization.

CONCLUSIONS

From the analysis of the results of this investigation, the following conclusions were made:

1) The expansion of SSA in lime-settled lateritic soil brought about a decrease in plasticity record at all levels for all the samples.
2) Introduction of SSA in lime-settled lateritic soil brought about increment in CBR values up to a level. However, the peak values for CBR for all the samples occurred at 8% addition of SSA.
3) The overall results showed that, lime-stabilized lateritic soils containing SSA up to 8% by weight of soil are able to sustain the conditions necessary for pozzolanic reaction for improved Geotechnical properties.

The addition of SSA in lime-stabilized lateritic soil increased the UCS, but the optimum values for all the samples were obtained at 6%

Though, optimum performances were obtained at 8% for CBR tests and 6% for UCS, by considering the lower bound principle, it can be concluded that 6% of SSA in lime-stabilized lateritic will results in optimum geotechnical performance of the soil.

REFERENCES

[1] Ola S. A., 2013. Essentials of Geotechnical Engineering, 3rd ed., University Press PLC, Ibadan Nigeria

[2] Amu O. O., Ogunniyi S. A., Oladeji O. O., 2011a. Geotechnical properties of lateritic soil stabilized with sugarcane straw. American Journal of Scientific and Industrial Research, Vol. 2, pp. 323-331.

[3] Amu O. O., Bamisaye O. F., Akomolafe I. A., 2011b. The suitability and lime stabilization requirement of some lateritic soil samples as pavement material. International Journal of Pure and Applied Science Technology, Vol. 2, No. 1, pp. 29- 46.

[4] Barasa P. K., Too D., Jonah K., Mulei S. M., 2013. Stabilization of expansive clay using lime and sugarcane bagasse ash. International Journal of Science and Research (IJSR), Vol. 4, No. 4, pp. 2112-2117.

[5] Barasa P. K., Jonah K., Mulei S. M., 2015. Stabilization of expansive clay using lime and sugarcane bagasse ash. Mathematical Theory and Modeling, Vol. 5, No.4, pp. 124-134.

[6] Dang L. C., Hasan H., Fatahi B., Jones R., Khabbaz H., 2016). Enhancing the engineering properties of expansive soil using bagasse ash and hydrated lime. International Journal of GEOMATE, Vol. 11, No. 25, pp. 2447 - 2454.

[7] Hasan H., Dang L., Khabbaz H., Fatahi B., Terzaghi S., 2016. Remediation soils using agricultural waste bagasse ash. Procedia Engineering, Vol. 14, No. 3, pp. 1368–1375.

[8] Ramteke N. B., Saxena A., Arora T. R., 2014. Stabilization of black cotton soil with sand and cement as a subgrade for pavement. International Journal of Engineering Sciences & Research Technology, Vol. 3, No. 6, pp. 688-692.

[9] Ahmed B., Rahman A., Das J., 2015. Improvement of subgrade CBR value by using Bagasse ash and Eggshell powder. International Journal of Advanced Structures and Geotechnical Engineering Vol. 4, No. 2, pp. 86-91.

[10] Chavan P., Nagakumar M. S., 2014. Studies on soil stabilization by using bagasse ash International Journal of Scientific Research Engineering and Technology (IJSRET), pp. 89-94.

[11] Rajakumaran, K. (2015). An experimental analysis on stabilization of expansive soil with steel slag and fly ash. International Journal of Advances in Engineering and Technology, Vol. 7, No. 6, pp. 1745-1752.

[12] Ali R. H., Khan A. A., Shah T., 2014. Expansive soil stabilization using marble dust and bagasse ash. International Journal of Science and Research (IJSR), Vol. 3, No. 6, pp. 2812-2816.

[13] Mudgal A., Sarkar R., Sahu A. K., 2014. Effect of lime and stone dust in the geotechnical properties of black cotton soil. International Journal of GEOMATE, Vol. 7, No. 2, pp. 1033-1039.

[14] Sadeeq J. A., Ochepo J., Salahudeen B. A., 2016. Effect of used oil contamination and bagasse ash on some geotechnical properties of lateritic soil. Leonardo Electronic Journal of Practices and Technologies, Vol. No. 28, pp. 119-136.

[15] Salim R. W., Ndambuki J. M., Adedokun D. A., 2014. Improving the bearing strength of sandy loam soil compressed earth block bricks using sugarcane bagasse ash. Sustainability 6, 3686-3696; doi:10.3390/su6063686.

[16] Yadav A. K., Gaurav K., Kishor R., Suman S. K., 2017. Stabilization of alluvial soil for subgrade using rice husk ash, sugarcane bagasse ash and cow dung ash for rural roads. International Journal of Pavement Research and Technology, Vol. 10, pp. 254–261.

[17] Ojeda-Farías O., Mendoza-Rangel J. M., Baltazar-Zamora M. A., 2018. Influence of sugar cane bagasse ash inclusion on compacting, CBR and unconfined compressive strength of a subgrade granular material. Revista ALCONPAT, Vol. 8, No. 2, pp. 194 – 208. doi: http://dx.doi.org/10.21041/ra.v8i2.282.

[18] Butt W. A., Gupta K., Jha J. N., 2016. Strength behaviour of clayey soil stabilized with saw dust ash. International Journal of Geo-Engineering, Vol. 7, No. 18, pp. 2-9.

[19] Nnochiri E. S., Ogundipe O. M., Oluwatuyi O. E., 2017. Effects of palm kernel shell ash on lime-stabilized lateritic soil. Slovak Journal of Civil Engineering, Vol. 25, No. 3, pp. 1-7. doi:10.1515/sjce-2017-0012.

[20] Chakraborty A., Borah A., Sharmah D., 2016. Stabilization of expansive soil using sugarcane straw ash (SSA). ADBU-Journal of Engineering Technology, AJET. Vol. 4, No. 1, pp. 2348-7305.

[21] Tan Y., Hu, M., Li D., 2016. Effects of agglomerate size on California bearing ratio of lime treated lateritic soils," International Journal of Sustainable Built Environment, pp. 168–175. http://dx.doi.org/10.1016/j.ijsbe.2016.03.002.
[22] Nnochiri S. E., Aderinlewo O. O., 2016. Geotechnical properties of lateritic soil stabilized with banana leaves ash. FUOYE Journal of Engineering and Technology, Vol. 1, No. 1, pp. 116-119.
[23] Bello A. A., Ige J. A., Ayodele H., 2015. Stabilization of lateritic soil with cassava peels ash. British Journal of Applied Science and Technology, Vol. 7, No. 6, pp. 642-650. doi: 10.9734/BJAST/2015/16120.
[24] Todingrara Y. T., Tjaronge M., Harianto T., Ramli M., 2017. Performance of laterite soil stabilized with lime and cement as a road foundation. International Journal of Applied Engineering Research, Vol. 12, No. 14, pp. 4699-4707.
[25] Onyebuchi M., Abdulhameed M., Yeke E., Michael T., 2018. Effect of sugarcane straw ash on cement stabilized lateritic soil for use as flexible pavement material. Journal of Emerging Technologies and Innovative Research (JETIR), Vol. 5, No. 2, pp. 563-567.
[26] Axelsson K., Johansson S., Andersson R., 2002. Stabilization of organic soils by cement and pozzolanic reactions - Feasibility Study (Report 3). The Swedish Deep StabilizationResearchCentre. http://www.swedgeo.se/sd.htm.
[27] British Standards BS: 1377-1., 2016. Methods of test for soils for Civil Engineering purposes. General requirements and sample preparation.
[28] Jha J. N., Gill K. S., 2006. Effect of rice husk ash on lime stabilization. Journal of the Institution of Engineers, Vol. 87, pp. 33-39.
[29] Mtallib M. O. A. and Bankole G. M., 2011. The improvement of the index properties and compaction characteristics of lime stabilized tropical lateritic clays with Rice Husk Ash (RHA) Admixtures. EDGE, Vol. 16.
[30] Martirena J. F. H., Middendorf B. Gehrke M. and Budelmann H., 1998. Use of wastes of the sugar industry as pozzolana in lime-pozzolana binders: Study of the reaction. Cement and Concrete Research. Vol 28, pp. 1525–1536.
[31] Nagaraj T. S., 1964. Discussion on Soil – lime research at Iowa State University ASCE, Vol. 90, No. 6, pp. 225-226.
[32] Das B. M., 2000. Fundamental of Geotechnical Engineering, 4th ed., Thomson Learning, New York.
[33] Muntohar G.D., Hantoro G., 2000. Influence of rice husk ash and lime on engineering properties of a clayey sub-grade. Dept of Civil Engineering, Muhammadiyah University of Yogyakarta, Indonesia.
[34] Bowles J. E., 1998. Foundation Analysis and Design, McGraw Hill International Book Company, London.
[35] ARRA, 2008. Asphalt Recycling and Reclaiming Association (ARRA), Soil stabilization. 2011 annual meeting presentation. #3, Church Circle Annapolis, Maryland.