Medicon Engineering Themes
Volume 4 Issue 4 April 2023
Article Type: Research Article
ISSN: 2834-7218

Chemically Stabilized Laterite Soil Using Rice Husk Ash

Somnath Paul[1]* and Dipankar Sarkar[2]

[1]*Graduate Engineer, NIT Agartala, Agartala, India*

[2]*Assistant Professor, NIT Agartala, Agartala, India*

***Corresponding Author:** Somnath Paul, Graduate Engineer, NIT Agartala, Agartala, India.

Received: March 09, 2023; **Published:** March 24, 2023

Abstract

This research focuses on optimum usage of industrial waste in soil stabilization. Shear strength alteration happens in subsoil due to environmental fluctuations or seismic events that are generally observed in hilly areas with unsupported backfills. This problem becomes worst in the case of problematic soil that causes collapse or swelling followed by shrinkage in contact with water due to the high anisotropic nature of the subsoil. The cyclic behavior of various problematic soils under transient loading directly incorporates the economic loss and human lives. The present experimental work has briefly described the suitability of using rice husk ash (RHA) in soil stabilization and reducing the dumping of toxic waste responsible for environmental pollution. In place of common stabilizer units such as fly ash and pond ash, we use a cheap stabilizing agent which has no use in soil improvement in past as single unit. RHA is used as a chemical stabilizer as it contains high percentage of silica. If the soil has a larger fraction of clay mineral, then RHA (produced by controlled incineration ~400-500°C) mixed soil in different proportion (4 and 6% by weight of soil sample) performed differently in serviceability and workability tests on soil sample like UCS, modified proctor test, CBR, Atterberg's limit, permeability, consolidation test, etc. Excellent results were obtained at 6% optimum dosage of RHA in locally available laterite soil (inside NIT Agartala campus) from NE part of India.

Keywords: Rice husk ash; Soil strength; Serviceability

Introduction

Soil stabilization is primary concern for geotechnical and transportation aspects in recent time. Many of new techniques like mixing and curing of soil with bitumen, tar emulsions [13], fly ash [4, 6], bagasse ash [2], cement [13], lime [13] and pond ash [9] can be used as binding agents for producing durable soil matrix in pavement construction. But, environmental safety and health issues should kept in mind during their usage. Because, each material can create detrimental effects on nature by erosion and release CO_2 in open atmosphere during their manufacturing. Among the top seven states with the highest rate in land degradation in last 10 years, six states are from NE, India. Weathering erosion and water logging on pavement cause poor performance of subgrade which is frequently observed in hilly area of NE, India, during monsoon. Central investigation [15] reports find that the most common cause of land degradation is acidification in soil. About 7.5 lakh hectares of land in Nagaland and 6.3 lakh hectare of land in Manipur are acidic in nature found by GSI [5]. Soil acidity increases when metallic ions like calcium, magnesium, potassium and sodium are lost from the soil and only hydrogen ions present. This hydration of soil minerals causes sudden disintegration of soil block from sides of hill cuts during heavy rainfall and causes devastating landslides. Those weaken the subgrade properties due to rearrangement of particle in pavements during course time. In recent investigations, some landslides were taken place at NE, India. One of those are landslide reportedly occurred at Lokchao area, Tengnoupal District, Manipur, heading as "Landslide hits NH-102" at August 3, 2018 (Fig. 1). The main causes of slide includes extensive slope cutting result in increase of gravity load, sparse vegetation above the crown, poor drainage along the faults, development of widening in cracks that covered the slope from top to bottom.

Another example of landslide took place at Lumding-Badarpur Railway Line that collapsed during heavy rainfall at July 2018. It caused a huge mass slide near Bandarkhal Railway Station in the midnight of July 14 (Fig. 2). Heavy rainfall, fluvial action, soil comprising of small and large fragments of sandstone, undrained surface run-off and seepage of water along the pre-existing cracks were identified as some of the contributing factors.

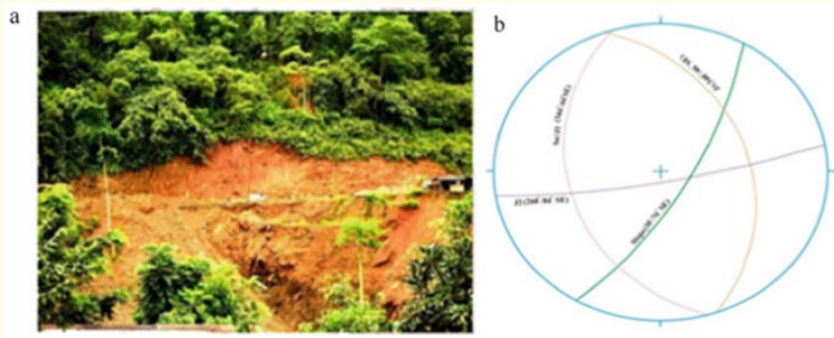

Figure 1: a Plane view of Lokchao slide along NH-102 along Imphal-Morch road, b stereographic projection of joint planes.

Figure 2: Slope fails and causes sliding failure on railway embankment of Lumding-Badarpur Line.

From the given examples, it is clear that in most of the places the soil is dispersive in nature and forms flocks in the presence of water which supports gravitational forces and causes landslides. The failure plane crosses toe of the slope and passes below the earth structures which causes global failure of soil slope system. Constructors are mainly focused on local stabilization of slope by installing gabion wall, retaining structure. But it is hard to identify the long term stability behavior of soil [10]. Different uncertainties like sudden drawdown of water table and the seismic shakes due to earthquake cause huge damage in form of sliding, overturning and topple of earth retaining structures. In highway embankment, fatigue crack and potholes appeared (Fig. 3) due to differential settlement which gradually split on surface of road pavement and frequently reduce serviceability of it. NH-208A also suffers from tremendous cracks during monsoon in every year due to heavy rainfall and water logging.

Therefore, soil stabilization is prime concern in NE part of India. The main objective of soil stabilization is to increase mechanical strength of soil, stability of soil slope and reduce construction cost with best use of locally available stabilizers. Cement and lime are two common materials used for soil stabilization [3, 7, 12]. These materials have rapidly increased in price due to sharp increase in production cost. Use of agricultural waste (e.g., RHA) will considerably reduce the cost of construction [8] and release less CO_2 in open atmosphere compared to other chemical stabilizers such as lime and fly ash. Rich husk is generally produced by using incineration process [14]. Rice husk is an agricultural waste obtained from milling of rice. About 20 million tons of husks are produced worldwide in every year [11]. The husk is not suitable as animal feed because of its abrasive character and almost negligible digestive protein content. Its high ash and lignin contents make it unsuitable as a raw material for paper manufacturing.

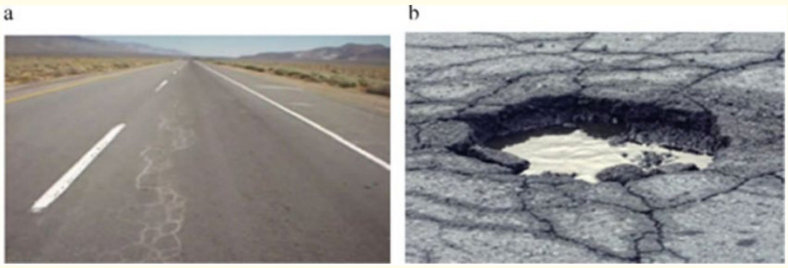

Figure 3: a Fatigue cracking, b potholes.

In present investigation, we use different dosage of rice husk ash (manufactured at control temperature burning of 400-500°C called incineration process) in the proportion of 4 and 6% weight of tested soil specimen to investigate the effects on index and engineering characteristics of problematic soil. The effect of soil stabilization on soil properties like compaction property, California bearing ratio, settlement characteristics, unconfined compressive strength and permeability is observed. The self-potential of optimum usage for rich husk ash still left to be unexplored on ground improvement and controlling soil migration in a heavy rainfall area (specifically hilly area) with improvement in local available laterite soil properties used for highway constructions.

Experimental Work

Materials

The tested soil sample was collected from west district of Tripura, India at a depth of 1 to 1.5 m using disturbed sampling process. The classification of soil is silty sandy (SM) type, and other geotechnical index properties are explained in Table 1.

Geotechnical characteristics	***Experimental values***
Natural moisture content (%)	19.81
Specific gravity, G s	2.59
Liquid limit (%)	34
Plastic limit (%)	25.5
Maximum dry density (gm/cc)	1.71
Optimum moisture content (%)	14
UCS (%) and CBR (kN/m^2)	6.34 and 57.98

Table 1: Geotechnical properties of the natural soil collected from Institute Campus.

Methods of Testing

The laboratory tests carried out mostly on RHA mixed soil in different dosage which includes particle size distribution, Atterberg's limits, compaction test, CBR and UCS test, Oedometer test and permeability test. The geotechnical properties of the soil are determined in accordance with Indian Standard Code.

Results and Discussion

Grain Size Distribution

About 99.6% of soil is finer then 4.75 mm aperture sieve size and 0.4% of soil is finer then 75μ aperture sieve size has been shown in Table 2. Hence, major percentage of specimen contains silt which is generated by weathering of quartz mineral.

For particle size less than 75μm is analyzed by hydrometer analysis which is based on the principle of Stoke's law that allows the particle to set in an infinite fluid under free boundary condition.

From Fig. 4, it is clearly noticed that more than 50% of fine fraction of soil is retained on 2μ sieve size and about 90% of soil is finer than 75μ aperture size.

Atterberg's Limit

The Atterberg's limits are tested according to the code of IS: 2720-Part V. The liquid limit comes to 23.78% (Fig. 5), and plastic limit comes to 14.58% on Institute soil. Plasticity index (I_p) comes to 9.21% which determines the range of water content in plastic state of soil. From plasticity chart, I_p obtained as 2.77. Therefore, soil ranges above the A-Line. But from hydrometer analysis, it proves that there is minor percentage of clay in current soil. So, it is obvious that silt is predominant in soil matrix.

IS Sieve size in mm	***Percentage finer (%)***
4.75	99.6
2.36	99.2
1.18	97.2
0.6	95.6
0.425	60.8
0.3	40.8
0.15	3.6
0.075	0.4

Table 2: Particle size distribution data of natural soil collected from Institute Campus.

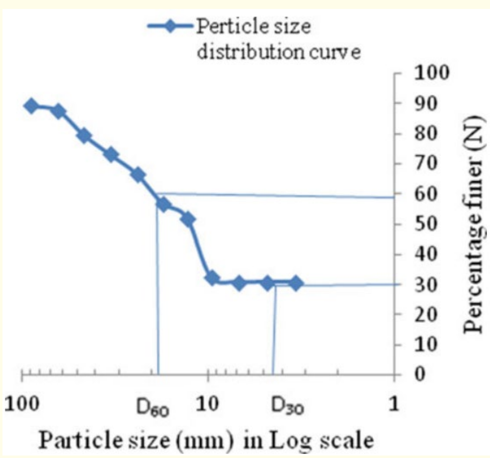

Figure 4: Particle size distribution curve of NIT Agartala soil.

The liquidity index of soil indicates the nearness of sample in-situ water content to its liquid limit Liquidity index calculated from the test is 0.56 means that the soil lies intermediate between plastic and semi-solid state.

$$I_{\mathrm{p}} = \frac{w - w_{\mathrm{p}}}{I_{\mathrm{p}}} \times 100 \quad (1)$$

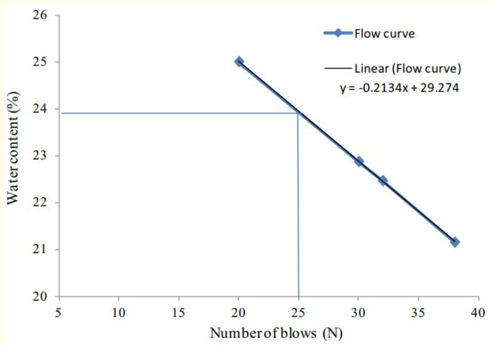

Figure 5: Flow curve for liquid limit testing.

Consistency index indicates the water content of soil nearness to its plastic limit.

$$I_{\mathrm{c}} = \frac{w_{\mathrm{l}} - w}{I_{\mathrm{p}}} \times 100 \quad (2)$$

Consistency index obtained from the test is 0.43, means that the soil has significant strength even at the intermediate stage of plastic and semi-solid stage.

Toughness index (I_t) can be measured as following,

$$I_{\mathrm{t}} = \frac{I_{\mathrm{p}}}{I_{\mathrm{f}}} \quad (3)$$

Where I_p = Plasticity index,

I_f = Flow index, slope of the flow curve obtained from liquid limit test.

12.05%.

I_t = comes out 1.31, shows higher shear strength at plastic limit by the given Eq. (4),

$$\mathrm{Log}_{10}(S_p) = I_t + \mathrm{C}, \mathrm{C} = \text{correction factor} = 0.431 \quad (4)$$

Modified Proctor Test

Using modified proctor test (IS 2720, Part-VIII), the optimum moisture content and maximum dry density are obtained as 15% and 1.85 gm/cc by using 6% of RHA (Fig. 6). Dry density decreases due to the presence of RHA which increased fine content and water retention capacity, respectively, using current available laterite soil.

California Bearing Ratio

California bearing ratio test is generally used to predict the bearing capacity and strength of subgrade with base soil.

It is observed from Fig. 7 that CBR value increases from 16.11 to 19.43% at 2.5 mm penetration due to stabilization of soil in between 4 and 6% RHA content with soil. Similar trend can be observed for the values of CBR at 5 mm penetration which rise from 14.86 to 16.82%. The increase in CBR values can be attributed to the fact that as percentage (%) of RHA content increases from 4 to 6%, there is an increase in the formation of cementations compound as the RHA forms bonds with other inorganic compounds present in the soil. If we further increase RHA content, there might be a gradual decrease in the value of CBR due to replacement of soil by finer fraction of RHA.

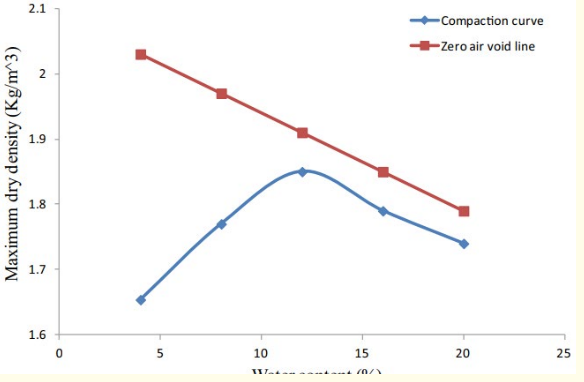

Figure 6: Graphical representation of modified proctor test.

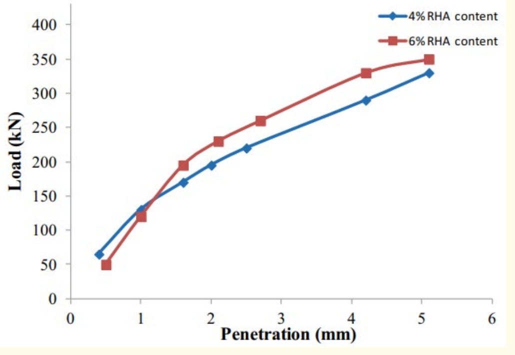

Figure 7: Graphical representation of CBR value of soil with 4 and 6% RHA mixture.

Unconfined Compressive Strength

UCS test helps to find different parameters like compressive strength and shear strength of soil. It helps to determine the strain rate at which a given specimen fails along with the maximum bearable compressive stress that a soil specimen can endure. The value of UCS at 4 and 6% use of RHA in soil was found to be 65.46 and 83.62 kN/m^2 as observed from Fig. 8. The specimen used for testing was remolded at OMC and MDD. An important change that can be observed was that the specimen used for determining UCS was predominantly cohesion-less soil specimen having negligible compressive strength in natural state. However the compressive strength substantially increased on stabilizing with RHA. Curing technique also increases the confining strength of specimen. If UCS value of stabilized soil is compared with that of natural soil which has UCS value of 57.98 kN/m^2, in both cases, UCS values have shown an increasing trend. However, it should kept in mind that the specimen is remolded at OMC and still remains in cohesion-less state, but adding RHA in soil helps to overcome disintegration by acting as a binder.

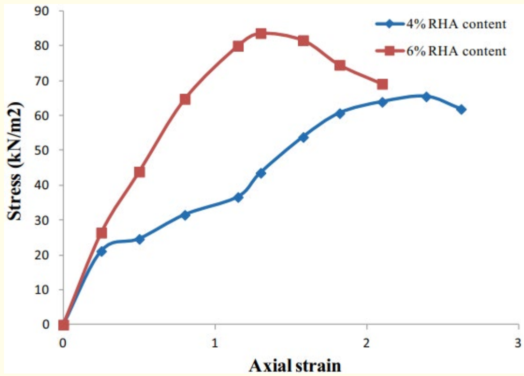

Figure 8: Graphical representation of UCS value of soil at 4 and 6% RHA mixture.

Permeability Characteristics

Subsequent increase in the percentage of RHA in soil, Permeability decreases in the power of 10 (Fig. 9). At 4% RHA content in soil specimen, permeability obtained from falling head permeability apparatus is 4.1 10^{-4} mm/s. However at 6% RHA content, permeability obtained as 1.49 10^{-5} mm/s (Table 3). This logarithmic decrease happens due to gradual migration of natural soil and subsequent occupation of RHA which has almost 70% of silica present in it. Thus it reduced the void spaces between two consecutive molecules. The metric suction of soil changes, and there will be less possibility of water infiltration in the subgrade of pavement system. Thus reduces crack formation and disintegration of soil specimen.

Oedometer Test

In consolidation test, the void ratio for each incremental load is calculated using height of solids method. Here, soil type is SM (silty sand), and hence, secondary or creep consolidation will not predominant. Primary consolidation is main concern.

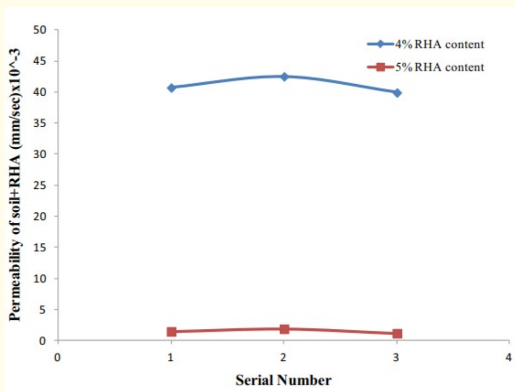

Figure 9: Permeability of soil at 4% and 6% RHA content.

Serial number	*K 27 °C at 4% RHA content (mm/s)*	*K 27 °C at 6% RHA content (mm/s)*
1	0.000407839	1.45138E−05
2	0.000425028	1.87679E−05
3	0.000399337	1.1554E−05
Average *K*	0.000410735	1.49452E−05

Table 3: Differences between the permeability values for soil at 4 and 6% RHA content.

The C_c and C_r values obtained from the test as 0.29 and 0.004, respectively. As per AASTHO [1], effective overburden pressure of one storey building is 20 kPa on the foundation soil, and consolidation test uses 800 kPa which is equivalent to 40 storey building. From test, it can observe that soil is safe for load up to 200 kPa (~10 storey building). It also can be used in the subgrade of highway carrying transient traffic loading because the residual strain will not affect the strength of subgrade as particle-to-particle interlocking is good due to mixing of optimum percentage in RHA (Figs. 10 and 11).

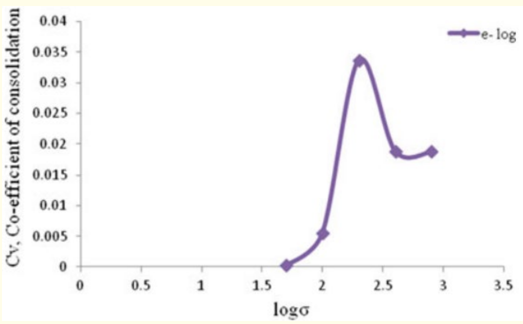

Figure 10: e (Void ratio) versus logσ curve.

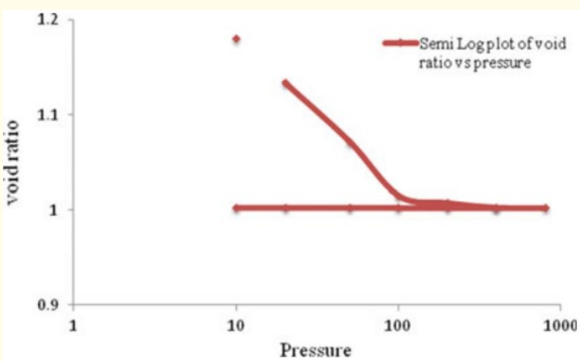

Figure 11: Semi-log plot between void ratio versus pressure.

The dial gauge reading for each load increment $\sqrt{t}$ is measured using graphical representation (Fig. 4.9) by applying Taylor method (t method) (Fig. 12).

XRD Pattern of Sample

The XRD pattern of the sample is shown in Fig. 13.

XRD analysis of RHA from laboratory-controlled incineration (RHA500, RHA650, RHA800, and RHA900) is given in Fig. 3.10. Peaks in the diffraction angles (2θ) such as 21.96, 31.42 and 36.35 degrees (^{o}) are observed in the XRD of the RHA which are characteristics of cristobalite (a crystalline form of silica generated at high temperature).

The chemical composition of rich husk ash is mentioned in Table 4.

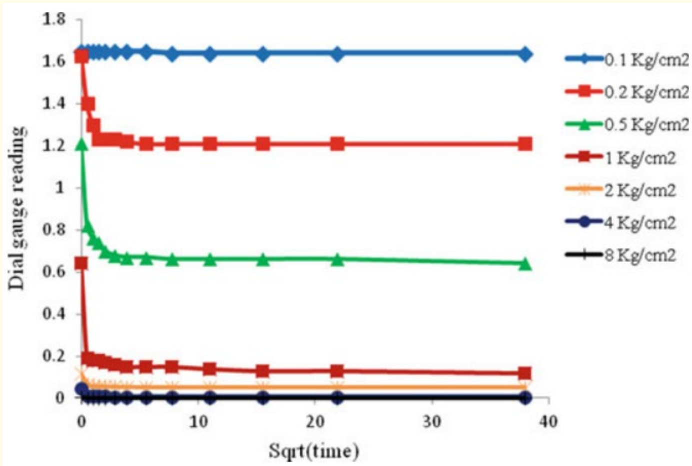

Figure 12: Dial gauge reading versus sqrt(t) graph from oedometer test.

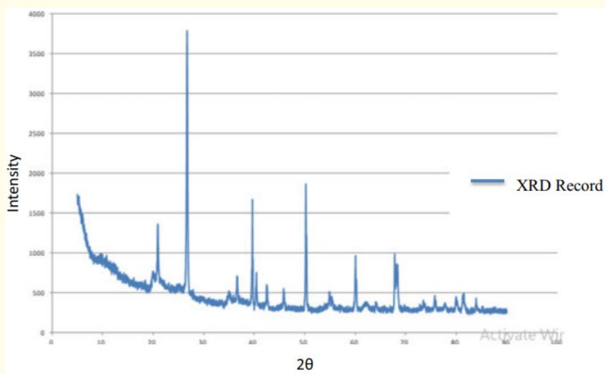

Figure 13: XRD pattern of 6% RHA mixed soil.

Compound	***Percentage (%)***
SiO_2	86
Al_2O_3	2.6
Fe_2O_3	1.8
CaO	3.6
MgO	0.3
Loss of ignition	4.2

Table 4: Chemical component of rice husk ash (collected from Agartala city) experimentally found based on XRD record.

Conclusion

Dispersive nature of soil causes major landslide, failure of road embankment and cracks on pavement during heavy rainfall in north-eastern part of India. The Atterberg's limit indicates that with addition of RHA to soil, the swelling potential (potential to volume change) reduces linearly in case of seasonal variation. Standard proctor test, permeability test and consolidation test have shown that mechanical as well as index properties of soil improves by using 6% RHA (optimum dosage) mixing with the natural soil sample (SM type) collected from institute campus. Soil skeleton got modified, interlocking has improved, and void sizes decreased which caused reduction in differential settlement at major overburden load on soil. However, the improvement got reduced when dosage of RHA increased beyond 6%. It is because of less Pozzolanic reaction happens in deficiency of water. Whereas, dosage less than 6% causes less formation in CSH gel which is not sufficient to hold discrete laterite soil particles during partially and fully submerged condition. Dumping of RHA is also harmful, as it reacts with soil and changes natural mineral composition. That's why RHA is used in soil improvement; less construction cost and provides more reliability in strength and stability of soil.

References

1. AASTHO (2011).
2. Ahmed B, Rahman A and Das J. "Improvement of subgrade CBR value by using Bagasse ash and Eggshell powder". Int J Adv Struct Geotech Eng 4.2 (2015): 86-91.
3. Alhassan M and Alhaji MM. "Utilisation of rice husk ash for improvement of deficient soils in Nigeria: a review". Niger J Technol 36.2 (2017): 386-394.
4. Andavan S and Pagadala VK. "A study on soil stabilization by addition of fly ash and lime". Mater Today: Proc 22 (2020): 1125-1129.
5. GSI (2018).
6. Gupta G, Sood H and Gupta P. "Performance evaluation of pavement geomaterials stabilized with pond ash and brick kiln dust using advanced cyclic triaxial testing". Materials 13.3 (2020): 553.
7. Jamsawang P., et al. "Three-dimensional numerical analysis of a DCM column-supported highway embankment". Comput Geotech 72 (2016): 42-56.
8. Jongpradist P., et al. "Efficiency of rice husk ash as cementitious material in high-strength cement-admixed clay". Adv Civ Eng (2018).
9. Jiang X., et al. "Analysis of strength development and soil-water characteristics of rice husk ash-lime stabilized soft soil". Materials 12.23 (2019): 3873.
10. Jha AK and Sivapullaiah PV. "Lime stabilization of soil: a physico-chemical and micro-mechanistic perspective". Indian Geotech J 50.3 (2020): 339-347.
11. Karatai TR., et al. "Soil stabilization using rice husk ash and natural lime as an alternative to cutting and filling in road construction". J Constr Eng Manag 143.5 (2017): 04016127.
12. Khan AN., et al. Different soil stabilization techniques (2020).
13. Lu N, Wayllace A and Oh S. "Infiltration-induced seasonally reactivated instability of a highway embankment near the Eisenhower Tunnel, Colorado, USA". Eng Geol 162 (2013): 22-32.
14. Liu Y., et al. "Stabilization of expansive soil using cementing material from rice husk ash and calcium carbide residue". Constr Build Mater 221 (2019): 1-11.
15. NECRP (2017).

Volume 4 Issue 4 April 2023