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Modification Potential of Saw Dust Ash on MakurdiClay Shale as Capping Material

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Abstract:*The delaysto construction projects overlain on expansive clay due to wet soilis a concern of construction industry.Clay modification with industrial stabilizers reduces the delays. Due to cost and environmental issues the use of waste is encouraged.This paper offers the potential of saw dust ash (SDA) to modify an A-7-6 Makurdi clay shale for application to highway pavement material. Using plasticity test data, 12% SDA addition achieved full modification of the clay shale. The moderate risk to damage due to volume change by the untreated Makurdi shale (57% free swell value) has been improved to low riskby the addition of 28% SDA to Makurdi shale(19% free swell value). The peak California Bearing Ratio (CBR) value of 18% for SDA-treated shale was achieved at 20% SDA addition. This CBR value is greater than 15% which is the minimum CBR value for stabilized capping layer. Based on strength requirements, this study suggests that 20% SDA-treated Makurdi shale is suitablefor application to capping layer.*

Keywords*: Shale modification, saw dust ash, plastic limit, capping layer.*

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I. INTRODUCTION

The construction of engineering functions such as road pavement, overlain onexpansive clay could be delayed or encountersite workability concerndue to wet weather [1].This usually leads to limitingearthwork season in the construction industry. Clay shale is one of the soils that possess expansive clayey material which mostly break down in the presence of moisture and frost [2]. During rainy season, shale absorbs water and swells but in thedry season, it releases the water due to evaporation and shrinks. The swelling and shrinking behaviour of shale is mainly due to its mineral composition which ispredominantly smectite and illite [3-5].

Some locations in Makurdi town in Benue State of Nigeria are extensively underlain with shale [3]. Avoiding or by-passing them is difficult due to increasing shortage of good construction materials. Also, in such localities where cost of haulage is high, there is need to make the unsuitable natural expansive materials fit for use in engineering work at economic cost.

Improvement of wet clay soilby addition of stabilizershas shown to enable excavation, movement and compaction, hence provides an option to extend earthwork season [6]. Limehas been successfully used for clay modification and subsequent site workability improvement [6, 7]. However, due to rising cost of industrial stabilizers such as cement and lime, the use of cheaper materials for the improvement of unsuitable natural soils for use in engineering work has been encouraged.The use of waste materials in soil improvement has been given attention due to increasing cost of waste disposal and the associatedenvironmental constraints. One waste with potential for soil improvement is saw dust ash (SDA)

This paper examines whether SDA could be used as a modifier of clay shale such as Makurdi shale forapplication to capping layer in road pavement. SDA modified shale couldresult in reducing the amount of waste materials requiring disposal and providing construction material particularly when it would be cheaper than the use of granular material or if environmental benefits are considered [8, 9]

Clay modification is the immediate improvements in plasticity and strength property of the clay that occur due to short term reaction when stabilizer such as lime is mixed with wet clay [1, 7].Earlier studies [10] showed that a material is suitable for clay modification if it could bring about large increase in plastic limit (PL) on addition to the clay.

Studies [1] conducted on lime modification of British clays demonstrated that PL is the best indicator for determining the required lime content for clay modification.PL indicator is consistent for any particular clay, but the patterns of liquid limit (LL) and hence plasticity index (PI) for a particular clay are more varied and could not be used in determining the lime content for clay modification. Also, their studies [1] established that the lime required for full modification is determined as the lime content at which full plastic limit is attained from a plot of PL versus lime content for a particular clay. This was demonstrated from the studies of lime-treated British clays with their resultsfor 24 hour cured samples prior to testing. It was pointed out that the lime content (calcium oxide) for full modification of lower Lias clay was at 3.0%, for English china clay (ECC) was at 1.0%, for London Clay at 3.0%and for Keuper Marl at 0.6%.

Saw dust ashis the product of combustedsaw dust, which is a by-products ofthe timber industry and wood cutting factories[11].Previous studies on the chemical composition of SDA as presented in Table 1 showthat it consists predominantly silica and lime[12]. Based on descriptions for coal fly ash [13],SDA could be classified as class C and self-cementingmaterial if CaO content is greater than 20% or could be grouped as class F (non self-cementing) material if the content is less than 10%[13]. Considering Table 1, some SDA have self-cementing properties due to their CaO contents of higher than 20%, therefore some SDA has the potential for soil modification.

Previous studies on the use of SDA or wood ash (WA) in the treatment of weak soil have shown improvement in some geotechnical properties. The addition of SDA or WA to weak soil resulted in improvement of their PI [15, 17],unconfined compressive strength (UCS) and California Bearing Ratio (CBR)[15, 17, 19]. However, reports on the suitabilityof SDAtreated clay shaleto capping layer in highway pavement is scarce. Therefore prompted the current study on the modification potential of SDA treated Makurdi shale for suitability to capping layer in highway pavement.

II. MATERIALS AND METHODS

2.1 Materials

To determine whether addition of SDA to clay shale could modify the clay, the following materials were used. Shale sample was obtained at 1.5 m depth from shale outcrop located at the entrance of Engineering complex, Joseph Sarwuan Tarka University Makurdi (JOSTUM), Nigeria. Makurdi town is located on 7º43’50’’N and 8º32’10’’E on the geographical map of Nigeria [20]. The sample was collected in heavy-duty polythene bags and conveyed to soil mechanics laboratory of the Department of Civil Engineering, JOSTUM, where tests were performed.

To produce SDA, saw dust was obtained from a saw mill yard in Makurdi, Nigeria and was incinerated into ash at the temperature of 1000^{o}C in an oven. SDA passing through sieve No. 200 with a 0.075-mm aperture was used for the study in accordance with BS 3892 [21].

2.2 Methods

The following tests were performed on the shale, SDA and SDA-treated shale.Particle size distribution (PSD)was conducted on untreated shale, alsospecific gravity was performed on untreated shale and on SDAall in accordance with BS 1377 [22].To prepare SDA-treated shale, shale samples were mixed with 4%, 8%, 12%, 16%, 20% 24% and 28%SDA (by dry mass) respectively. Tests such as LL, PL, compaction andUCS were conducted on untreated shale and SDA-treated shale in accordance with BS 1377 [22`] and BS 1924-2 [23] respectively. The pH of the Makurdi shale was determined using an Orion 710A pH/ISE meter in accordance with BS 1924 Part 2 [23]

Compaction was carried out at the energy level of the British Standard (BS) light compact effort only, because it is easily achieved in the field. The preparation of specimens for UCS and CBR were conducted at the optimum moisture contents (OMC) and maximum dry densities (MDD) using BS light compaction. To determine the development of strength with time, untreated and SDA treated clay shale were cured for 7, 14 and 28 days respectively prior to UCS testing. To achieve curing, specimens were wrapped in cellophane and aluminium foil to retain their water content, then kept in the laboratory at ambient temperature (20^{o}C±1). CBR test was carried out in accordance with BS 1377 [22] with slight modification to comply with theNigerian General specification [24], which specified that specimens be cured unsoaked for six days and later immersed in water for 24 hours before testing.

To conduct free swell test, the clay shale passing No 40 sieve (425 micron size) was used [25].10 cm^3 of dry shale soil was slowly poured into a 100cm^3 graduated cylinder then filled with water.After 24 hours, the volume of settled soil was measured to obtain the final volume. The free swell was determined as the ratio of change in volume of soil due to swelling after dissolution in water for 24 hours compared with the initial dry volume of the same soil [3, 26].

To determine the oxide composition of the materials used, chemical composition was conducted on the SDA and Makurdi shale using Compact Energy Dispersive X-ray Spectrometer Method (mini Pal) at the Centre for Energy Research and Training, ABU Zaria,Nigeria.

Modification of SDA-treated shale was achieved using the plasticity definition by [1]. It states thattheamount of limestabilizer required for full modification of clay is the lime content at which PL rises to asymptote from a plot of plastic limit versus lime content for a particular clay. In the current study, SDA is the stabilizerconsidered for the soil modification instead of lime. SDA is a lime-based waste material as discussed further in Results Section.

III. RESULTS AND DISCUSSION

3.1 Index Properties

The resultsshowing the index properties of untreated Makurdi shale is presented in Table 2.According to AASHTO classification [27]the shale isan A–7– 6 soil,based on Unified Soil Classification systems (USCS) [28] it is a CH soil. The specific gravity of the shale is 2.68, whilst that of the SDA is 2.0. The PL and PI of untreated Makurdi shale is 25% and 19% respectively.The PL of untreated shale in the current study is consistent with those of shale soil from previous studies which is in the range of 14-26%[3-5].Also, thePI of the untreatedMakurdi shaleconcurs with the results of previous studies on shale which reported PI from 16-56%[3-5]. Additionally, the free swell value (57%) of shale in the current study is consistent with the free swell values(23%-65%) forthe shale in previous studies [3]. Makurdi shale with PI of 19% exhibit a medium swelling potential, it also shows a medium volume change (57% free swell value) and could pose moderate risk of damage to lightly loaded structures [29]. The PI and free swell show that Makurdi shale need improvement to support structuralload.

The oxide composition of SDA and that of Makurdi shale is presented in Table 3. The major oxides components of the SDA is CaO (34.1%), followed by K_2O (26.45%), SiO_2 (16.5%) and MgO (6.7%). The presence of high CaO (34% which is greater than 20%) in SDA is an indication of the material with high reactivity and cementitious properties [30].

3.2 Atterberg Limits

The results showing the Atterberg limits of SDA-treated shale is presented in Figure1. The results show that PL increased with SDA addition up to 12%, then showed no further change with additions above 12% SDA.The reason for increased PL with SDA addition could be due to exchange of calcium ions released by SDA with metal ions associated with the clay lattice through the process ofcation exchange capacity (CEC). At 12% SDA addition, the quantity of lime (CaO) released by SDA might be sufficient for full exchange with metal ions in the clay lattice, resulting in full modification.This sufficient lime quantity is called lime fixation percentage addition(LFPA) [1].The maximum ability of the soil to exchange its associated metal ions with calcium released by lime is called lime fixation capacity (LFC) [31].Additions of SDA above 12% to the shale suggests the additionof calcium ionsabove LFPA. This would provide excess calcium above LFC of the clay, resulting in no corresponding cation exchange reaction and could be the reason for no further change in PL with SDA additions above 12%.

Additionally, the current study shows that PI decreased with SDA additions.With 28% SDA addition, the PI decreased from 19% to 10% compared with untreated shale. The reduction in PI with SDA addition is consistent with previous studies which reported similar reductions [15, 17].Based on relationship between PI and swelling potential[26], the medium swelling potential (SP) of natural Makurdi shale (PI value of 19%) have been improved to low swelling potential (PI value of 10%) due to 28% SDA addition.This is an indication of improvement in swelling property of the shale due to SDA addition.

It is known that modification of soil is carried out to improve soils for construction purposes [1].The main reason for soil modification is to improve site workability, trafficability and bearing strength due to large increase in PL and decrease in PI. Soil modification in the construction industry helps to extend earthwork season. Unlike stabilization, the strength development sought during modification is not much [10]. In the current study, asymptotic PL value of the A-7-6 Makurdi clay shale was attained at 12% SDA stabilizer content(Figure 1). Therefore, 12% SDA stabilizer content is adequate for modification of the A-7-6 Makurdi clay shale.

To compare the PL changes on SDA addition with that of changes on lime addition in shale, the results of PL of SDA-treated shale against SDA stabilizer content in the current study was plotted as presented in Figure 2. On the same axis, the results of PL of lime-treated shale against lime stabilizer content in the current study was plotted, again presented in Figure 2. The pattern of lime-treated shale shows asymptotic PL value at 4% lime ($Ca(OH)_2$) content, hence the lime content adequate for Makurdi shale modification. It is shown that the SDA content adequate for Makurdi shale modification is thrice the lime content required for the shale modification.

According to [10], larger increase in PL due to stabilizer addition is an indication of plasticity improvement. Because a higher PL value would have a higher tendency to resist wet and sticky condition than a lower PL of untreated clay. In the current study, due to 12% SDA addition to Makurdi shale, the PL increased by 44% (from 25% to 36%). This indicates that 12% SDA addition to the shale could result in higher potential of 44% to withstand wet and sticky condition than untreated shale. As previously mentioned, the PL of untreated Makurdi shale is 25%, if the water content of the shale is above 25% the untreated shale will be in a wet and sticky condition. Consequently, compaction and trafficability on the shale will be difficult. However, with the addition of 12% and higher SDA content, the shale would not be in a sticky condition for water content less than 36%. This would allow for easy compaction and trafficability on the shale. Generally, there exist a required stabilizer content for the modification of a particular clay [1]. In the current study, 12% SDA stabilizer content shows to be adequate for the modification of Makurdi shale.

3.3 Free swell

The results of free swell for SDA treated shale is presented in Figure 3. The results show that the free swell of untreated shale decreased from 57% to 19% when treated with 28% SDA. Usually, free swell is used to predict the volume change of soils and the subsequent effect on the overlain structures [31]. In the current study, the free swell of untreated Makurdi shale reduced from 57% to 19% due to 28% SDA treatment (Figure 3). This shows that the untreated shale (57% free swell value) having medium volume change has been improved to low volume change (19% free swell value) due to 28% SDA addition. This SDA treated Makurdi shale will exhibit low risk of damage compared with the moderate risk of damage to lightly loaded structures posed by the untreated shale.

3.4Effect of Saw Dust Ash on the Compaction of Makurdi Shale

The results showing the effect of SDA addition on the compaction properties of clay shale is presented in Figure4. The results show that all additions of SDA resulted in increased OMC and decreased MDD. With 28% SDA addition, the value of OMC increased from 14% to 25% whilstthe MDDvalue decreased from 1.61 Mg/m^3 to 1.33 Mg/m^3 compared with the value of untreated shale.

The decrease in MDD could be due to flocculation and agglomeration of SDA and shale mixture, which in turn is a result of cation exchange between calcium ions (released by SDA) with metal ions associated with the clay lattice. The SDA-shale agglomerates occupied larger spaces and produced higher voids content than those of the corresponding untreated shale. This resulted in reduced mass to volume ratio, hence decrease in dry densities [7]. Additionally, SDA with relatively lower specific gravity of 2.0replaced shale with a higher specific gravity of 2.68 in a fixed volume, thus could result in reduced mass to volume ratio and hence the reason for reduction in dry density.

The increase in OMCwith SDA additions could be due to additional water needed for hydration of SDA (lime-based waste) to calcium hydroxide ($Ca(OH)_2$) and subsequent dissolution of calcium ions and hydroxyl ions for cation exchange reaction. This increase of OMC in SDA-shalemixture pattern is consistent with previous studies on SDA treated soils [15, 17].

3.5Strength Development

The results showing the effect of SDA on the strength of shale is presented in Figure 5. The 7 dayUCS of SDA-treated shale increased from 252 kN/m^2 to a peak value of 440kN/m^2at 20% SDA addition compared with the untreated shale. The strength improvement is 74% higher than the untreated shale.Also, the addition of 20% SDA content resulted in increasedUCS values from 252 $kN/m^2$to 467kN/m^2 and from 252 kN/m^2 to 476$kN/m^2$for 14 and 28 days curing respectively.

It is known that there is immediate improvement in strength that accompanies plasticity improvement due to the short term reaction of modification [2, 10]. In the current study, due to 20% SDA addition, the 7 day UCS of Makurdi shale increased by 74% (from 252 kN/m^2 to 440 kN/m^2) compared with untreated shale. Also at 20% SDA addition the UCS increased by 85% (from 252 $kN/m^2$to 467 kN/m^2) and by 89% (from 252 kN/m^2 to 476 kN/m^2) for 14 days and 28 days curing respectively. This suggests that much of available lime has been used up for pozzolanic reaction during 14 days curing, beyond which the strength increase was marginal.

3.6California Bearing Ratio

The variation of CBR with SDA additions to shale is presented in Figure 6. The peak CBR value of 18% was achieved at 20% SDA additions. The observed peak CBR at 20% SDA content is similar to the optimum SDA (20%) content at which the peak compressive strength was achieved.

CBR is important for assessing the bearing strength of materialsand its suitability for application in either base, subbase or subgrade of road pavement[22]. In the current study on SDA-treated shale, the peak CBR value was 18%. This is low compared to the CBR value of above 70% required for sub-base or base material[10].However, the CBR value of 18 % is greater than 15% which is the minimum CBR value required for stabilized capping layer [10]. Based on bearing strength requirements, the 20% SDA-treated shale is suitable for use asa stabilized capping layer.

IV. CONCLUSIONS

The current work has looked at the effect of SDA on the plasticity properties of Makurdi shale and subsequent suitability of SDA modified Makurdi shale for application to capping layer in road pavement. Based on laboratory studies, the following conclusions can be drawn:

- Makurdi shaleis an A-7-6 soil based on AASHTO [27]and CH soil according toUSCS [28] classification.
- Addition of SDA to the Makurdi shale resulted in the improvement of swelling property. The medium swelling potential (SP) of the untreated shale (PI value of 19%) has been improved to low swelling potential (PI value of 10%) due to 28% SDA addition.
- There is an improvement in volume change by the addition of SDA to Makurdi shale. The shale with medium volume change (57% free swell value) has been improved to low volume change (19% free swell value) due to 28% SDA addition. This SDA treated Makurdi shale will exhibit low risk of damage compared with the moderate risk of damage to lightly loaded structures posed by the untreated shale.
- Based on PL results, 12% SDA stabilizer content is adequate for modification of the A-7-6 Makurdi clay shale.
- The peak CBR value of SDA-treated shale of 18% was achieved at 20% SDA addition. This is greater than 15% which is the minimum CBR value required for stabilized capping layer [10]. Based on strength requirement, the 20% SDA-treated shale is suitable for use as a stabilized capping layer.
- SDA has shown the potential to modify Makurdi shale based on plasticity properties. Considering strength requirement, SDA-treated shale is suitable for use as a stabilized capping layer.

This study has shown that SDA could be used as a modifier of A-7-6 Makurdi shale. The treatment of the shale with 20% SDA is recommended for application to stabilized capping layer.

REFERENCES

[1]. Rogers, C. D. F. and Glendinning, S.: 'Modification of Clay Soils Using Lime', in: Dixon, N., Glendinning, S. and Rogers, C. D. F. (Eds.), Lime Stabilisation. *Thomas Telford*. London, pp.99-114, (1996).

[2]. O' Flaherty C. A:. *Highway Engineering*, Vol. 2. Edward Arnold London, p. 95, (1974).

[3]. Agbede, I. O. and Smart, P.: 'Geotechnical Properties of Makurdi Shale and Effects on Foundations', *Nigerian Journal of Technology*, Vol. 26, No. 2, pp 63-73, (2007).

[4]. Aghamelu, O. P., Nnabo, P. N. and Ezeh, H. N.: 'Geotechnical and Environmental Problems Related to Shales in the Abakaliki area, Southeastern Nigeria', *African Journal of Environmental Science and Technology*, Vol. 5(2), pp. 80-88, (2011).

[5]. Maduka, R. I., Ayogu, N. O., Ayogu, C.N. and Gbakurun, G. A.: 'Role of Smectite-Rich Shales in Frequent Foundation Failures in Southeast Nigeria' *J. Earth Syst. Sci*., DOI 10.1007/s12040-016-0727-5, 125, No. 6, pp. 1215–1233, (2016).

[6]. Rogers, C. D. F., Glendinning, S. and Roff, T.E.J.: 'Lime Modification of Clay Soils for Construction Expediency', *Proceedings of the Institution of Civil Engineers-Geotechnical Engineering*, 125(4), pp.242-249, (1997).

[7]. Vitale, E., Deneele, D. and Russo, G.: 'Microstructural Investigations on Plasticity of Lime-Treated Soils', *Minerals* 10, 386, pp.1-11, (2020).

[8]. *Manual of contract documents for highway works, Specification for Highway Works*, vol. 1, HMSO, London, amended February, (2016).

[9]. *Design Manual for Roads and Bridges, Treatment of fill and capping materials using either lime or cement or both*, DMRB Vol 4, Section 1, Part 6 (DMRB 4.1.6), Ha 74, HMSO, London, May, (2007).

[10]. Sherwood, P. T.:*Soil Stabilisation with Cement and Lime – State of the Art Review*. Transport Research Laboratory, Department of Transport. HMSO publications, ISBN 0-11551171-7(1993).

[11]. Siddique, R.: *Waste Materials and By-products in Concrete*. Springer Science & Business Media(2007).

[12]. Chowdhury, S., Mishra, M., and Suganya, O.: 'The Incorporation of Wood Ash as a Partial Cement Replacement Material for Making Structural Grade Concrete: An overview'. *Ain Shams Eng Journal* 6, pp. 429–437, (2015).

[13]. Tishmack, J. K, Olek, J. and Diamond, S.: 'Characterization of High-Calcium fly Ashes and their Potential Influence on Ettringite Formation in Cementitious Systems' *Cem.Concr.Aggr.J*. 2188–2192(1999).

[14]. Elinwa, A. U., Yakubu Abba Mahmood, Y. A.: 'Ash from Timber Waste as Cement Replacement Material' *Cement & Concrete Composites* 24, pp. 219–222(2002).

[15]. Okagbue, C.O. 'Stabilization of Clay using Woodash' *Journal of Materials in Civil Engineering*, 19(1), pp.14-18, (2007).

[16]. Vassilev, S.V., Baxter I., Anderson, I.K and Vassileva, C.G.: 'An Overview of the Chemical Composition of Biomass. *Fuel* 89, 913-933, (2010).

[17]. Edeh, J. J., Agbede, I. O. and Tyoyila, A.: Evaluation of Sawdust Ash–Stabilized Lateritic Soil as Highway Pavement Material. Journal of Materials in Civil Engineering, 26:367-373, (2014).

[18]. Ekeagwani, C. C. Obeta, I. N. and Agunwamba, J. C.: 'Stabiliztion of Black Cotton Soil using Saw Dust Ash and Lime' *Soils and Foundations*, 59 pp. 162-175, (2019).

[19]. Butt, W. A., Gupta, K. and Jha, J. N.: 'Strength Behavior of Clayey Soil Stabilized with Saw Dust Ash', *International Journal of Geo-Engineering*, 7(18), pp. 1-9, (2016).
[20]. Makurdi, ;Wikipedia the Free Encyclopedia' http://en.wikipedia.org/wiki/Makurdi, (accessed June 24, (2021).
[21]. BS 3892.:Pulverized-fuel ashPart 1. Specification for Pulverized-Fuel Ash for use with Portland cement. BSI, Milton Keynes, UK, (1997).
[22]. BSI BS 1377. 'Methods of test for Soils for Civil Engineering Purposes', British Standards Institution, Milton Keynes, Uk, (2016)..
[23]. BSI BS 1924-2: 'Hydraulically Bound and Stabilized Materials for Civil Engineering Purposes Part 2: Sample Preparation and Testing of Materials During and After Treatment', British Standards Institution, Milton Keynes, (2018).
[24]. Nigerian General Specification: 'General Specification for Bridge and Roads Work' Federal Ministry of Works, Lagos, Nigeria (1997).
[25]. ISO 3310-1: Test sieves— Technical requirements and testing— Part 1: Test sieves of metal wire cloth. The International Organization for Standardization), Switzerland, (2013).
[26]. Dąbska, A. and Lethel, A. 'Swelling Behaviours of Compacted Lime-Softening Sludge for Application in Landfill Liners', *Scientific Reports*, *11*(1), pp.1-13, (2021).
[27]. ASTM (1992) 'Annual Book of ASTM Standard'. American Society for Testing and Material, Philadelphia.
[28]. USCS: 'Unified Soil Classification System for Roads, Airfields, Embankments and Foundations' Military Standard; MIL-STD-619A, US. Dept. of Defence, Washington D.C, (1962).
[29]. Murthy, V.N.S.: *Geotechnical engineering: principles and practices of soil mechanics and foundation engineering*. CRC press, (2002).
[30]. Menendez, E., Argiz, C. and Sanjuán, M.A.: 'Reactivity of Ground Coal Bottom Ash to Be Used in Portland Cement. *J*, *4*(3), pp.223-232(2021).
[31]. Gueridi, F. and Derriche, Z.: Strength Development and Lime Consumption Progress Relationship in Lime Stabilized Bentonite Samples. *Bulletin of Engineering Geology and the Environment*, pp.1-10, (2021).

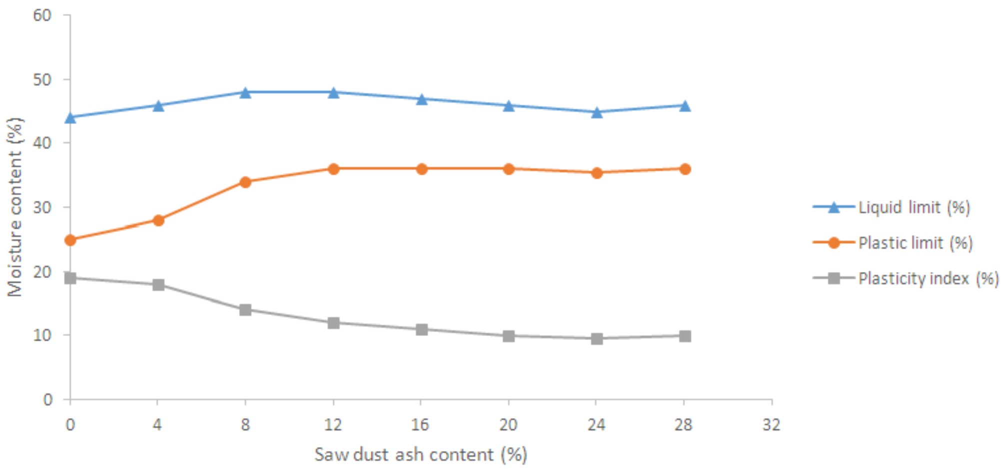

Figure 1: Plasticity changes of Makurdi shale due to saw dust ash addition

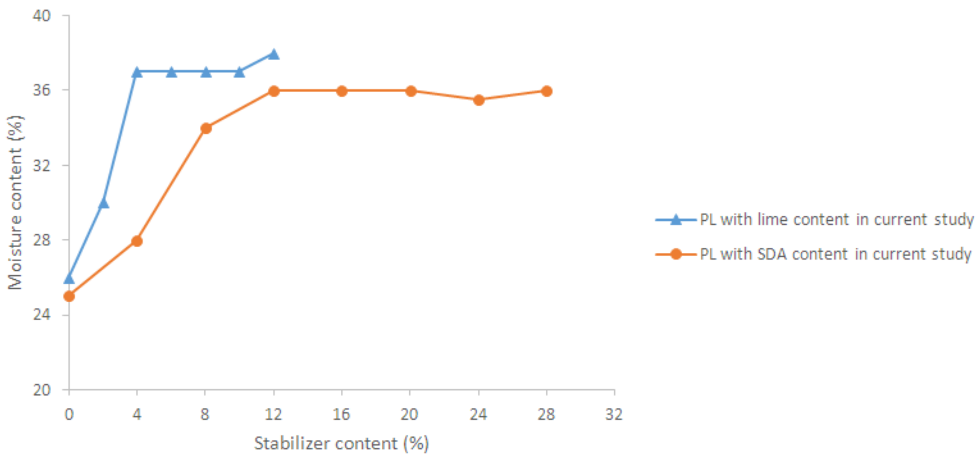

Figure 2: Effect of saw dust ash (SDA) and lime on plastic limit of Makurdi Shale

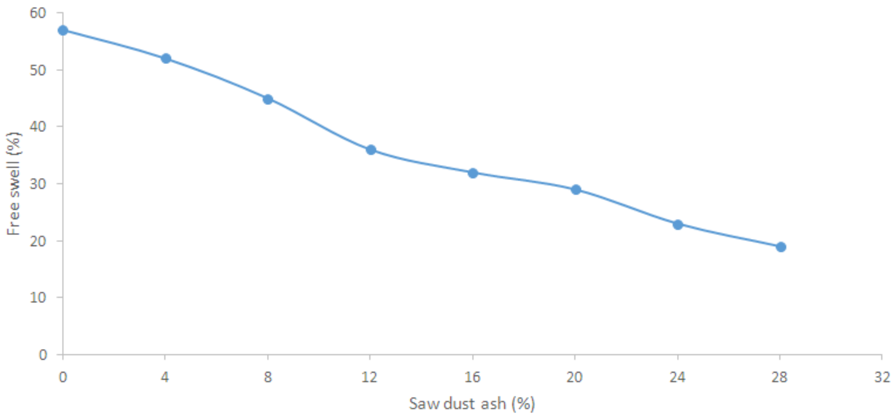

Figure 3: Variation of free swell of shale with saw dust ash addition

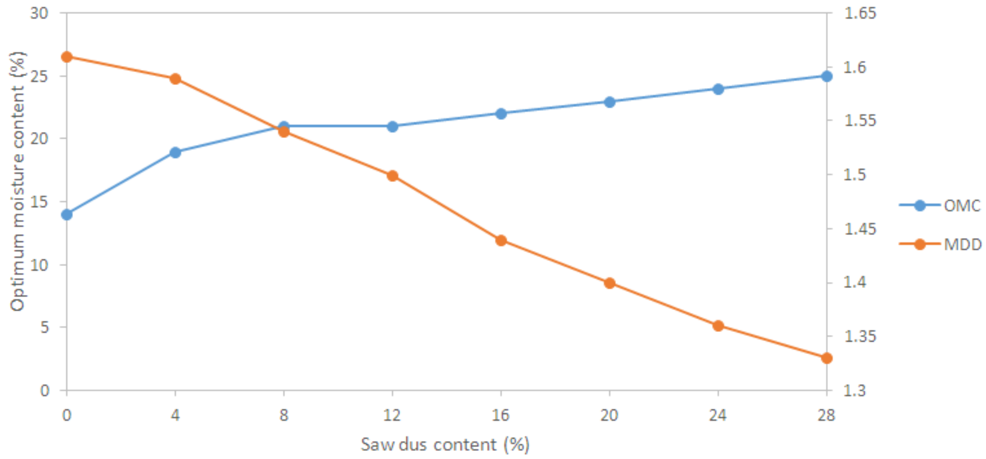

Figure 4: Effect of SDA on compaction properties of clay shale

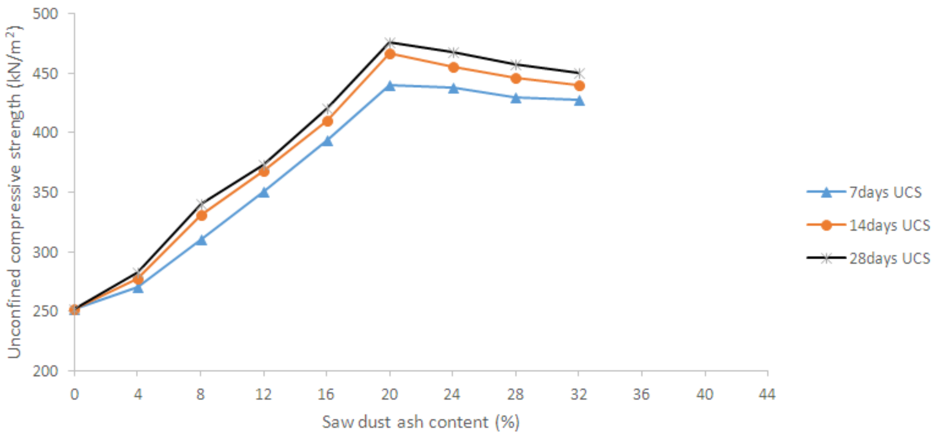

Figure 5: Effect of saw dust ash on the unconfined compressive strength (UCS) of shale

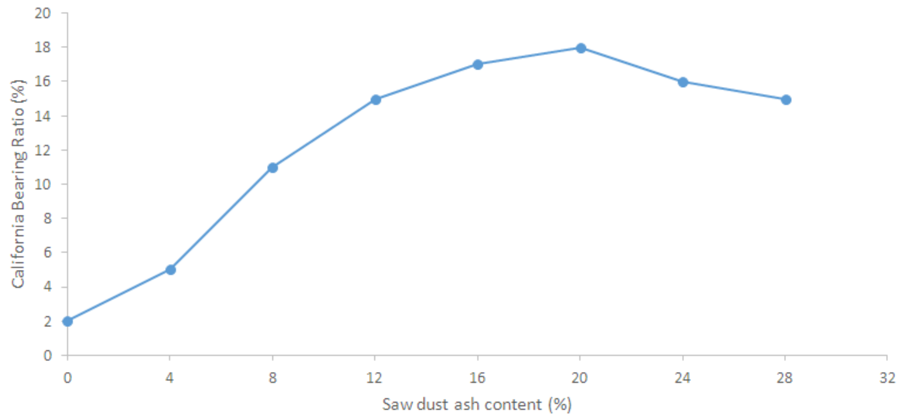

Figure 6: Variation of CBR with SDA additions to shale

Table 1: Chemical composition of saw dust ash from previous studies

Author	SiO_2	**CaO**	MgO	Al_2O_3	K_2O	Na_2O	Fe_2O_3	SO_3	P_2O_5	TiO_2	LOI
[14]	67.20	9.98	5.8	4.09	0.11	0.08	2.26	-	0.48		NA
[15]	53.14	34.34	1.10	1.44	0.32	2.52	5.19		0.02	-	
[16]	26.17	44.11	5.34	4.53	10.83	2.48	1.82	2.05	2.27	0.4	
[17]	6.6	33.4	4.8	-	27.5	-	1.11	4.1	3.9		17.56
[18]	33.20	45.98	1.2	-	10.65	1.33	0.03	3.81	2.20	0.5	NA

Table 2: Index properties of Makurdi shale

Properties	Quantity
Percentage passing BS sieve No.200 (%)	84.2
Liquid limit, LL (%)	40
Plastic limit, PL (%)	25
Plastic Index, PI (%)	19
Shrinkage limit, LS (%)	5.7
Free Swell (%)	57
Specific gravity G_s	2.68
AASHTO classification	A-7-6
USCS classification	CH
Maximum Dry Density MDD (Mg/m^3)	1.61
Optimum Moisture Content, OMC (%)	14.4
Unconfined Compressive strength (kPa) 7days	252
pH	6.80

Table 3: Oxide composition of saw dust ash and Makurdi shale

Element Oxide	Percentage Composition (%)		
	Cement	Saw Dust Ash	Shale
CaO	62.0	34.10	0.26
MgO	1.40	6.7	-
SiO_2	-	16.5	49.02
Al_2O_3	6.0	2.3	25.24
TiO_2		0.12	1.98
MnO		0.41	0.03
Fe_2O_3		3.41	8.37
P_2O_5		2.67	3.80
K_2O		26.45	1.85
Na_2O		1.57	2.57
SO_3		0.7	-
ZnO		0.07	-
LOI		5.1	-

Dr. Iorliam, A.Yala, et. al. "Modification Potential of Saw Dust Ash on MakurdiClay Shale as Capping Material."*American Journal of Engineering Research (AJER)*, vol. 11(01), 2022, pp. 67-74.