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Effect of mining tailing waste on properties of cement stabilized black cotton soil

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Abstract

In most cases, not all available materials for road construction do meet the nominal requirements, as such; stabilization becomes necessary. This study presents the results of a laboratory experiments carried out to assess the effect of mining tailing waste (MTW) as an admixture to ordinary Portland cement (OPC) stabilized Black Cotton Soil (BCS). The MTW was obtained from a tin mining site in Bukuru, Jos South LGA of Plateau State, Nigeria, while the BCS was obtained along Kanawa-Jauro-Gotel road, in Yemaltu-Deba, Gombe, Nigeria. The specimens were prepared by admixing the four blends of OPC stabilized BCS (using 0, 4, 6, and 8% OPC) with stepped percentage of MTW(0, 5, 10, 15 and 20%) by dry weight of BCS. Atterberg's limits, Sieve analysis, Compaction, soaked California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) test were carried out on the natural and stabilized BCS. The BCS classifies A – 7 – 6 (40) and CH (high plasticity clay) according to the American Association of State Highway and Transport Officials (AASHTO M 145-2012) and the Unified Soil Classification System (ASTM D 2487-2011), respectively. Addition of MTW to OPC stabilized BCS affected the compaction characteristics and improved both the soaked CBR, and the UCS. The optimum blend was achieved with 20% MTW admixed to BCS stabilized with 8% OPC which gave a 4-days soaked CBR value of 35% and a 7 days cured UCS value of 1273 kN/m2. This satisfies the sub-base requirements of the Nigerian general specifications. Thus, this study recommends the use of 20% MTW with 8% OPC for BCS stabilization.

Keywords: Black Cotton Soil; California Bearing Ratio; Mining Tailing Waste; Plasticity Index; Unconfined Compressive Strength

1. Introduction

Black cotton soils (BCS) are clays or very fine silts that have a tendency for volume changes, to swell and soften or shrink and dry-crack, depending on the increase or decrease in moisture content. The swell-shrink movements in BCS have historically caused frequent problems because of the unpredicted upward movements of structures or cracks in pavements resting on them. In addition, they also affect the serviceability performance of lightweight structures supported on them. Pavements are in particular, susceptible to damage by BCS because they are lightweight and extend over large areas. Dwelling houses transferring light loads to such soils are also subjected to severe distress. Similarly, earth structures such as embankments, canals built with these soils suffer slips and damages [1]. It is therefore necessary to upgrade the engineering properties of this deficient soil before been put to use in construction.

Despite the proven performance of the stabilizers in the modification of engineering and allied properties of problematic soils, the cost of blending the soils with these stabilizers is usually prohibitive. Moreover, the environmental impact caused by cement is also an issue of concern [2]. In order to abate the cost of road base stabilization and reduce the environmental effect, one reasonable alternative is to mix the soil-lime or soil-cement blends with requisite amount of admixture [3]. Many researchers [4, 5 and 6] attempted proposals to stabilize problematic soils for construction purposes by using various waste as admixtures with Portland cement and lime as stabilizers. Hence, the proposed use

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of Mining Tailing Waste (MTW), a waste by-product recovered in the process of tin extraction as an admixture to cement stabilized problematic soil.

2. Material and methods

2.1. Materials

2.1.1. Black cotton soil (BCS)

The soil sample used in this study was obtained by a method of disturbed sampling at a depth of at least 0.8 m below ground level along Kanawa-Jagali-Jauro Gotel road in Yamaltu Deba Local Government of Gombe State, Nigeria.

2.1.2. Mining Tailing Waste (MTW)

Mining tailing waste (MTW) was obtained from a tin mining site in Bukuru, Jos South LGA of Plateau State, Nigeria. The material is a waste from the tin mining industries. The mineral obtained from the ground is casseterite or tin stone, from which tin metal is obtained by melting.

2.1.3. Cement

Cement Grade 42.5N, Dangote brand of ordinary Portland cement, which is commonly available in the open market, was used in the study.

2.2. Methods

Laboratory tests were conducted in accordance with BS standard. The Atterberg limit tests, Compaction, California bearing ratio tests (CBR) and unconfined compressive strength tests (UCS) were conducted in accordance with [7 & 8]. Compaction tests were conducted on BCS with varying percentages of OPC from 2, 4, 6, 8 and optimum mixes were obtained. After obtaining the optimum mix proportion, varying percentages of MTW was added to the optimum mix of BCS-OPC from 5% - 20% at an increment of 5% by dry weight of the soil. The California Bearing Ratio (CBR) test was conducted on the BCS and OPC/MTW stabilized BCS mixtures, the samples were compacted at their respective optimum moisture content in the CBR mould. Two set of each sample were prepared and subjected to un-soaked and soaked CBR test. The soaking was done for 48 hours. Unconfined compressive strength test was carried out on OPC/MTW stabilized BCS samples, the samples were compacted at optimum moisture content using the standard Proctor. Test's specimen are of specified height to diameter ratio in accordance with [7], the cylindrical specimens used in this test are of diameter 38 mm and height 76 mm. After compaction, the OPC/MTW stabilized BCS samples were extruded from the mold and sealed with double wrappings in polythene bags that were kept at a constant temperature of 25 ± 2°C. This was done for various periods to allow for uniform moisture distribution and curing. After curing, specimen were placed in a load frame machine with a driven strain controlled at 0.10 %/min and crushed until failure occurred. Specimens were cured for 7, 14 and 28 days.

3. Results and discussion

3.1. Index properties of BCS and MTW

Table 1 presents the test results of black cotton soil used. Physical inspection shows that the soil is dark grey in color. The index properties test and sieve analysis classified the soil as A-7-6 in accordance with the American Association of State Highway Transportation Officials (AASHTO) soil classification system [9] and CH (clay with high plasticity) in accordance with the unified soil classification system [10]. The California bearing ratio (CBR) of the soil was 2 %, while the unconfined compressive strength 1s 160KN/m^2. It is dark grey in colour with a plasticity index of 37 %. The OMC & MDD values recorded are 24.6 % and 1.38 Mg/m^{3}with corresponding soaked CBR values of 2 % and UCS value of 160 KN/m^2. The high index values recorded coupled with the low values of MDD, UCS and CBR recorded shows that the soil falls below the standard recommendation for most geotechnical construction works. Especially for sub-base or base courses in highway construction [11, 12 &13].

The MTW has a moisture content of 0.24 %, specific gravity of 3.10, bulk density of 1.72 Mg/m^3 and pH of 10.6, indicating that it is alkali. The oxide compositions determined using the XRF spectroscopy is summarized in Table 2, the major oxide compositions consists majorly of Silicon oxide (SiO_2), Aluminium oxide (Al_2O_3), Iron oxide (Fe_2O_3) and Titanium oxide (TiO_2) contributing 15.9 %, 12.8 %, 40.71 % and 19.73 % of the total.

Table 1 Test results of the soil and MTW

Property	**BCS**	**MTW**
Natural moisture content (%)	8.34	0.24
Liquid limit (%)	72	
Plastic limit (%)	35	
Plasticity index (%)	37	
Percentage passing No. 200 sieve	88.4	
Specific gravity	2.65	3.10
Bulk density (Mg/m^3)		1.72
Maximum dry density (Mg/m^3)	1.38	
Optimum moisture content (%)	26.4	
Unconfined compressive strength (kN/m^2) @ 7days	160	
Soaked California bearing ratio (%) @ 48 Hrs	2	
pH	7.6	10.6
Colour	Dark grey	
AASHTO classification	A-7-6 (40)	
USCS classification	CH	

Table 2 Oxide Compositions of MTW

Oxide	**MTW**	**Oxide**	**MTW**	**Oxide**	**MTW**	**Oxide**	**MTW**
Al_2O_3	2.8	V_2O	0.61	ZnO	0.46	TiO_2	29.73
SiO_2	15.9	Cr_2O_3	0.641	Nb_2O_3	3.15	NiO	0.008
K_2O	0.25	MnO	2.41	LiO	0.45	Ta_2O	1.70
CaO	0.889	Fe_2O_3	40.71	Yb_2O	0.22	ReO_2	0.07

3.2. Compaction characteristics

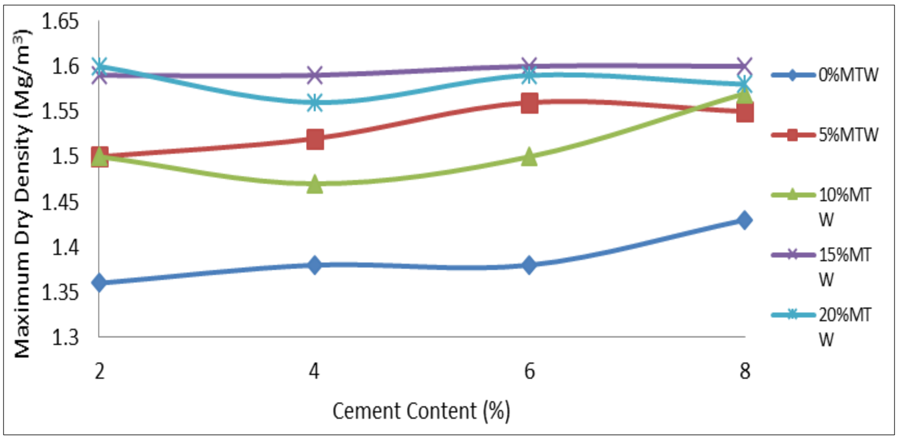

Figure 1 Variation of maximum dry density with MTW

Variation of MDD for the BCS treated with OPC/MTW blends is shown in Figure 1. The MDD plot shows an increase in MDD with increase in MTW content for the entire blends. However, the optimum MDD was observed at 8% OPC/15% MTW blend gave an MDD value of 1.60 Mg/m^3. The increase in MDD was attributed to the formation of new compounds and increase in surface area of particles at higher dosage of OPC/MTW, as well as improved workability of the soil [6 & 14]. The variations of OMC is shown in Figure 2. The OMC decreased with increase in OPC/MTW blend, this may be attributed to the fact that the OPC/MTW dosage increased the surface area of soil particles and also due to cations exchange causing flocculation of the clay particles, [14].

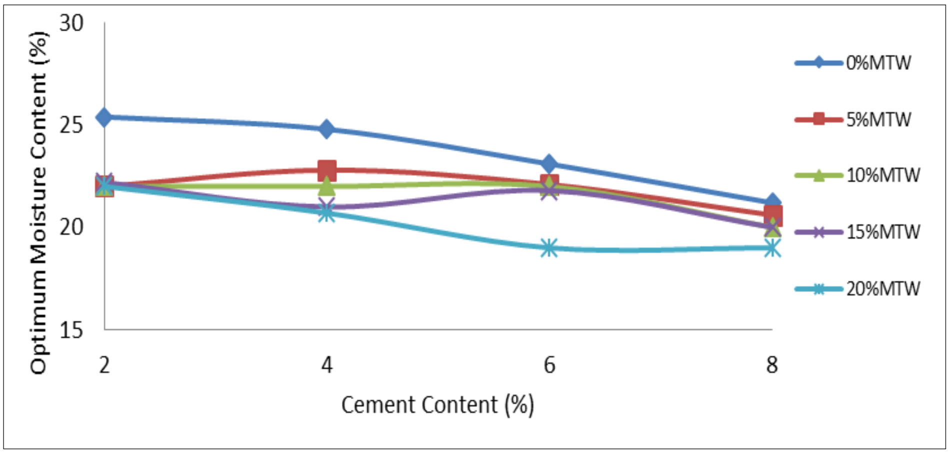

Figure 2 Variation of optimum moisture content with MTW

3.3. California bearing ratio (CBR)

The California bearing ratio is a penetration test for evaluation of mechanical strength of road sub-grades and base courses. It is an important parameter used to indicate the strength and bearing capacity for base and sub-base in road construction. It is worth noting that soaked CBR test was the primary CBR test carried out as the Nigerian General Specification (2013) sub-base and base course requirement are based on soaked CBR values. The variation of soaked CBR (96 hours soaking) of BCS treated OPC/MTW blends is shown in Figure 3. The CBR values increased with higher blends when compared with the natural CBR values. The peak value of 35 % was recorded at 8 % OPC/ 20 % MTW blend. Considering the trend, it can be seen that the variation of additives give rise to a linear increase in strength of soaked CBR values. The improvement in CBR is attributed to the cation exchange, flocculation and agglomeration reactions taking place within the admixtures. The trend is in conformity with the results reported by [6 & 14].

Unfortunately, none of these blends met the nominal 80% soaked CBR requirement for base course stipulated by the Nigerian General Specifications (2013). However, the soaked CBR values of 34 & 35 % which corresponds to 8 % OPC/ 5 % MTW and 8 % OPC/ 20 % MTW blends do meet the nominal 30% CBR required for sub-base utilization.

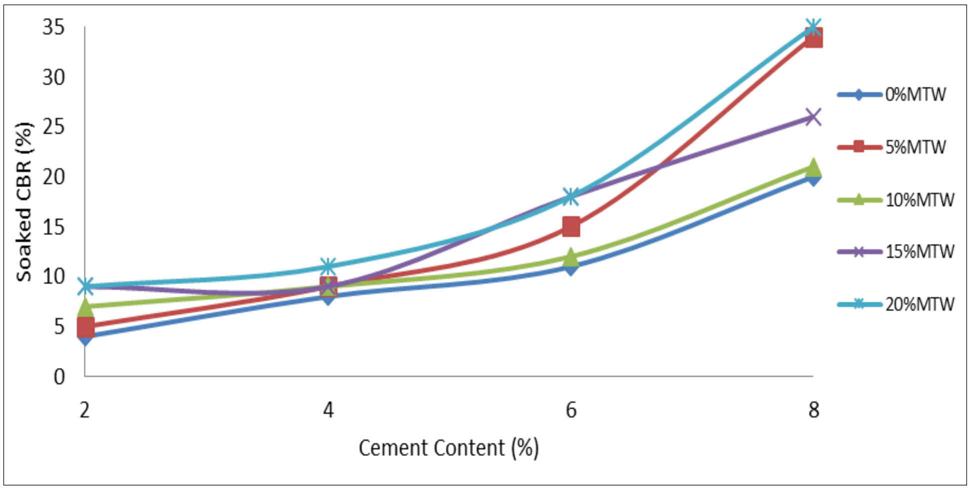

Figure 3 Variation of soaked CBR with MTW

3.4. Unconfined compressive strength (UCS)

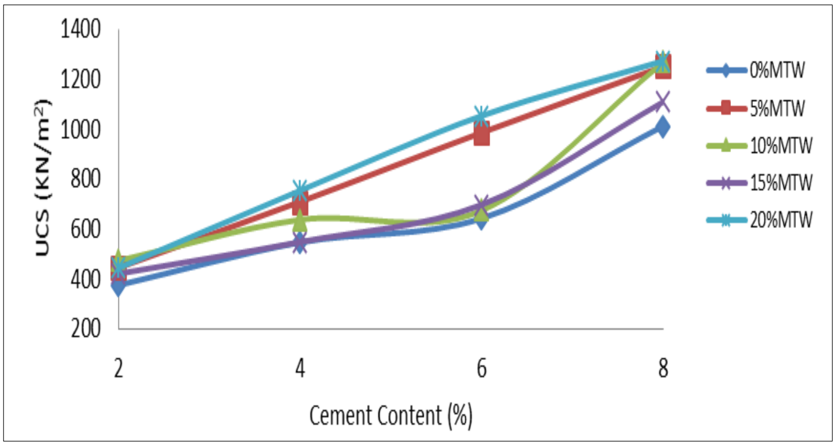

Figure 4 Variation of 7-days ucs with mtw

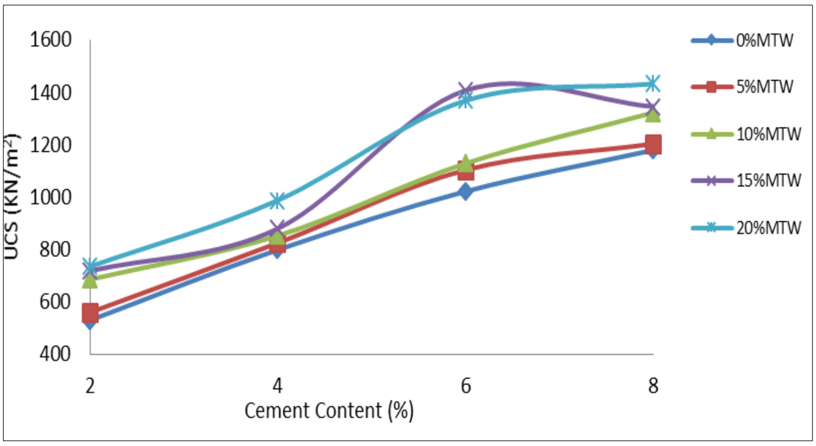

Figure 5 Variation of 14- days UCS with MTW

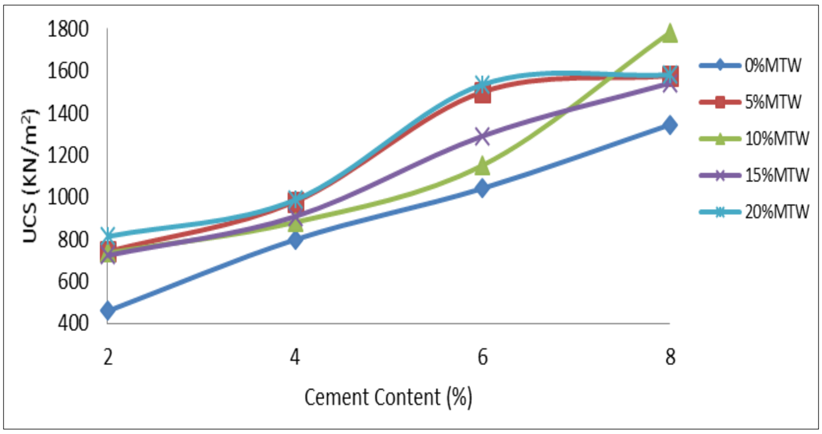

Figure 6 Variation of 28-days UCS with MTW

The Unconfined Compressive Strength (UCS) test is recommended by [12] for evaluating the strength of cemented materials for use as either base, or sub-base. The test is vital for determining the additive quantity to achieve optimum soil stabilization. The minimum 7-days UCS values required by the specification, ranges between 750 – 1500 kN/m^2 for sub-base and 1500 - 3000 kN/m^2 for base course. The results of the UCS tests conducted on the cement stabilized BCS admixed with MTW for 7, 14 and 28-days curing, are shown in Figures 4 - 6. Peak UCS (7-days cured) values of 1012 kN/m^2 for blend with 8% OPC/ 0% MTW, 1250 kN/m^2 at 8% OPC/ 5% MTW, 1268 kN/m^2 at 8% OPC/ 10% MTW, 1109 kN/m^2 at 8% OPC/ 15% MTW and 1273 kN/m ^{2} at 8%OPC/ 20% MTW were recorded. The entire blends did not meet the UCS criterion for base course. However, all blends with 8% OPC/ (0 -20) % MTW and 6% OPC/ (5 & 20)% MTW did met the UCS requirement for sub-base. There was a significant strength development with curing age due to pozzolanic activity as shown in Figures 5 & 6, in comparison to the 7-days UCS.

4. Conclusion

The Black Cotton Soil (BCS) used in this study was classified as A – 7 – 6 (40) and high plasticity clay CH under the AASHTO and USCS classification systems respectively. Therefore, the natural BCS is very poor for engineering applications. The MDD's and OMC's of the soil were affected by treatment with both OPC and MTW. Similarly, 35% Soaked (7-days) CBR value was achieved with 8% OPC/20% MTW stabilization of the BCS. This value is below the recommended 80% CBR for base course material; however, it met the CBR requirement of a sub-base material. In addition, the BCS blend with 8% OPC/(0-20)% MTW have 7-days UCS values that did not met the base course requirement of [12], but fell within the range (750 - 1500 kN/m^2) of the 7-days UCS recommended for sub-base. Finally, this study recommended the use of 8% OPC/ 20%MTW as the optimum blend for the stabilization of black cotton soil.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

There is no conflict of interest in this research.

References

[1] Mishra AK, Dhawan S, Rao SM. Analysis of swelling and shrinkage behavior of compacted clays. *Geotechnical and Geological Engineering*. 2008; *26*(3): 289-298.

[2] Provis, J. L., & Van Deventer, J. S. (Eds.). (2013). *Alkali activated materials: state-of-the-art report, RILEM TC 224-AAM* (Vol. 13). Springer Science & Business Media.

[3] Matawal, D. S., Umar, S. Y., & Bala, Y. U. (2006). Effect of Oil Palm Ash (OPA) on Cement Stabilized Soil. *Journal of Civil Engineering, Nigerian Institution of Civil Engineers*, *5*(3), 5-12.

[4] Ahmari S, Zhang L. Utilization of cement kiln dust (CKD) to enhance mine tailings-based geopolymer bricks. *Construction and Building Materials*. 2013; *40*: 1002-1011.

[5] Salahudeen AB, Eberemu AO, Osinubi KJ. Assessment of cement kiln dust-treated expansive soil for the construction of flexible pavements. *Geotechnical and geological engineering*. 2014; *32*(4): 923-931.

[6] Ikara IA, Kundiri AM, Mohammed A. Influence of standard and modified Proctor compactive efforts on cement stabilized black cotton soil (BCS) with waste glass (WG) admixture. *IOSR-JMCE*. 2016; *13*(3): 7-16.

[7] Standard, B. (1990). Methods of test for soils for civil engineering purposes. *BS1377*.

[8] Standard, B. (1990). Methods of tests for stabilized soils. *British Standards Institute, London*.

[9] AASHTO M 145-91. (2012). Classification of soils and soil-aggregate mixtures for highway construction purposes.

[10] ASTM, D. 2. 9. (2011). Standard practice for classification of soils for engineering purposes (unified soil classification system).

[11] Bucther F, Sailie EL. Swelling behaviour of tropical black clays. In *Regional conference for Africa.* 1984; *8*: 81-86.

[12] Specification, N. G. Federal Ministry of Works and Housing (2013) Testing for the selection of soil for roads and bridges. *Vol. II*.

[13] Ikara IA, Kundiri AM, Mohammed A. Effects of waste glass (WG) on the strength characteristics of cement stabilized expansive soil. *American Journal of Engineering Research (AJER)*. 2015; *4*(11): 33-41.

[14] Batari A, Chinade AU, Saeed SM, Ikara IA, Kabir N, Mamuda A. Effect of bagasse ash on the properties of cement stabilized black cotton soil. *Int J Transp Eng Technol*. 2017; *3*: 67-73.