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Novel admixture for improvement of foundations on tropical expansive soils.

Hadi A. Abba [1], Lawal Sani [1], Mahmoud Hijab A. [2,*], Zawawi Daud [3]

[1] Department of Civil Engineering, Kaduna polytechnic, Nigeria
[2]Department of Civil Engineering, Modibbo Adama University of Technology, Yola. Nigeria.
[3]Centre of Advanced Research for Integrated Solid Waste Management (CARISMA), Universiti Tun Hussein Onn Malaysia

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Abstract: Black cotton soils have excessive shrinkage and swelling properties with respect to changes in the moisture conditions. Thus, construction on these soils may result in foundation problems. conventionally some approaches have been used to mitigate the problem by stabilization with lime or cement and which are relatively expensive for sustainability, an alternative stabilization was experimented with terrazzo waste. The polishing process of the terrazzo tiles produces a significant amount of waste slurry that it's disposal could pose some environmental pollution threat. Laboratory experiments were conducted to determine the suitability of terrazzo waste as admixture in the stabilization of black cotton soil. Natural moisture content, atterberg limits, maximum dry density and optimum moisture content parameters were determined using 2, 4, 6, 8 and 10% proportion of terrazzo waste admixture. The results of the parameter analysis found the natural moisture content was 23.43%, liquid limit varied from 32.8 to 56.5%, Plasticity index varied from 4.71 to 13.52%, MDD varied from 1.61 to 1.67 (g/cm3) and OMC from 8.5 to 22.6%, the CBR value was indicates unsuitability for use as a base and sub-base material. The terrazzo waste admixture produced can be used for stabilization with the potential to minimize the cost of waste disposal as well as provide substitute to the use of conventional stabilizers for use in places such as parks or pathways.

Keywords: Black cotton soil, CBR, Index tests, stabilization, terrazzo waste

1. Introduction

Black cotton soils (BCS) are dark grey colored expansive clays found in North-East Nigeria, India, USA and other parts of the world. They present various challenges to engineers all over the world due to their characteristics of severe loss of strength, excessive swelling and shrinking with respect to changes in moisture regime, (Oyekan et al., 2013;Meshida et al., 2013). Thus, road structures and highways constructed on black cotton soils are subject to severe deformations and frequent repairs leading to high cost of maintenance. Black cotton soils have the potential to absorb large quantity of water due to the presence of montmorillonite mineral in their structure (Amadi et al., 2014;Hijab et al., 2012;Aziz et al., 2015). Though the utilization of cement apparently has been used conventionally, the cost of stabilizing with cement is economically expensive requiring huge production cost which is seldom met with in developing countries. Researchers are continually exploring other alternative which less expensive and environmentally friendly such as waste products from agriculture in the form of bagasse ash, rice husk ash among others. The use of waste products is gaining popularity as it has the potential to minimize the cost of waste disposal as well as mitigate in the intensive use of conventional stabilizers (Prasad et al., 2009; Mohammadinia et al., 2015). Under ordinary conditions the waste materials create a potential negative impact on the environment causing air pollutions, water pollution and finally affecting the local ecosystems. (Pérez et al., 2013;Sharma et al., 2016;Osinubi et al., 2011;Oriola et al., 2010).

Terrazzo is made from a mixture of onyx, granite, marble and sometimes glass, combined with cement. Cast terrazzo is a kind of cement as the main raw material of composite ground material, because of its integrity, slip resistance, durability and economy which have wide application in Hospital floors, factories, Offices, schools, Commercial establishments, Cultural and entertainment centres, Airports, Railway Stations and Docks as well as Canteens and other buildings. The polishing process of the terrazzo tiles produces a significant amount of waste slurry that is not always easy to dispose of, and is an environmental concern Moreover, considering the fact that terrazzo comprises of granite and cement, it is imperative that the slurry would possess traces of granite and cementitious elements, which have the tendency to exhibit binder properties which is usually desirable in stabilization of expansive soils using ordinary Portland cement in road construction. The application of terrazzo waste in soil stabilization would be of much economic and environmental benefits. This study attempts to

Corresponding author: hijabmahmoud@yahoo.com

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determine the potential of terrazzo waste to improve the properties of black cotton soil.

2. Materials and methods

The soil used in this study is a black cotton soil (dark grey in colour) collected from Cham town (latitude 09˚43.686˝N and longitude 11˚43.686˝) in Balanga Local Government area of Gombe State in the Northern Eastern part of Nigeria. The black cotton soil was collected by method of disturbed soil sampling after the top soil was removed. 1 meter in depth was excavated and the sample was collected in bags. Some amount of soil was also collected in airtight polythene bags and sealed for natural moisture content determination. The soil was then transported to Kaduna Polytechnic Soil and Geology Laboratory where it was pulverized, dried and sieved through sieve no 4 (4.75mm aperture) British Standard sieve. The terrazzo waste was obtained from construction site waste in Kaduna polytechnic, during the construction of Electrical/Computer Departments. It was collected at ambient temperature condition using zip lock polythene bags.

Moisture content determination was carried out using the oven drying method as specified by the BS 1377 (1990) code. For the determination of natural moisture content, samples moisture content was calculated as a percentage of the soil mass to the nearest 0.1% using equation 1.

$$w = (m_2 - m_3 / m_3 - m_1) \times 100 \quad (1)$$

Where; m_1 = Mass of Container (g), m_2 = Mass of container and wet soil (g), m_3 = Mass of container and dry soil (g).

The specific gravity of the soil sample was determined using the density bottle method as specified by BS 1377 (1990) part 2:8:3. The specific gravity was determined using equation 2.

$$G_s = [(m_2 - m_1)/(m_4 - m_3) - (m_3 - m_2)] \quad (2)$$

where;

m_1 = Mass of bottle, = Mass of bottle + sample,

m_3 = Mass of bottle + water + bottle, m_4 = Mass of bottle + water.

Sieve analysis was performed to determine the distribution of the coarser, larger sized particles, and the distribution of the natural soil was determined using the method specify by BS 1377 (1990) for cohesive soil.

BS 1377 (1990) also described the procedure for determination of the liquid limit test of a soil. The flow graph or 'flow curve' was plotted at the best fit straight line and the moisture content corresponding to 25 blows from the flow curve was selected as the liquid limit of the soil sample.

The plastic limit (PL) was determined per BS 1377 (1990). The soil was rolled and shaped to a uniform body and rolled again until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The pieces of soil thread fragments were collected and the moisture content was determined and recorded as the plastic limit.

The plasticity index (PI) is computed as the difference between the liquid limit (LL) and the plastic limit (PL) using equation 3.

$$PI = LL - PL \quad (3)$$

For linear shrinkage BS 1377 (1990) described the procedure for linear shrinkage adopted in this study.

The compaction tests were carried out for the natural and the stabilized soils according to BS 1377, (1990) part 4, using the west African standard in accordance with the Nigerian General Specification (1997). Various percentages by weight of the terrazzo waste was added to black cotton soil again with increasing water content from 2% - 10%. The bulk density in mg/m³ was later calculated for each compacted layer using equation 4.

$$\rho_b = (m_2 - m_1)/1000 \quad (4)$$

Where; ρ_b = Bulk density, m_1 = Mass of mould and base (g), m_2 = Mass of mould, base and soil (g).

The dry density was also calculated using equation 5:

$$\rho_d = \rho_b/(1 + w) \quad (5)$$

Where; ρ_d = Dry density, w = Moisture content of each compacted layer.

The value of the dry densities obtained from equation 5 were plotted against their respective moisture contents and the maximum dry density (MDD), was deduced as the maximum point on the resultant curves which corresponds to the optimum moisture contents (OMC).

California Bearing Ratio (CBR). The tests were carried out as specified in BS 1377 (1990), BS 1924 (1990) and the Nigerian General Specification for roads and bridge works (1997). The CBR was calculated at the penetration of 2.5mm and 5.0mm using equation 6.

$$CBR = \frac{(measured\ force)}{(Standard\ force)} \times 100\% \quad (6)$$

3. Results and Discussion

Index tests on the terrazzo waste stabilized black cotton soils were carried out in accordance with the procedures outline in BS 1377 (1990) and BS, 1924 (1990) respectively, step percentages of terrazzo waste by dry weight of soil were 0,2,4,6,8 and 10% was admixed with the soil.

3.1 Natural moisture content

The natural moisture content of the sample was determined to be 23.43%, this indicates that the soil was in an unsaturated condition.

3.2 Specific gravity

The variation in specific gravity (Gs) of black cotton soil treated with the addition of different percentages of terrazzo waste as admixture indicates that the Gs increased at a range from 2.31 to 2.39 with the addition of terrazzo waste (see figure 1).

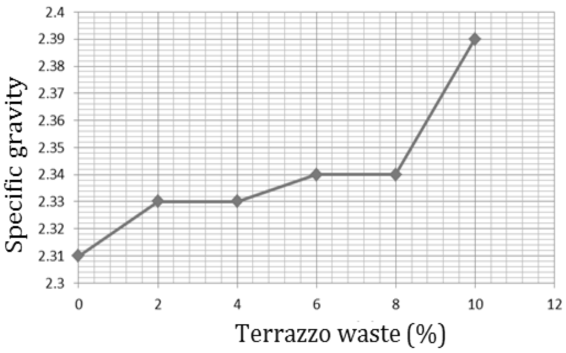

Fig.1 Effect of variation of terrazzo waste content on the specific gravity.

3.3 Atterberg limit test

The Atterberg limit test was carried out and the result of the liquid limit, plastic limit and plasticity index was presented in figure 2.

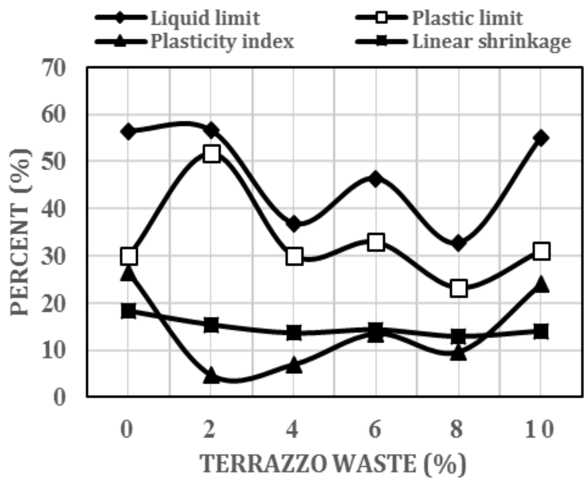

Fig.2 Atterberg limits for 0 - 10% admixture.

It was found that the soil plasticity index varied with the addition of the admixture. The 2% terrazzo waste sample tended to reduce the plasticity of the soil to the least amount and may be considered as low plasticity material, however the remaining samples with subsequent mixing proportion ranged from medium to high plasticity samples and fall within A-7-6 per AASHTO classification system and CH per unified soil classification system. The shrinkage limit also gradually decrease with increment in admixture to the soil.

3.4 Sieve analysis

Sieve analyses of the modified samples have been determined. Figure 2 represents the unmodified sample, while figures 3 -7 represents the modified sample with various proportion (2,4,6,8,10%) of terrazzo waste. From the graphs, it can be seen that the modification seem to achieve a well graded condition. The 2% terrazzo waste modified sample was found to achieve adequate grading condition with less admixture.

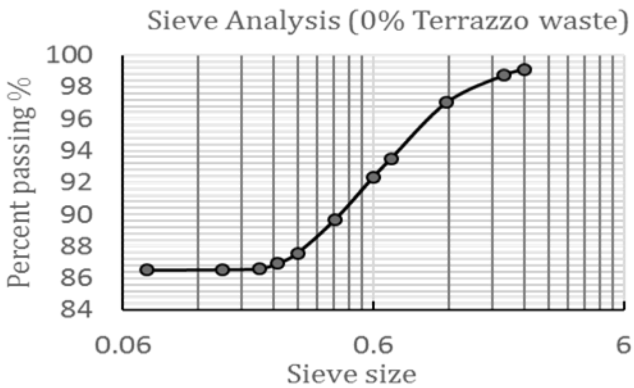

Fig.3 Sieve analysis for 0% admixture.

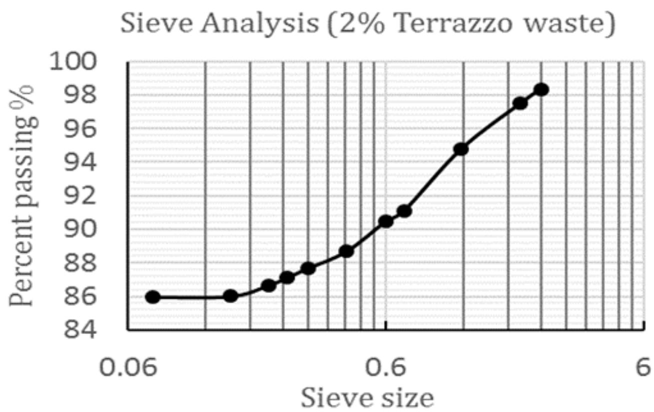

Fig.4 Sieve analysis for 2% admixture.

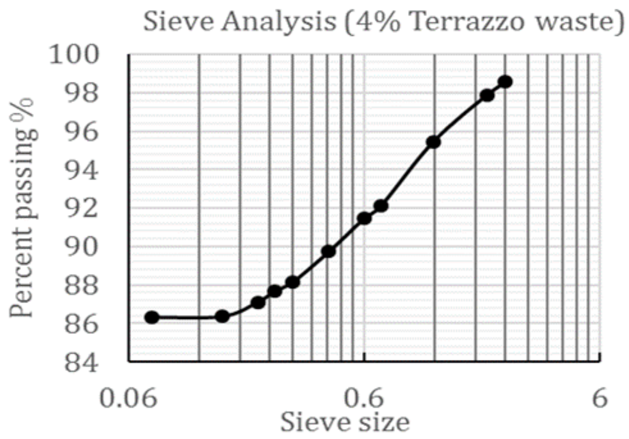

Fig.5 Sieve analysis for 4% admixture.

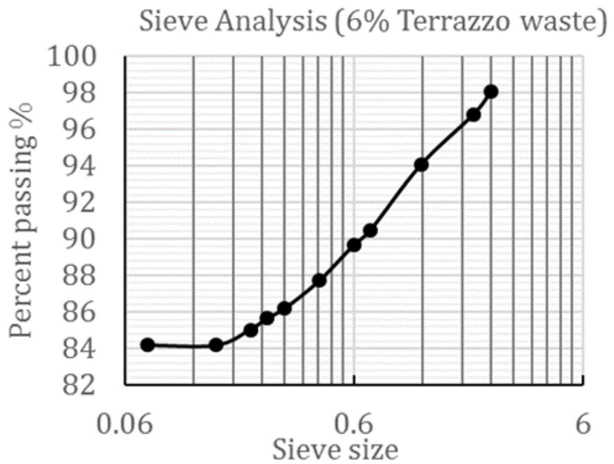

Fig.6 Sieve analysis for 6% admixture.

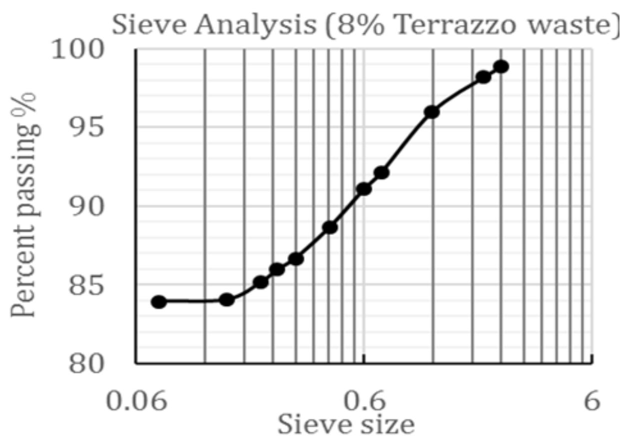

Fig.7 Sieve analysis for 8% admixture.

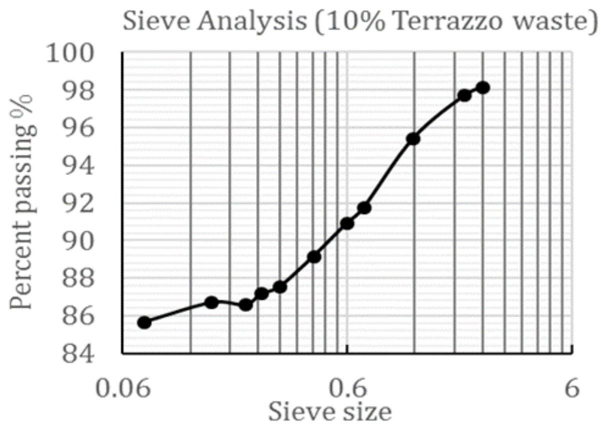

Fig.8 Sieve analysis for 10% admixture.

3.5 Compaction test

The variation in optimum moisture content (OMC) of black cotton soil admixed with different percentages of terrazzo waste was determine using West African compaction. The results of the OMC for 2, 4, 6, 8 and 10% modified black cotton soil were 22.6, 20,15,20.5 and 8.5% respectively (see figure 8). The optimum moisture content continued to decrease from 2 to 6% terrazzo waste increment and then increased from 8% to 10%. The decrease in OMC could be due to the presence of more terrazzo waste content which resulted to the use of the available water and subsequent incomplete hydration that lowered the OMC.

The effect of terrazzo waste on the maximum dry density (MDD) of the black cotton Soil was shown in figure 9. The MDD for natural soil was found to be 1.67g/cm3 and the MDD for 2, 4, 6, 8 and 10% terrazzo waste was found to be 1.65, 1.66, 1.67, 1.61 and 1.66g/cm3 respectively. Addition of terrazzo waste to the black cotton soil tend to increase the MDD. The peak value of MDD attained were 1.67g/cm3 at 6% terrazzo waste. The increase in MDD could be due to soil becoming lower in plasticity as the admixture increased in quantity. The decrease in MDD after 6% could be due to a relatively low clay content not filling up available air voids of the admixture as it attains a certain amount.

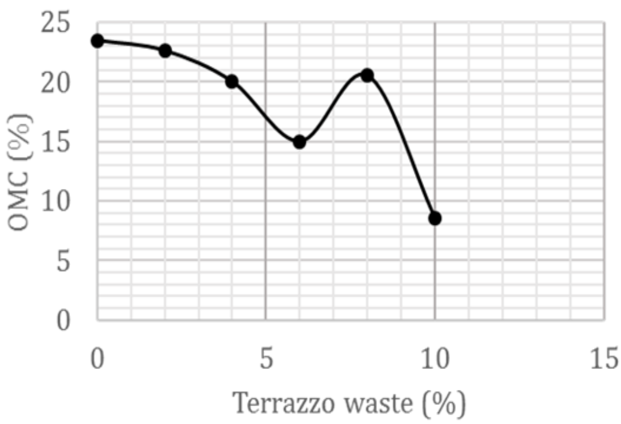

Fig.8 OMC optimums for 2 - 10% admixture.

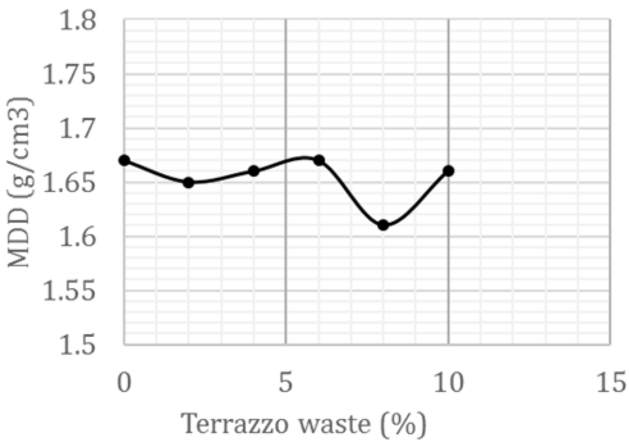

Fig.9 MDD optimums for 2 - 10% admixture.

3.6 CBR

The variation in unsoaked CBR for 7 and 28 days' black cotton soil admixed with terrazzo waste is shown in Fig. 10. The CBR value obtained for the natural soil was 0.45% and that of 2, 4 and 6% for 7 and 28 days were 0.30, 0.14, 0.20 and 1.0, 0.39, 0.43% respectively. At 2% admixture for both 7 and 28 days, the CBR had a peak value, and then decreased at 4% and later increased at 6% for both 7 and 28 days curing. The increase in CBR value could be due to the OMC obtained due to addition of terrazzo waste content, and the decrease could be due to a lower value in MDD obtained as a result of the lower specific gravity of the terrazzo waste with the soil. Osinubi, 2001 recommend that a CBR value of 60-80% is required for base and 20-30% for sub-base both when compacted at optimum moisture and 100% West Africa standard. Though the admixture had gained some strength the California bearing ratio obtained fell short of the recommended value for base and sub-base layers.

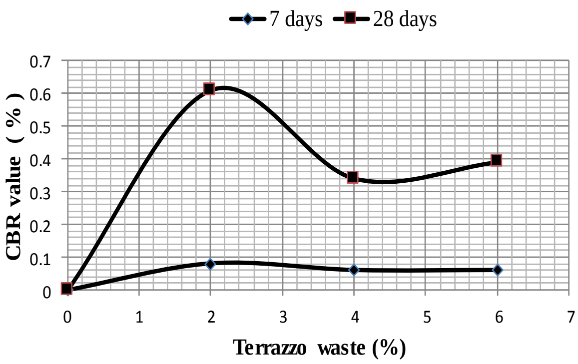

Fig.10. CBR values for 7 and 28 days unsoaked at 0, 2,4, and 6 % admixture.

The variation in soaked CBR for 7 and 28 days' black cotton soil admixed with terrazzo waste is also shown in Fig. 11. The CBR value obtained for the natural soil was 0.25% and that of 2, 4 and 6% for 7 and 28 days were 0.08, 0.06, 0.07 and 0.61, 0.34, 0.39% respectively. At 2% admixture for both 7 and 28 days, the CBR has a peak value, and then decreased at 4% and later increased at 6% for both 7 and 28 days curing. The results show that although there was some improvement in strength, it was below the recommended limit to be used for base and sub-base layers.

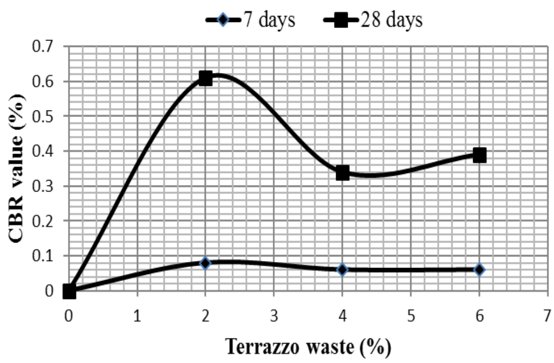

Fig.11. CBR values for 7 and 28 days soaked at 0, 2,4, and 6 % admixture.

3.7 UCS

The effect of addition of terrazzo waste to black cotton soil for 7 and 28 days curing are shown in fig. 12. The UCS for natural soil was obtained to be 44.25kn/m^2 and for 2, 4, and 6% admixtures with respect to 7 and 28 days were 210.35, 131.60, 175.47 and 739.70, 243.92 and 345.25 kn/m^2 respectively. The UCS increased for both 7 and 28 days at 2% terrazzo waste thereafter it decreased, with an increase at 7 and 28 days for both 4 and 6% respectively. The increase in UCS of black cotton soil with addition of terrazzo waste could be due to pozzolanic reactivity of the terrazzo waste with the soil and the decrease could be due to chemical oxidation of the terrazzo waste in the black cotton soil.

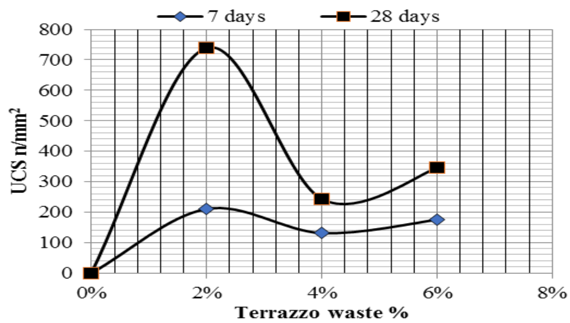

Fig.12.Variation of UCS values at 2, 4 and 6% admixed terrazzo waste for 7 and 28 days curing.

4. Conclusions

In this study, the ability of terrazzo waste as admixture in the stabilization of black cotton soil was investigated. The geotechnical parameters such as natural moisture content, atterberg limits (LL, PL and PI), maximum dry density and optimum moisture content was determined. The results of the parameter analysis were established (based on admixture variation from 2-10%

except in its natural condition) as follows: natural moisture content of 23.43%, liquid limit varied from 32.8 to 56.5%, Plasticity index varied from 4.71 to 13.52%, maximum dry density varied from 1.61 to 1.67 (g/cm3) and optimum moisture content from 8.5 to 22.6%. The CBR value was below the recommended limit for use in a base and sub-base layer. The terrazzo waste can be used as an admixture to improve the properties of the black cotton soil for possible use in pathways and parks. The current findings add to the growing body of literature on alternative to conventional admixture for soil stabilization. Further research is ongoing to assess other factors that may affect the subject of study.

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