Improving Properties of Black Cotton Soil with Quarry Dust

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ABSTRACT: *Black cotton soils are among a group of soils termed as problematic soils. These soils have undesirable characteristics in relation to construction works and therefore need some form of improvement when encountered in construction projects. Techniques for improvement of black cotton soils include replacement, moisture control or adding a stabilizer. Cement and/or lime has been commonly used in soil stabilization for ages. However, due to the associated cost, required quality control and the need to utilize waste materials in construction, new stabilizing materials are emerging. This paper presents a study on application of quarry dust for improving properties of black cotton soil in Mbeya region, Tanzania. The targeted improvement was to achieve minimum acceptable characteristics for road subgrade as per Tanzania standards. It was determined that 40% by weight of quarry dust added to the black cotton soil was able to improve the characteristics by increasing CBR value from 3.8 to 15.7 and reducing PI from 32% to 15%. It will be worthy studying the cost implication of the suggested improvement in relation to other techniques before application of the study findings.*

KEYWORDS: *black cotton soil, expansive soil, soil improvement, quarry dust, waste materials for construction*

1. Introduction

Black cotton soils are among a group of soils termed as problematic soils. In character, black cotton soils are grayish to blackish, fertile, inorganic clays of medium to high compressibility. They are susceptible to shrink and swell under moisture variations, therefore very likely to cause damage to building structures or pavements constructed over them without proper treatment. These soils have very low strength when wet but very hard when dry, posing a problem when pulverization is required. Cracks in dry black cotton soils have been reported to be in the order of up to10 – 15 cm wide and 0.5 – 2.0 m deep. The clay in black cotton soils is in form of montmorillonite structure which is expansive in nature. In their original state, black cotton soils and the rest of problematic soils are not suitable for road or structural foundation. In Tanzania, it is highly recommended to carefully analyse cost and forecast potential problems which may be associated to a road project before suggesting a method of treating soils with expansiveness such as black cotton soils (MoW, 1999).

Improvement of black cotton soils may come in different forms, replacement is one of them. This is may be suitable in road constructionwhere the encountered black cotton layer is relatively thin. However, this methodology can be uneconomical if the layer extends deeper than 1.5 m and stabilization is normally thought instead. Lime stabilization has been extensively studied to stabilize black cotton soils with recent literature including Nagdouda and Hegde (2010),Negi et al. (2013),Shailendra and Vasaikar (2015) and Mishra (2015), among others. In the process of stabilization with lime, a chemical reaction occurs that makes silica present in the soil be more soluble and cementitious. A strength increase may also be achieved in lime stabilization. However, when the expected chemical reaction due to lime stabilization does not happen, the result may be poor. It has been reported that presence of organic mattersrequires higher percentages of stabilizer as compared to when they are absent in the soil that needs stabilization (Mow, 1999).

Cement is capable of binding material together when hardening. It reduces plasticity and increases both flexural and shear strength of the soil when applied. The problem with cement stabilization is that it is relatively expensive especially in consideration of rural road construction in developing countries. Cement requires a high degree of quality control, an element that cannot easily be attainable in rural roads construction. Moreover, cement is not very effective for stabilization of highly plastic soils unless extra efforts are implemented to improve the workability (MoW, 1999). A cement – lime mixture has been commonly applied for improving black cotton soils. There are also some studies indicating use of cement with sand, example Ramteke et al. (2014) and Ramesh Babuet al. (2016) or cement with fly ash (PrakashBabuet al. 2016). The benefit of cement – lime mixture is that the two materials complement one another; while the lime will be more responsible for reducing plasticity, the cement will basically act to improve the strength of the stabilized soil. However, with all the benefits of cement – lime mixture, comes the cost of construction as well as the technical requirement of proper quality control. There is also the risk of having the stabilized layer crack when a high percentage of stabilizer is applied.

Cost and technical challenges of applying cement and lime for stabilization have led to introduction of relatively new techniques of dealing with black cotton soils. Furthermore, some techniques have emerged as an effort of disposing industrial wastes. Such alternative methods include use of fly ash (Hakari and Puranik, 2012; Gupta and Sharma 2016), quarry dust (Sai Ganesh Kumar et al. 2015)and control of moisture content, among others. Control of moisture content is possible by first saturating the soil through wetting. But this too has its own challenges; first the saturation may not be possible for some hydraulic conductive soils and then again the process of controlling moisture around the whole useful life of the pavement is of concern. Even with an abundance of studies on stabilization of black cotton soils, local studies are of importance in order to have more relevant results. This is because black cotton soils from different regions of the world show variation in properties.

2. Study Objective

This study aims at improving geotechnical characteristics of black cotton soil sourced fromKyela in Mbeya region Tanzania by using quarry dust obtained from Mswiswi quarry, also in Mbeya. Pavement and materials design manual applicable in Tanzania (MoW, 1999) requires all subgrades to have minimum CBR value of 15% either naturally or through treatments where necessary. The CBR must be obtained at 95% of BS heavy compaction test. In additional to strength requirement, MoW (1999) recommends a plasticity index (PI) of maximum 25% and a CBR swell of 1.5% maximum after the improvement. It was therefore targeted to determine the minimum amount of quarry dust in percentage of the black cotton soil that will make the mixture achieve the minimum requirements for an acceptable subgrade according to MoW (1999).

3. Testing Program

Material testing involved characterization of natural black cotton soil, characterization of quarry dust and characterization of blended material. Blending was performed by varying the percentage of quarry dust by weight of black cotton soil at 10%, 20%, 30% and 40%. The following tests were performed; sieve analysis for soil classification, determination of Atterberg limits, linear shrinkage, Proctor compaction for determination of maximum dry density and optimum moisture content and CBR test for determination of soaked strength. All tests were conducted in accordance to Tanzania´s laboratory testing manual (MoW, 2000).

4. Results and Discussion

Result of sieve analysis indicates that the black cotton soil has gravel amounting to 3.6%, sand 27.8% and fines 68.7%. The quarry dust has gravel amount of 35.6%, sand 54.6% and fines 9.7%. Gradation curves for the two materials are plotted in Fig. 1. Atterberg limits parameters for the black cotton soil were found to be as follows; liquid limit (LL) = 59%, plastic limit (PL) = 27%, plasticity index (PI) = 32% and linear shrinkage (LS) = 18%. According to AASHTO soil classification system, the black cotton soil is classified as an A-7-6 material. Proctor compaction test results for the black cotton soil indicated a maximum dry density (MDD) of 1559 kg/m^3 at an optimum moisture content (OMC) of 20.7%. The soaked CBR value at 95% of MDD for the black cotton material was determined to be 3.8% which according to MoW (1999) is classifies as an S3 subgrade material that definitely needs improvement. The quarry dust had an MDD of 1663 kg/m^3 at an OMC of 12.6% and the value of CBR obtained was 13.

After obtaining characteristics of the materials in thenatural state, quarry dust was added to black cotton soil starting with 10% by weight up to 40% at intervals of 10%. At each quarry dust increment Atterberg limits, compaction parameters and CBR values were determined. Table 1 indicates results of Atterberg limits at different percentages of quarry dust. It can be observed from Fig. 2 that both PI and LS decreases gradually with increase in quarry dust such that at 10% quarry dust, the PI had already reduced to an acceptable value for subgrades. However, a further increase in quarry dust was necessary to attain the minimum subgrade strength qualification.

Changes in compaction characteristics of the black cotton soil due to addition of quarry dust are reported in Table 2. Generally there is a decrease in OMC and an increase in MDD with increase in quarry dust content. This trend was also observed by Arun Kumar and Biradar (2014). Fig. 3 indicates the trend of OMC and Fig. 4 is the trend of MDD with increase in quarry dust content. As indicated in Table 2 and Fig. 5, increase in quarry dust content resulted to increase in CBR values from 3.8 for the natural subgrade to 15.7 after mixing with 40% quarry dust. This increment is of more than 75% which is larger than what was observed by Arun Kumar and Biradar (2014) as well as by Sai Ganesh Kumar et al. (2015) at the similar amounts of quarry dust. The significantly larger improvement in strength may be attributed to the characteristics of the quarry dust used in this study as it has a significantly large percentage of gravel sized particles.

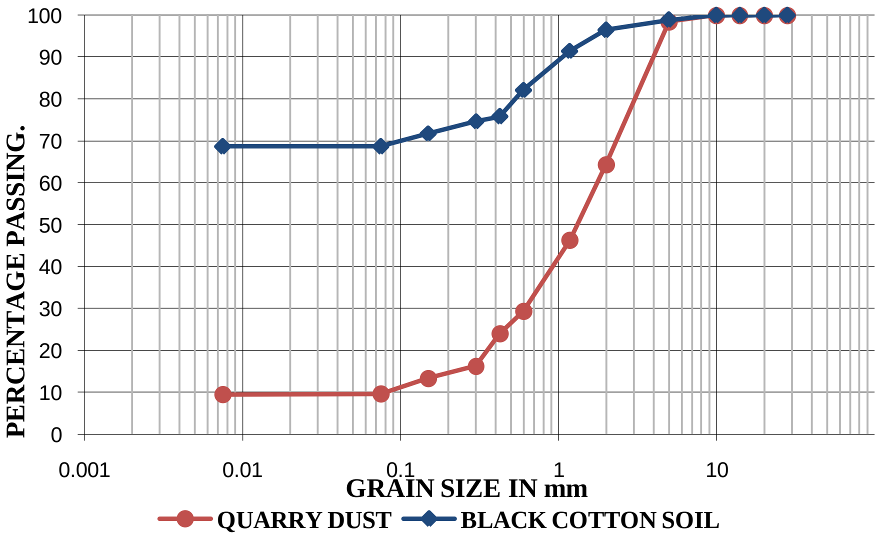

Figure 1: Gradation curves for quarry dust and black cotton soil

Table 1:Variation of Atterberg parameters with quarry dust content

% QUARRY DUST	LL%	PL%	PI%	LS%
0	59	27	32	18
10	58	34	24	14
20	55	35	19	12
30	54	36	17	9
40	52	37	15	6

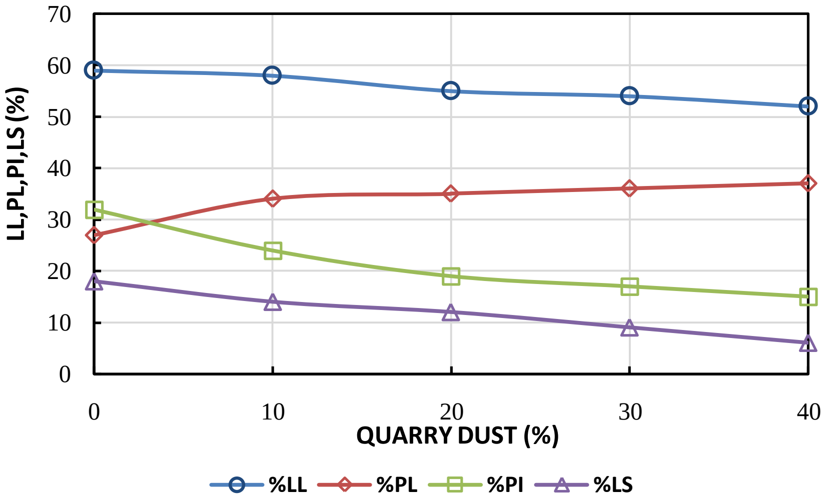

Figure 2: Variation of Atterberg limits with percentage quarry dust

Table 2: Variation of OMC, MDD and CBR values with percentage quarry dust

% QUARRY DUST	OMC %	MDD kg/m^3	CBR
0	20.7	1559	3.8
10	18.3	1641	7.1
20	16.2	1676	8.5
30	14.1	1710	11.5
40	12.2	1731	15.7

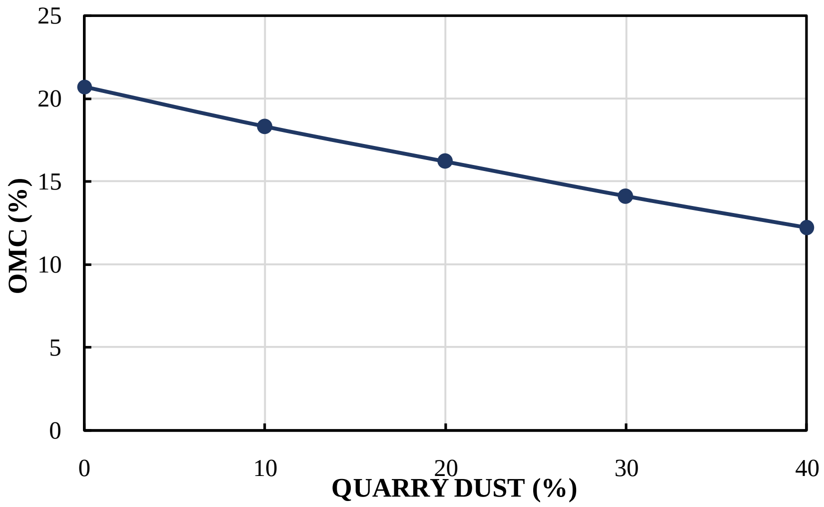

Figure3: Variation of OMC with percentage quarry dust

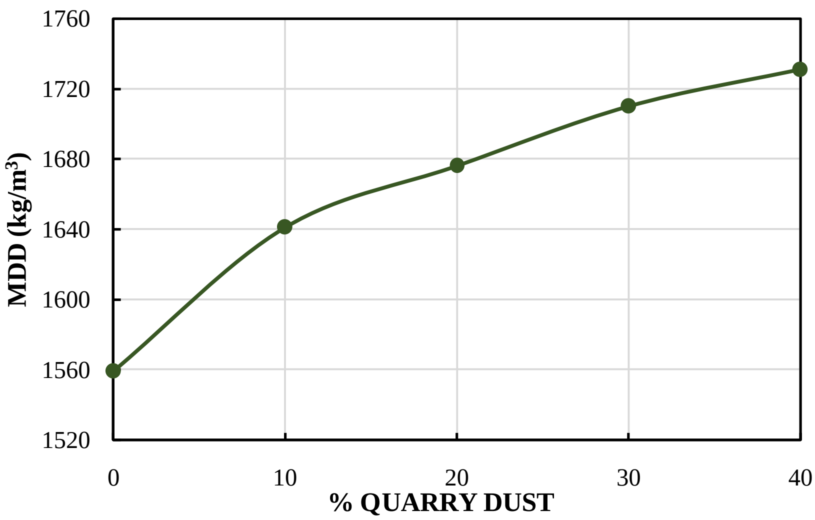

Figure 4: Variation of MDD with percentage quarry dust

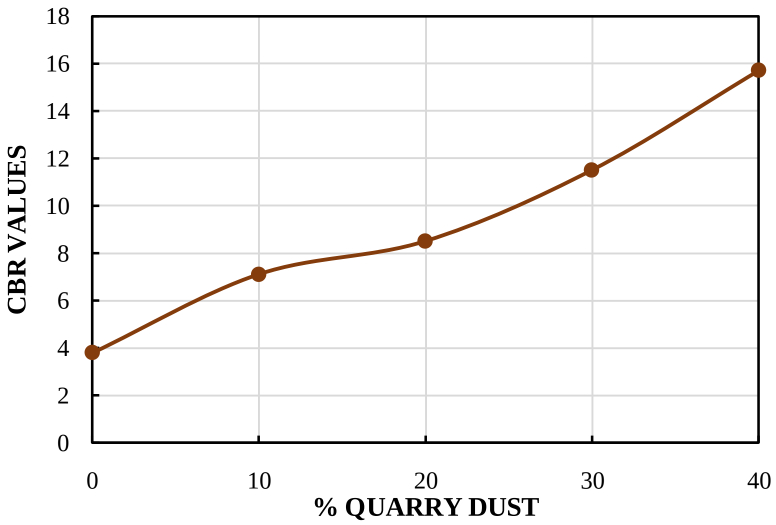

Figure 5: Variation of CBR values with percentage quarry dust

5. Conclusion

This study was performed to establish the possibility of applying quarry dust from Mswiswi area for improving properties of black cotton soil which is abundant in Kyela district, Mbeya region in Tanzania. It was determined that adding 40% of quarry dust enables the black cotton soil to acquire minimum characteristic requirements of a road subgrade as stipulated in the relevant pavement design and materials design manual (MoW, 1999). The following were observed:

- The existing black cotton soil is characterized as an A – 7 – 6 material with gravel 3.6%, sand 27.8% and fines 68.7%. The soil has a PI of 32% and a CBR of 3.8 and therefore needs improvement before being accepted as a road subgrade
- The quarry dust material is made of 35.6% gravel, 54.6% sand and 9.7% fines. It had an MDD of 1663kg/m^3at an OMC of 12.6%. The CBR value was 13.
- Addition of quarry dust to the black cotton soil improved the soil by lowering the PI from 32% at its natural state to 15% at 40% quarry dust content.
- Addition of quarry dust resulted to a reduction of OMC of the soil mix from 20.7% to 12.2% at 40% quarry dust content.
- The MDD of the soil increased with increased percentage of quarry dust where by at 40% quarry dust, the MDD of the mixture was 1731kg/m^3. The natural black cotton soil had an MDD of 1559 kg/m^3.
- Addition of quarry dust improved the CBR from 3.8 for the natural black cotton soil to 15.7% at 40% quarry dust content.

It is recommended to perform a cost comparison between application of quarry dust and other waste materials for improvement of black cotton soils before application.

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