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Research Paper

Utilization of Laterite Soil Stabilized With Quarry Dust and Lime As Subgrade Material

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ABSTRACT: *Road construction makes extensive use of lateritic soils. Their geotechnical properties and suitability as base, sub-base, and sub-grade materials for road construction, however, are not fully explored. This study is aimed at utilizing quarry dust and lime in improving the geotechnical properties of laterite for use as a subgrade material in accordance with regulatory standards of Nigeria. The samples were collected at 1.0m depth and were subjected to the following laboratory test; Particle size analysis, Atterberg limits test, Compaction test, Californian Bearing Ratio test. Test results revealed that the liquid limit of the samples ranged from 34.46% to 35.88% while the plasticity index ranged from 50.91% to 52.02%, which belong to the A-2-4 group which is basically clayey soils. Test results also revealed that the maximum dry densities of the samples ranged from 1712 kg/m^3 to 1884 kg/m^3 conforming to AASHTO A-2-4 group class, while the optimum moisture content of the samples ranged from 12.66% to 21.06%. Test results generally indicated that the addition of quarry dust and lime to an amount not exceeding 5% quarry dust and 5% lime improved the suitability of the laterite soil as a subgrade amount.*

KEYWORDS: *laterite, lateritic soil, CBR, subgrade, quarry dust, lime, stabilization*

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I. INTRODUCTION

The subgrade soil is an integral part of the road pavement structure as it provides the support to the pavement from beneath. The main function of the sub grade is to give adequate support to the pavement and for this the subgrade should possess sufficient stability under adverse climatic and loading conditions. The soil in the subgrade is not consistent throughout the road alignment. By selecting industrial bi-products and locally available soils for the construction of subgrade and subbase course, the cost of road construction in such land can be significantly reduced. A variety of subgrade materials from expansive clay to granular materials can be treated with soil stabilization.

Laterite soil is rich in iron and aluminium, and it is generally considered to have formed in hot and wet tropical areas. Because of the presence of high iron oxide, almost all laterite soil is of rusty-red colour.

Lime stabilization is one of the oldest process of improving the engineering properties of soils and can be used for stabilizing both base and sub base materials [1]. The addition of lime to reactive fine-grained soils has beneficial effects on their engineering properties, including reduction in plasticity and swells potential, improved workability, increased strength and stiffness, and enhanced durability. Generally, the oxides and hydroxides of calcium and magnesium are considered as 'lime', but the materials commonly used for lime stabilization are calcium hydroxide ($Ca(OH)_2$) and dolomite ($Ca(OH)_2$ + MgO), [1]. Calcium hydroxide (hydrated lime) is a fine, dry powder formed by 'slaking' quicklime (calcium oxide, CaO) with water; quicklime is produced by heating natural limestone (calcium carbonate, $Ca(CO)_3$) in a kiln until carbon dioxide is driven out [2]. Quicklime is also an effective stabilizer used but not usually used for stabilization because it is caustic hence dangerous to handle, susceptible to moisture uptake in storage, and gives off much heat during hydration [3].

During crushing operations, quarry dust is generated. It represents 20–25% of the output of each crusher system. Quarry dust is a very low-cost replacement for sand which satisfies the need behind the alternative product. It even includes the risk of processing the crusher dust as it causes pollution of the

atmosphere. The quarry dust imparts higher shear strength and it turns out to be a more advantageous geotechnical material [4].
This study presents the influence of quarry dust and lime on the geotechnical properties of lateritic soil.

II. METHODOLOGY

The soil sample used in this study was obtained from Rivers State, Nigeria. It was collected as disturbed sample. Excavated to a depth not less than 1.0m so as to avoid any organic material. The samples were packaged in an unsealed plastic bags for use in the laboratory. The collected soil sample was air-dried and pulverized into particles passing BS No. 4 (4.75 mm).

Preliminary tests (natural moisture content, specific gravity, sieve analysis and Atterberg's limits) were performed on the soil samples. The test conducted for the research were conducted in accordance of procedure outlined in [5] and [6] for natural as well as stabilized soil respectively. 5%, 10%, 15% and 20% of quarry dust (by weight) was added to the soil and mixed thoroughly. The mixed soil sample were left for 48 hours to cure and subsequently remixed to achieve a homogenous mix prior to compaction at both West Africa and Modified AASHTO [7] levels of compaction. The West African level involved compacting the soil in five layers in a CBR mould with each layer subjected to 25 blows using a 4.5 kg rammer that falls through the height of 0.46m while the Modified AASHTO compaction involved 55 blows resulting in a higher energy of compaction usually achievable with conventional field equipment. The lateritic soil-stone dust, in the present investigation, were mixed with pulverized hydrated lime in various proportions, i.e. 1%, 3% and 5% by dry weight of oven dried soil mix. The samples were tested for California Bearing Ratio (CBR) of the soil with Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). Proper care was taken to maintain the homogeneity of the mix.

The subgrade in this research was classified using the Nigerian standard for pavements and materials design. The classification to represent realistic basis of design was based on the California Bearing Ratio (CBR) specified in the Nigerian standard and represented in Table 1.

Table 1. Nigerian Standard for Subgrade Classification (Source: [8])

	Subgrade Class Designation					
	S1	S2	S3	S4	S5	S6
Subgrade CBR ranges (%)	2	3-4	5-7	8-14	15-29	30+

III. RESULTS AND DISCUSSION

Atterberg Limits (LL, PL and PI) Test

The Atterberg limits comprise of liquid limit (LL), plastic limit (PL) and plasticity index (PI). These index tests are used in the classification of soil using the AASHTO chart [6]. These tests revealed that the Liquid Limit of the samples ranged from 34.46% to 35.88%, the Plastic Limit ranged 50.91% to 52.02% while the plasticity index ranged from 50.91% to 52.02%, which belong to the A-2-4 group which is basically clayey soils.

Grain Size Distribution

The particle size distribution of the lateritic soil sample and quarry dust is presented in Figure 1 and Figure 2.

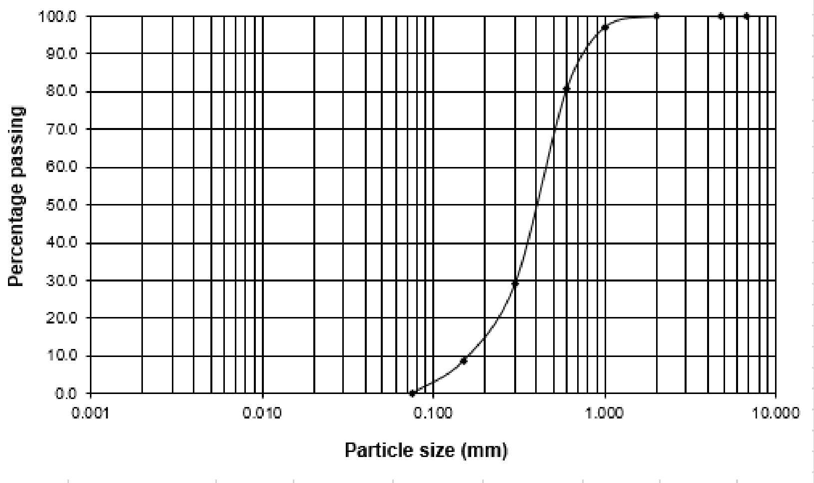

Figure 1: Particle size distribution for laterite

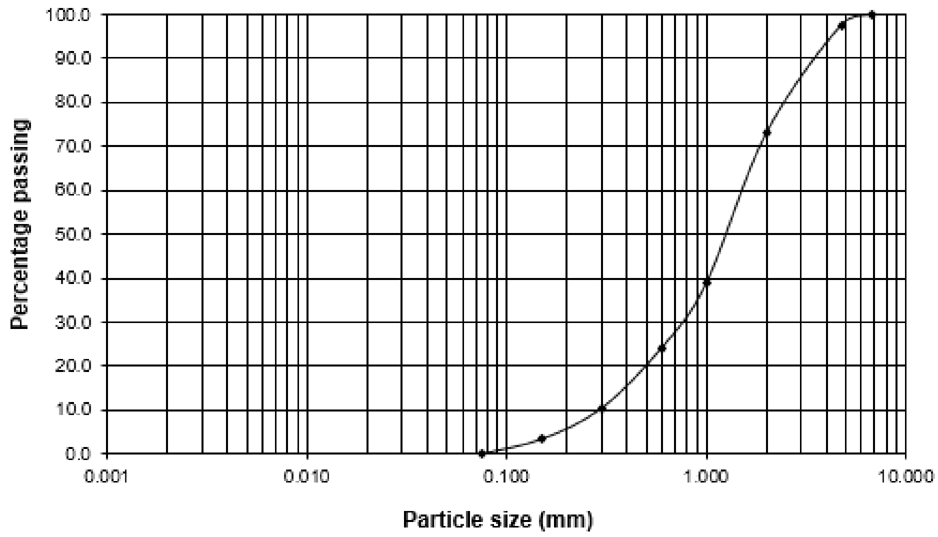

Figure 2: Particle size distribution for quarry dust

Proctor Compaction Test

The variation of maximum dry density with the percentages of quarry dust and lime is presented in Figure 3. It can be seen from the graph that the maximum dry densities of the samples ranged from 1712 kg/m^3 to 1884 kg/m^3 conforming to AASHTO A-2-4 group class.

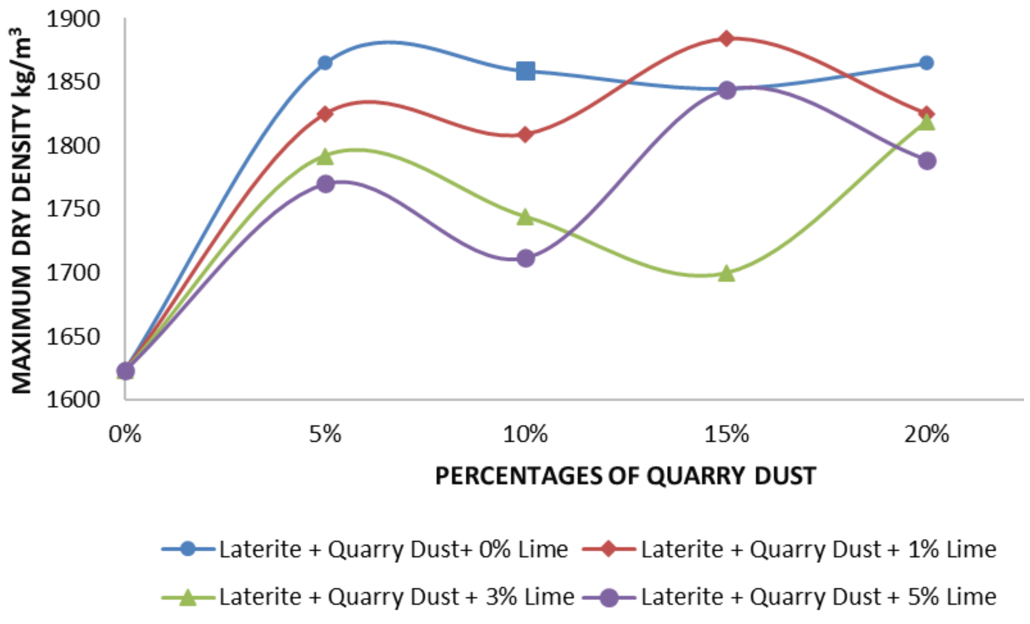

Figure 3: Variation of Maximum Dry Density (MDD) with Quarry Dust and Lime.

The variation of optimum moisture content with the percentages of quarry dust and lime is presented in Figure 4. It can be seen from the graph that the optimum moisture content of the samples ranged from 12.66% at 15% of quarry dust and 1% of lime to 21.06% also at 15% of quarry dust and 1% of lime.

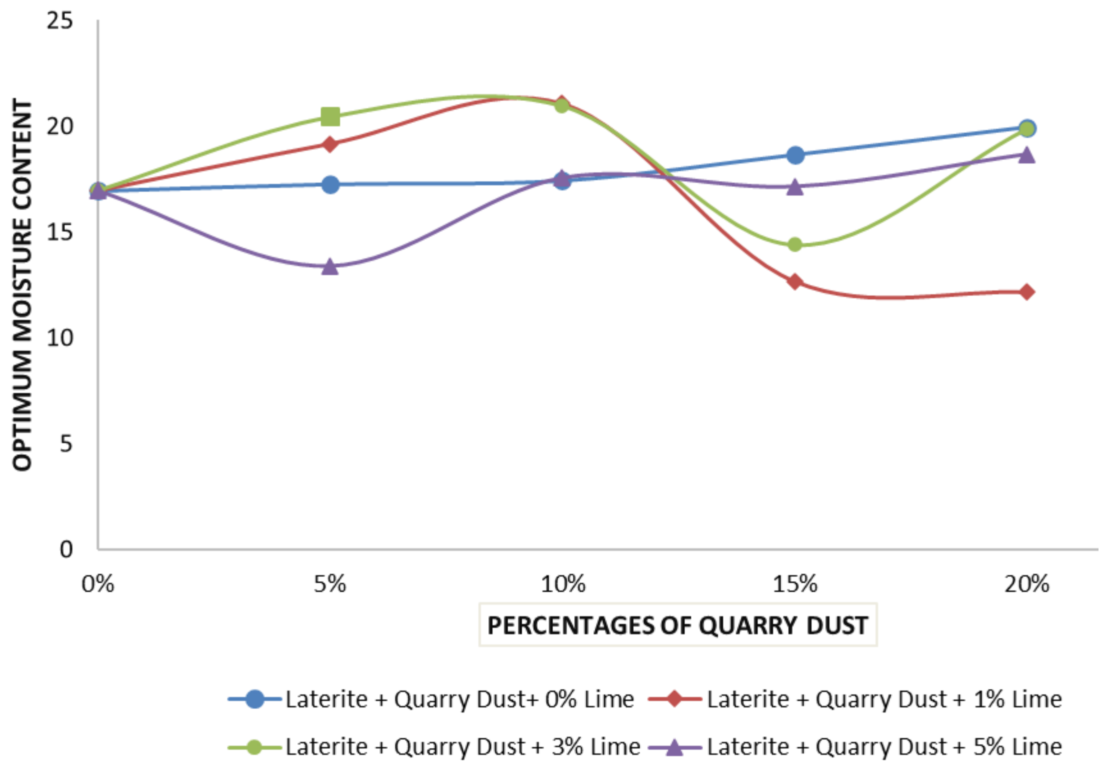

Figure 4: Variation of Optimum Moisture Content (OMC) with Quarry Dust and Lime

California Bearing Ratio

The change in unsoaked CBR value with quarry dust and lime content can easily be seen in Figure 5. It can be observed from the figure that the unsoaked CBR of the untreated laterite soil sample was 5.29% which fell into the S3 subgrade class which is a poor soil for subgrade. Test results also revealed that the unsoaked CBR of the quarry dust and lime stabilized soil ranged from 7.0% to 13.65% which fell into the S4 subgrade class which is a good soil for subgrade.

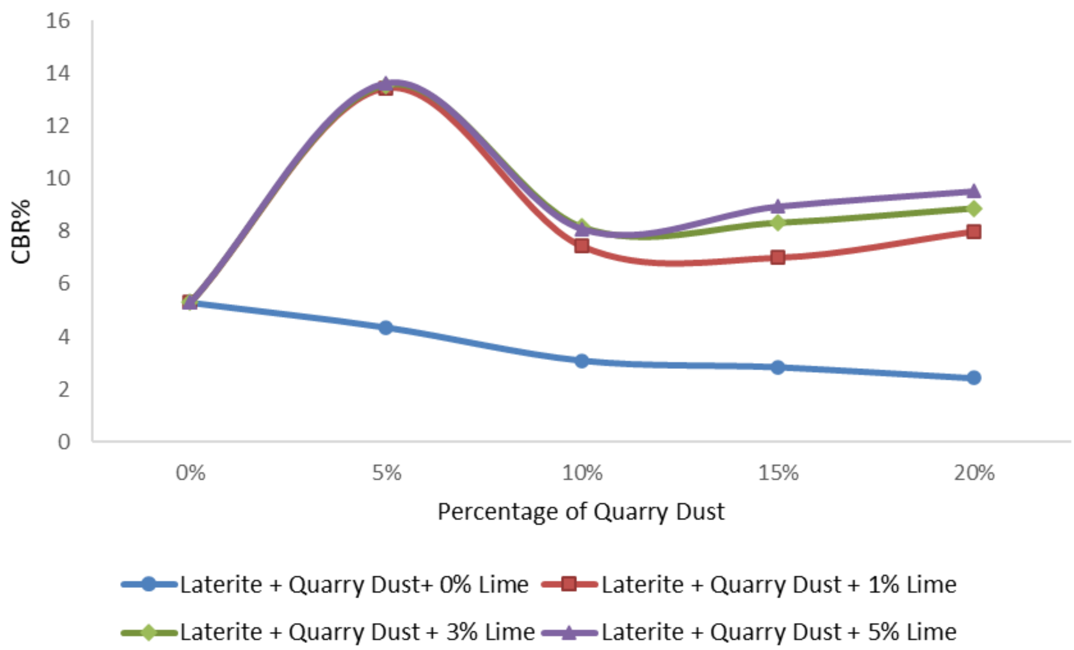

Figure 5: Variation of unsoaked California Bearing Ratio (CBR) with Quarry Dust and Lime

Optimal Stabilization

From the research, it was observed that 5% quarry dust content and 5% lime gave an optimal stabilization for laterite that met the Nigerian Specifications of subgrade martials [8].

Table 3: Some Geotechnical Properties at Optimal Stabilization

Properties	At Optimal Stabilization with Quarry Dust and Lime	*Subgrade Requirement
Liquid Limit (%)	35.17	≤ 80
Plasticity Index (%)	51.47	≤ 55
Unsoaked CBR (%)	13.65	≥ 8

*** Federal Ministry of Works Specifications, Nigeria (2013)**

IV. CONCLUSION

Test results revealed that the liquid limit of the samples ranged from 34.46% to 35.88% while the plasticity index ranged from 50.91% to 52.02%, which belong to the A-2-4 group which is basically clayey soils. Test results also revealed that the maximum dry densities of the samples ranged from 1712 kg/m^3 to 1884 kg/m^3 conforming to AASHTO A-2-4 group class, while the optimum moisture content of the samples ranged from 12.66% to 21.06%. Test results generally indicated that the addition of quarry dust and lime to an amount not exceeding 5% quarry dust and 5% lime improved the suitability of the laterite soil as a subgrade amount. Therefore, 5% optimal stabilization of the A-2-4 soil effectively improved the suitability to meet the requirement for use as subgrade course materials.

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