# Utilization of Marble as a Stabilizer of Lateritic Soil for Pavement Works in Southwestern Nigeria

Adedoyin, A.D.[1], Yusuf, I.T.[2], Alebiosu, M.T.[1], David, O.O.[1], Agbaje, M.O.[1] and Babalola, F.M.[1]
[1]Department of Geology and Mineral Sciences, Faculty of Physical Sciences, University of Ilorin.
[2]Department of Civil Engineering, Faculty of Engineering, University of Ilorin.
deleadedoyin@yahoo.com

## Abstract

The increasing cost of traditional stabilizing agents and the need for the economical utilization of alternative materials for beneficial engineering purposes requires an investigation into the stabilizing potential of marble for the stabilization poor lateritic soils, to improve their geotechnical properties for pavement works. A lateritic soil classified as A-2-6(0) according to AASHTO classification system was treated with 0 – 6% (2% increment) proportions of crushed marble by dry weight of soil. A total of ten samples of laterite, five samples each, were collected from burrow pits in Oyun and University of Ilorin campus, Ilorin, Kwara State, Central Nigeria. The samples were mixed with marble in various proportions, and subjected to Compaction and California Bearing Ratio (CBR) tests. It was observed that the Maximum Dry Density (MDD) at 0, 2, 4 and 6% marble content were 2.0, 2.1, 1.9 and 2.0 g/cm$^3$, respectively and the Optimum Moisture Content (OMC) were 14.5, 10.5, 13.5 and 15% for the laterite sample at Oyun. The corresponding values of MDD and OMC for the sample at the University of Ilorin Campus were 1.65, 1.83, 1.69 and 1.87g/cm$^3$ and 20, 17, 21 and 12%, respectively. Results show that, for all marble contents, the unsoaked and soaked CBR values increased with increase in marble content from 0-2%, and decreased for further increase in marble content up to 6%. Also, the CBR for both the unsoaked and soaked conditions reached maximum values at 2% marble content, indicating that the optimum content of marble required to stabilize an A-2-6(0) lateritic soil is 2%. The soaked CBR values of %0 and 47% obtained, respectively for unsoaked and soaked conditions for the sample at Oyun, which are greater than 30% imply that 2% marble content is suitable for stabilizing lateritic soil for the production of subbase course in pavement works.

**Keywords**

Stabilizer, marble, lateritic soil, maximum dry density, optimum moisture content, california bearing ratio.

## 1. Introduction

Lateritic soils are the most abundant soils that are developed in the tropical areas (Nixon et al., 1957) such as Nigeria. The essential components of lateritic soils are oxides of iron, some oxides of aluminum, silica and clay minerals, especially kaolinite (Gidigasu, 1976). The formation is favoured by alternating wet and dry seasons which are prevalent in the tropical climate (Ushie, et al., 2011). Lateritic soils are widely used as a base or subbase course materials in pavement works and other construction purposes, because it is relatively cheap and readily available. However available data on geotechnical characteristics of lateritic soils show that these soils range in performance from excellent to poor for engineering purpose (Nixon et al., 1957).

As a result of this range in performance, soil stabilization which is the alteration of the properties of a soil to improve its engineering performance (Lambe, 1951) has been adopted to improve the swelling potentials, permeability, shearing and compressive strength of the soil. The technique of stabilizing a soil is by increasing its strength and stability through the addition of cement, lime, fly ash and hydrated lime. Others include sand (Madjadoumbaye et al., 2011) and tar sand (Amu et al., 2005).

The Oreke marble, a very large deposit of dolomitic marble in southwest Nigeria, has been well studied in terms of its mineralogy and industrial applications (Adedoyin et al., 2012; Adedoyin, 2015) but its application as stabilizer for construction materials has not been determined. In this work the Oreke marble was used as the stabilizer. Marble is a coarse grained rock composed of interlocking calcite crystals, it forms when limestone recrystallizes during metamorphism. The temperature and pressure of formation destroy any fossils and sedimentary textures present in the original rock (Clayton and Speed, 1975). This study therefore is aimed at investigating the strength characteristic of lateritic clay soil using marble as stabilizer, to improve their geotechnical properties for road construction. The locations were chosen because of the large deposits of materials in them as well as their easy accessibilities to major towns. This paper, therefore, aims at investigating the potentials of marble obtained from Oreke in southwestern Nigeria for improving the strength properties of a lateritic soil in pavement works.. The objectives are to;

(i) crush marble into powdery form to enhance mixing with lateritic soil,

(ii) determine the strength properties (MDD, OMC and CBR) of the lateritic soil sample,

(iii) determine the strength properties (MDD, OMC and CBR) of the marble-lateritic soil mixtures, and hence,

(iv) determine the optimum content of marble required to produce the suitable strength for stabilizing a lateritic soil to meet the requirement for pavement works.

## 2. Geology of the Area

The area under study falls within the Basement Complex of south western, Nigeria. It is essentially a Precambrian suite of intensely deformed metasediments which occupy a linear belt underlain by rock of migmatite gneiss complex (Adedoyin et al., 2012; Adedoyin, 2015). In the Late Precambrian, the tectonic episode (the Pan-African orogeny) which was partially accompanied by sedimentation brought about the deformation of rocks in parts of the African terrain, underlying the study area. This led to basement rejuvenation accompanied by plutonism, deformation and metamorphism. The metasedimentary rocks were folded, faulted, intruded and metamorphoses (Adedoyin et al., 2012; Adedoyin, 2015). Varieties of intrusions such as quartz veins, pegmatites and related were found within the schist. The rock types found in the studied area include; quartzite, schist, marble, pegmatite and dolerite. The marble deposit has a general trend from North-South around Elewa River, extending for about 2.5km as shown in Figure 1. It is coarse to medium-grained in texture, whitish to grayish in color and lies between the quartzite ridge and mica schist.

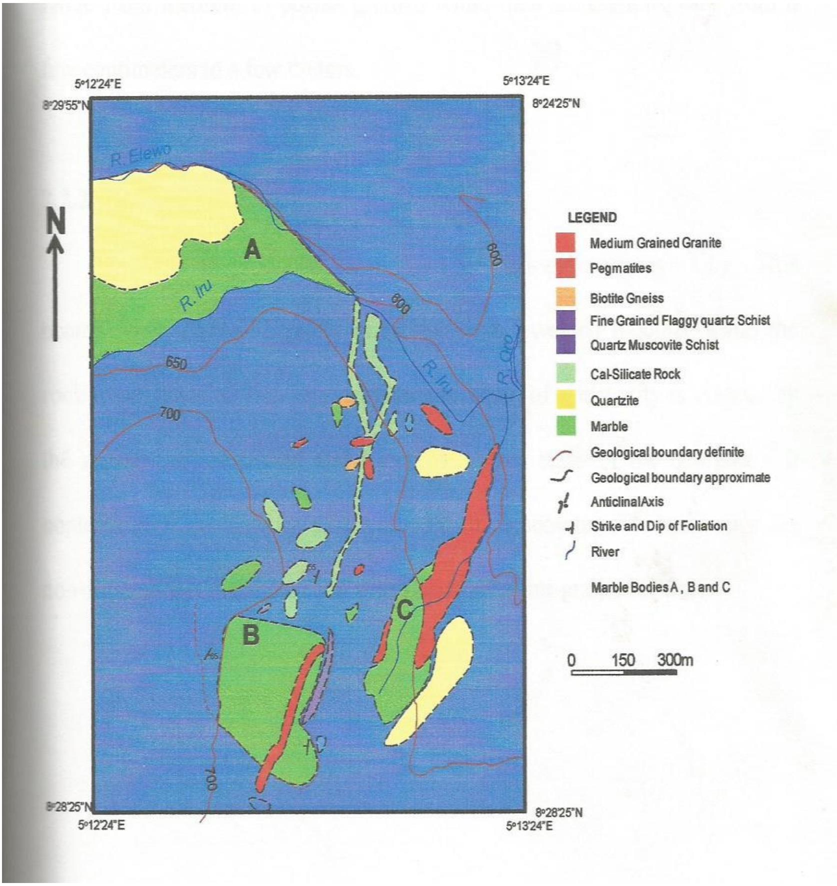


Figure 1: Geological Map of Oreke Marble Deposit (Adedoyin, 2015)

## 3. Methodology

The lateritic soil samples were collected from burrow pits in University of Ilorin campus and Oyun in Ilorin East Local Government Area within Latitude 008° 29′N and Longitude 004° 40′E as well as Latitude 008° 33′N and Longitude 004° 33′E. The marble on the other hand was collected from Oreke, Kwara State and the area is bordered by Latitude 008° 31′N and 005° 10′E. Marble samples collected were taken to the laboratory for crushing and pulverizing after which it was mixed with the lateritic soil in 0, 2, 4 and 6% proportions by weight of lateritic soil.

Compaction and CBR tests were carried, first on the lateritic soil and then on the marble-lateritic soil mixture. Graphs of density versus moisture content were plotted to determine the MDD and OMC for the marble-lateritic soil mixtures at various proportions using Microsoft Excel software. Also the optimum marble content at which CBR values for the production of suitable layers in pavement works were established

# 4. Results and Discussions

## 4.1 Results

The results of compaction and the plot of density against moisture content for 6% marble content for Unilorin lateritic soil and 2% marble content for Oyun lateritic soil are shown in Tables 1 and 2 and Figures 2 and 3, respectively. The results of the unsoaked and soaked CBR tests are presented in Table 3

Table 1 Compaction Test Result (6% marble content) for Unilorin Lateritic Soil

| Sample No | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Moisture can No | D8 | L | T | X | N | 5 | 4 | 6 | 19 | 3A |
| Weight of can + wet soil | 46 | 46 | 39 | 44 | 41 | 42 | 62.5 | 51 | 62 | 68 |
| Weight of can+ dry soil | 44 | 45 | 36 | 41 | 37 | 40 | 57 | 47 | 55.5 | 59 |
| Weight of water | 2 | 1 | 3 | 3 | 4 | 2 | 5.5 | 4 | 6.5 | 9 |
| Weight of can | 14 | 15.5 | 15 | 18 | 16 | 16 | 16 | 11 | 16 | 17 |
| Weight of dry soil | 30 | 29.5 | 21 | 23 | 21 | 24 | 41 | 36 | 39.5 | 42 |
| Water content % | 6.67 | 3.39 | 14.29 | 13.04 | 19.05 | 8.33 | 13.42 | 11.11 | 16.46 | 21.43 |
| Moist. content, % | 5.03 | | 13.67 | | 13.69 | | 12.27 | | 18.95 | |
| Wet density, g/cm³ | 1.59 | | 1.57 | | 1.89 | | 2.10 | | 2.06 | |
| Dry density, g/cm³ | 1.51 | | 1.38 | | 1.66 | | 1.87 | | 1.73 | |

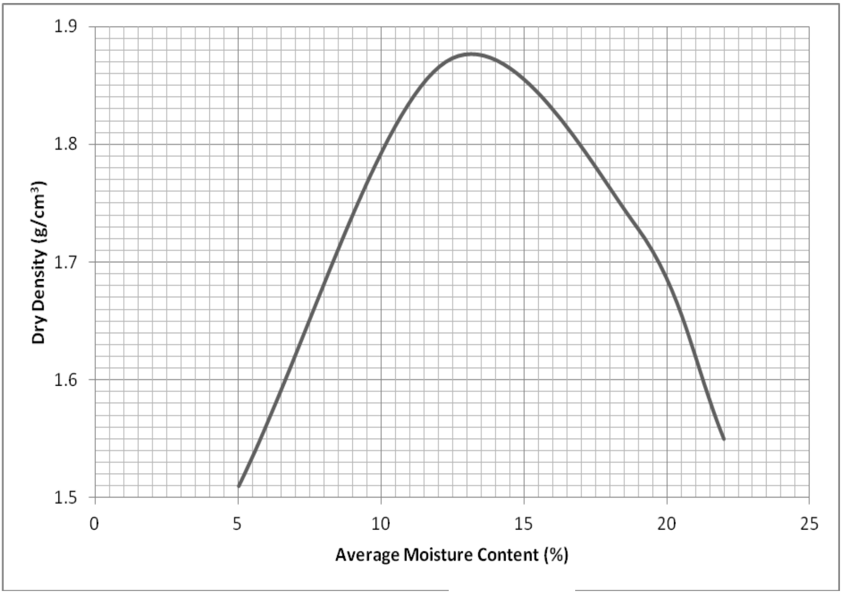


Figure 2: Dry Density Versus Moisture Content (6% marble).
Maximum Dry Density (MDD) = 2.1 (g/cm³)
Optimum Moisture Content (OMC) = 10.5 %

Table 2 Compaction Test Results (2% marble content) for Oyun lateritic Soil

| Sample No. | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Can + wet soil | 76 | 87 | 54 | 55 | 62.5 | 66 | 90 | 90 | 103 | 84 |
| Can +dry soil | 74 | 84 | 51 | 53 | 57 | 61 | 81 | 79 | 88 | 75 |
| Weight of can | 21 | 21 | 17 | 12 | 12.5 | 15.5 | 13.5 | 13 | 16.5 | 14 |
| Weight of dry soil | 53 | 63 | 34 | 41 | 45.5 | 46.5 | 68.5 | 66 | 72.5 | 61 |
| Weight of water | 2 | 3 | 3 | 2 | 5.5 | 5 | 9 | 11 | 15 | 9 |
| Moisture content, % | 4.27 | | 6.85 | | 11.41 | | 14.19 | | 17.27 | |
| Wet density, g/cm³ | 1.72 | | 1.91 | | 2.15 | | 2.15 | | 2.02 | |
| Dry density, g/cm³ | 1.65 | | 1.79 | | 2.08 | | 1.88 | | 1.72 | |

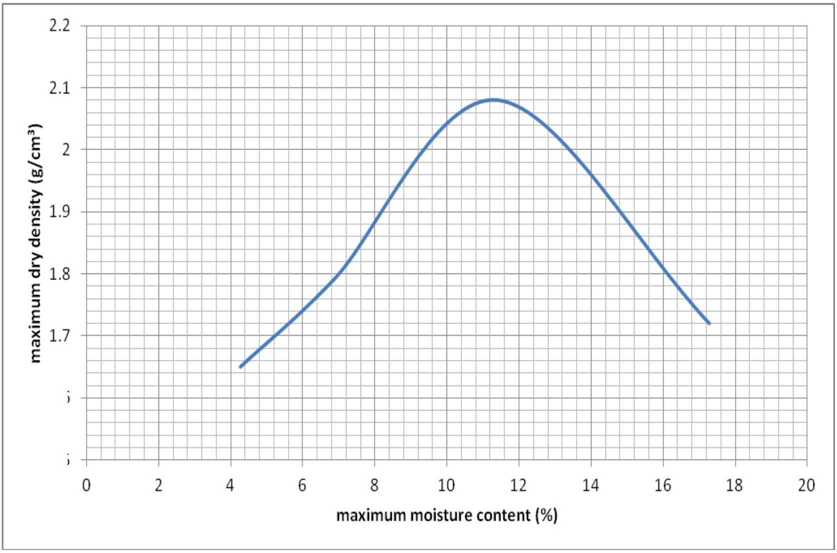


Figure 3: Dry Density Versus Moisture (2% marble)
Maximum Dry Density (MDD) = 2.1 (g/cm³)
Optimum Moisture Content (OMC) = 10.5 %

Table 3: Results of Unsoaked and Soaked CBR

| Marble content (%) | Oyun lateritic soil | | Unilorin lateritic soil | |
|---|---|---|---|---|
| | Unsoaked CBR (%) | Soaked CBR (%) | Unsoaked CBR (%) | Soaked CBR (%) |
| 0 | 9 | 11 | 7 | 3 |
| 2 | 50 | 47 | 7.5 | 7.1 |
| 4 | 15 | 17 | 7 | 0.28 |
| 6 | 13 | 6 | 6.2 | 0.14 |

**4.2 Discussions**

The results revealed that the dry density increased with increase in moisture content in each case until the optimum moisture content (OMC) is attained, after which the dry density begins to fall for both pits. For Oyun Lateritic soil, the Maximum dry density (MDD) for 0% marble content was 2.0g/cm$^3$, which increased to 2.1g/cm$^3$ at 2% marble content, then it began to fall with further increase in marble content. Also for Unilorin lateritic soil, the MDD at 0% marble content was 1.65g/cm$^3$, which increased to 1.83g/cm$^3$ at 2% marble content, and reduced for further increase in marble content.

Results of Table 3 show that, for all marble contents, the unsoaked and soaked CBR values increased with increase in marble content from 0-2%, and decreased for further increase in marble content up to 6%. Also, the CBR for both unsoaked and soaked conditions reached maximum values at 2% marble content for both burrow pits, indicating that the optimum content of marble required for stabilizing lateritic soil is 2% by weight of the lateritic soil sample. The unsoaked and soaked CBR values of 50 and 47%, respectively for the Oyun sample were greater than the minimum value of 30%, and less than minimum value of 80% specified for subbase and base courses of pavements, respectively (Ako and Yusuf, 2016). The values for the University of Ilorin did not meet these criteria.

## 5. Concluding Remarks

From the outcome of the study, the following conclusions and recommendations were drawn:

The strength characteristics of the lateritic soil from both pits were, generally, improved by the addition of marble.

The maximum CBR values obtained for unsoaked and soaked conditions for the sample at Oyun pit were 50 and 47%, respectively at marble content of 2%, while the corresponding values for University of Ilorin pit were 7.5 and 7.1%. This indicates that the optimum content of marble for stabilizing lateritic soil is 2%.

The CBR values of 50 and 47% for unsoaked and soaked conditions, respectively for Oyun pit are greater than the minimum value of 30% and less that the minimum of 80% specified for subbase and base courses of pavements, respectively. However, the values for University of Ilorin pit did not meet up with these specifications.

The lateritic soil at Oyun pit stabilized with 2% marble content is, therefore suitable for the production of subbase course for use in pavement works.

Lateritic soil stabilized with 2% marble content should be used as subbase course material in pavement works.

Marble can be more profitable used as an admixture with a conventional stabilizer, such as cement or lime in order to improve resulting CBR and other strength properties so as to meet requirement for its use as base course material.

Further studies should be carried out to determine marble's cost effectiveness by comparing it with the conventional stabilizing agents.

## References

Adedoyin, A.D. (2015), Geology and Structural Features of Parts of Sheets 203 (Lafiagi) SW and 224 (Osi) NW, Southwestern, Nigeria. Unpublished Ph.D. Thesis, University of Ilorin, Nigeria, 224.

Amu, O.O., Okunade, E.A., Faluyi, S.O., Adam, J.O. and Akinsola, T.A. (2005), The Suitability of Tar Sand as a Stabilizing Agent for Lateritic Soils, Journal of Applied Sciences, 5(10), 1749-1752.

Clayton, R.N. and Speed R.C. (1975), Origin of Marble by Replacement of Gypsum in Carbonate, Journal of Geology, 83, 233-237

Gidigasu, M.D. (1976), Mode of Formation and Geotechnical Characteristics of Lateritic Materials of Ghana in Relation to Soil Forming, Engineering Geology, 6, 79-140

Lambe, T.W. (1951), Soil Testing for Engineering, 2nd edition, John Wiley, New York. 34-38

Madjadoumbaye, J., Ngapgue F., Nouanga, P., Abdou M. C., Tamo, T. T. (2011), Improving the Bearing Capacity of Laterite by Adding Sand, 23-32.

Nixon, I.K. and Skip, B.O. (1957), Air field Construction on Overseas Soils, British Institute of Civil Engineers, London, 253-292

Ushie, F.A. and Anike, O.L. (2011), Lateritic weathering of Granite-Gneiss in Obudu Plateau, Southeastern Nigeria, Global Journal of Geological Science, 9(1):75-83.

Ako, T. and Yusuf, I.T. (2016), Utilization of Palm Kernel Shell Ash as a Stabilizer of Lateritic Soil for Road Construction, Epistemics in Science, Engineering and Technology, 6(1), 423-433, http://www.epistemicsgaia.webs.com/cuurentissue.htm