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# Effect of Volcanic Ash on Cement Stabilized Lateritic Soil: A Laboratory and Field Approach

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**ABSTRACT**

This research work is aimed at strengthening weak soil using volcanic ash with ordinary Portland cement for road stabilization. Standard laboratory tests were carried out on the lateritic soil which includes Specific gravity, Atterberg limits, Particle size distribution, Compaction test and California Bearing Ratio (CBR) were carried out. The soil was classified as A-7-5 soil according to AASHTO soil classification system. A 15 m section of untarred road was identified and demarcated into three sections (A, B and C) of 5.0 m each, materials on section A of the road composed of lateritic soil, 4 % cement and 2 % volcanic ash. Section B contains lateritic soil and 4 % cement while section C composed of lateritic soil only. In-situ density test and CBR test using Dynamic Cone Penetration (DCP) were carried out on the three sections of the road after 1, 7, 14, 28, 60 and 90 days. Results shows that the laboratory and field densities agreed, the laboratory and field California Bearing Ratios (CBR) differed widely.

**Keywords:** *Cement, Laterite, Stabilization, Volcanic ash.*

## 1 INTRODUCTION

Road construction in the developing nations has been a major challenge to Government and different specialists in the construction industry. The challenge facing Government is the limited resources available for the construction of roads and the high cost of road building normally put forward by the construction companies. On road construction site, the contractor is faced with the problem of non-availability of suitable road construction materials within the vicinity of most road projects.

Laterite as defined by Osula (1993) is a highly weathered tropical soil, rich in secondary oxide of any combination of iron, aluminum and manganese. Laterite soils according to Bello (2010) are formed in hot, wet tropical regions with an annual rainfall between 750 mm to 3000 mm (usually in area with a significant dry season) on a variety of different types of rocks with high iron content.

Nigeria according to Umar & Elinwa (2005) is among the countries blessed with vast deposits of laterite, which is residual in nature, and one of the cheapest material for road construction. However, not all deposits of laterite are suitable for use as base and sub-base material in their natural state. Treatment with additives is normally required before such laterite can attain the desired properties.

Soil stabilization is any treatment applied to a problem soil to improve its strength and reduce its vulnerability to water. It is a substantial improvement of the mechanical behavior and mechanical strength using low content of stabilizer. It is the process of mixing additives with soil to improve its volume stability, strength, permeability and durability (Amu and Komolafe, 2012).some of the additives used includes cement, lime and volcanic ash.

Volcanic ash is a finely fragmented magma or pulverised volcanic rock, measuring less than two millimeter in diameter, that is emptied from the vent of a volcano in either a molten or solid state. The most common state of ash is vitric (glass like), which contains glassy particles formed by gas bubble busting through liquid magma (Encarta, 2008). Volcanic ash comprises small jagged piece of rock minerals and volcanic glass that was erupted by a volcano (Shoji *et at*., 1993). Volcanic ash is opined not to be a product of combustion like soft fluffy paper. It is hard, does not dissolve in water and is extremely abrasive, mildly corrosive and conducts electricity when wet.

## 2 METHODOLOGY

### 2.1 LABORATORY TEST

The laboratory Laterite used for this research was obtained from a borrow pit at Lapai Gwari, along Talba farm road, Minna, Niger State by disturbed

Figure 1: Pile of laterite Soil

sampling method in accordance to BS 1377:1 (2016) standard procedure for sample collection as shown in Figure 1. The ordinary Portland cement was obtained from a Mini depot in Minna, Niger State. Volcanic ash was obtained from Jos, Plateau State.

The laboratory aspect of this study was carried out in Civil Engineering laboratory of Federal University of Technology, Minna, Niger State, Nigeria. The preliminary test that was carried out on samples of lateritic soils collected includes Specific Gravity, Atterberg limit test, Particle size analysis, Compaction test, and California Bearing Ratio (CBR).

## 2.2 FIELD TEST

The field test was carried out on an access road between Central Workshop and Civil Engineering laboratory at Federal University of Technology Minna, leading to Agricultural Engineering workshop. This study was carried out on a section of the road whose width was 8.0m and 15.0m length. The 15.0m length was divided into three sections of 5.0m each. The first section was filled with a mixture of lateritic soil, 4% cement and 2% of volcanic ash. The second section was filled with a mixture of lateritic soil and 4% of cement, while the third section was filled with the lateritic soil only. The surface was pegged with lines and the sections was demarcated using wooden planks to avoid soil from one section mixing with that in the other during placement and compaction. After forming and preparation of the sections, the mixtures for each of the sections were constituted and placed to 30cm lift manually. A vibratory roller was used to roll and compact the

Figure 2: Demarcation of laterite Soil

Figure 3: In-situ density test

material for 15 drives after which another 30cm lift of the material was placed on top of the initial layer and rolled in the same manner (Figure 2 and 3). Field performance evaluation is carried out using In-situ density test and California Bearing Ratio (CBR). The CBR is determined using Dynamic Cone Penetration (DCP) test. In-situ density test was carried out using a sand replacement method on the compacted surfaces to determine the maximum in-situ density at day1, 7, 14, 28, 60 and 90 days of compaction. Dynamic Cone Penetration (DCP) tests were also conducted at three positions after 1, 7, 14, 28, 60 and 90 days of compaction.

# 3 RESULTS AND DISCUSSION

## 3.1 INDEX PROPERTIES OF LATERITE SOIL

Results of index properties of the laterite soil are presented in Table 1. The laterite soil is classified as A-
7-5 soil according to American Association of State Highway and Transportation Officials (AASHTO) standard, and Clay of High Plasticity (CH) according to Unified Soil Classification System (USCS).

TABLE 1: SUMMARY OF PHYSICAL PROPERTIES OF LATERITIC SOIL

| Description | Lateritic Soil |
|---|---|
| Natural moisture content (%) | 16.69 |
| Description | Pinkish brown clay soil |
| Specific Gravity | 2.63 |
| Percentage Passing BS sieve No 200 (%) | 74.77 |
| Liquid Limit (%) | 49.49 |
| Plastic Limit (%) | 31.22 |
| Plasticity Index (%) | 18.27 |
| AASHTO Classification | A-7-5 |
| USCS Classification | CH |
| Maximum Dry Density (MDD) (BSH) (g/cm$^3$) | 1.822 |
| Optimum Moisture Content (OMC) (%) | 17.94 |
| California Bearing Ratio (CBR) (%) | 34.77 |

This soil, according to Nigeria General Specification for Roads and Bridge Works (1997), cannot be used as sub-base and base courses for road pavement structures and will require stabilization to improve its strength and durability. The mixture of terrazzo waste sludge, cement and laterite soil can positively improve its strength, thereby, increasing its engineering properties.

## 3.2 LABORATORY AND FIELD TEST

### 3.2.1 LABORATORY TEST

Specific Gravity test for terrazzo waste sludge is 2.65. Summary of the compaction values is shown in Table 2. Compaction test conducted at the laboratory shows that the MDD for laterite, 4 % cement and 2 % terrazzo waste sludge is 1.800 g/cm3, while laterite and 4 % cement is 1.815 g/cm3 and 0 % additive is 1.822 g/cm3. The OMC are 17.61 %, 19.47 % and 17.94 %, respectively.

Laboratory CBR was conducted based on the method highlighted in BS 1377 (1992). The test was conducted on the A-7-5 lateritic soil.

Summary of the CBR values is shown on Table 3. Based on CBR criteria highlighted in Nigerian General Specification for Roads and Bridge Works (1997), the mixture of soil and 4 % cement can only be used as sub-base material, while the mixture of soil, 4 % cement, and 2 % terrazzo waste sludge can be used as sub-base and base course material. CBR test shows that the mixture of laterite, 4 % cement and 2 % terrazzo waste sludge is 151.44%, while the combination of laterite with 4 % cement is 140.61 %, and 0 % laterite is 34.77 %.

TABLE 2: SUMMARY OF COMPACTION TEST

| Composition | Maximum Dry Density (MDD) (g/cm$^3$) | Optimum Moisture Content (OMC) (%) |
|---|---|---|
| 4 % cement + 2 % terrazzo waste sludge | 1.800 | 17.61 |
| 4 % cement | 1.815 | 19.47 |
| 0 % Additive | 1.822 | 17.94 |

TABLE 3: SUMMARY RESULT OF CALIFORNIA BEARING RATIO (CBR) TEST

| Composition | CBR (%) 2.5 mm | CBR (%) 5.0 mm | Average CBR (%) At 2.5 & 5.0 mm |
|---|---|---|---|
| 4% cement + terrazzo waste sludge | 151.44 | - | 151.44 |
| 4% cement | 140.61 | - | 140.61 |
| 0% Additive | 36.92 | 32.62 | 34.77 |

### 3.2.2 FIELD DENSITIES

The field densities were determined using a sand replacement method as highlighted in BS 1377 (1992). This test was conducted continuously on the three compacted surfaces of the road during compaction. This was repeated after 1, 7, 14, 28, 60 and 90 days, it was observed that the dry densities for section A, B and C do not vary significantly throughout the 90 days of the study and the results are presented on (Table 4).

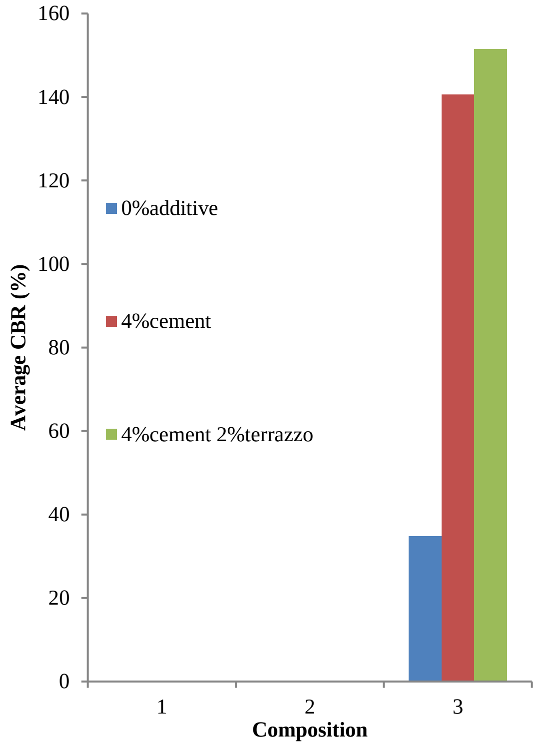


Figure 4: Bar Chart of CBR at 0 % Additive, 4 % Cement and 4 % Cement with 2 % Terrazzo Waste Sludge

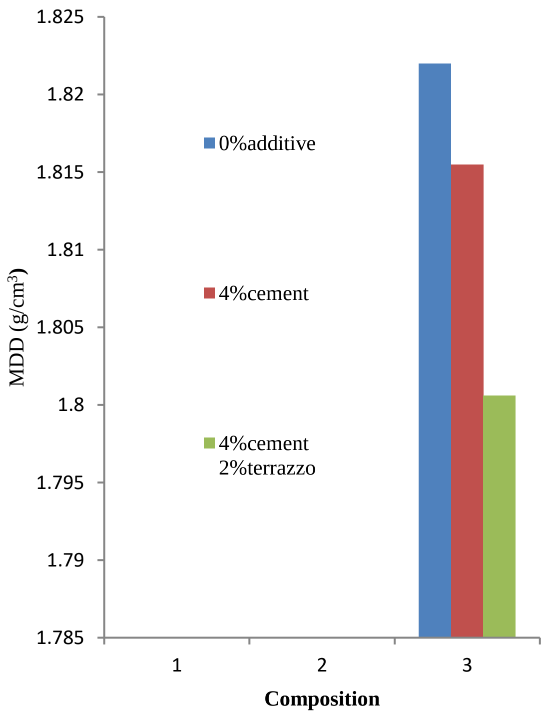


Figure 5: Bar Chart of MDD at 0 % Additive, 4 % Cement and 4 % Cement with 2 % Terrazzo Waste Sludge

TABLE 4: SUMMARY TABLE FOR IN-SITU DENSITIES

| Sections of Road | 1 Day | 7 Days | 14 Days | 28 Days | 60 Days | 90 Days |
|---|---|---|---|---|---|---|
| Section A (mixture of lateritic soil, 4%cement and 2% of terrazzo waste sludge) ($g/cm^3$) | 1.307 | 1.824 | 1.667 | 1.739 | 1.648 | 1.579 |
| Section B (mixture of lateritic soil and 4% cement) ($g/cm^3$) | 1.545 | 1.739 | 1.704 | 1.649 | 1.650 | 1.550 |
| Section C (lateritic soil) ($g/cm^3$) | 1.516 | 1.748 | 1.717 | 1.766 | 1.590 | 1.427 |

TABLE 5: SUMMARY TABLE FOR IN-SITU OPTIMUM MOISTURE CONTENT (OMC)

| Sections of Road | 1 Day | 7 Days | 14 Days | 28 Days | 60 Days | 90 Days |
|---|---|---|---|---|---|---|
| Section A (Mixture of Lateritic Soil, 4 %Cement and 2 % of Terrazzo Waste Sludge) (%) | 12.91 | 4.61 | 4.40 | 7.97 | 12.50 | 15.00 |
| Section B (mixture of lateritic soil and 4 % cement) (%) | 7.55 | 4.57 | 4.72 | 9.72 | 11.50 | 12.88 |
| Section C (lateritic soil) (%) | 4.96 | 3.60 | 2.82 | 8.66 | 11.89 | 14.45 |

### 3.2.3 FIELD CBR

The field CBR was evaluated using the DCP test on the compacted surfaces with the aid of an empirical relationship developed by TRL (2014) in equation 1.

$$Log(CBR) = 2.48 - 1.057Log(PI) \qquad Equation\ (1)$$

$Where\ PI, is\ the\ penetration\ index.$

TABLE 6: SUMMARY OF THE FIELD CBR VALUES USING DCP TEST

| Number of Days | Road Section (Average Number of Blows) (%) | | |
|---|---|---|---|
| | Section A | Section B | Section C |
| 1 | 29.20 | 35.13 | 36.10 |
| 7 | 31.10 | 34.17 | 36.10 |
| 14 | 23.93 | 31.60 | 32.67 |
| 28 | 37.80 | 42.80 | 41.33 |
| 60 | 35.25 | 38.03 | 31.33 |
| 90 | 33.50 | 36.57 | 22.25 |

Average number of blows were used to obtain penetration index which was used in equation 1 to evaluate the CBR values. Table 6 shows the variation of the CBR values with days for the three (A, B and C) sections of the road.

## 4 CONCLUSION

From the study, the following conclusions were drawn:

1. The lateritic soil was classified under A-7-5 soil, according to AASHTO, and CH according to USCS which was classified as poor soil, hence there is need for improvement before used as pavement.
2. Addition of laterite, 4 % cement and 2 % terrazzo waste sludge increases the laboratory MDD and CBR value of the soil, while the field in-situ density varies from 1 day to 90 days, which is as a result of cement water hydration.
3. Field results of compacted laterites in section A and section B agreed with the laboratory results after roller compaction.

4. The CBR used in section A and B was observed to be lower than the laboratory results. This confirms that the dynamic cone penetration test does not overestimates the strength of clay soils.

5. It is suggested as a future work for a similar study to be carried out using other stabilizing agent with Portland cement for prolong development in strength.

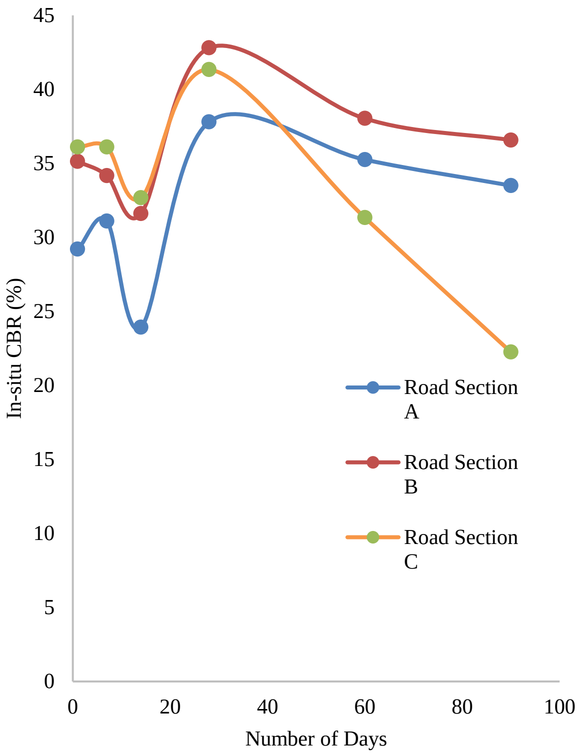


Figure 6: Variation of In-situ CBR Values with Number of Days

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