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***Research Paper***

# Effect of Lime Variation on the Moisture Content and Dry Density of Lateritic Soil in Ilorin, Nigeria.

Emmanuel Sunday Ajayi
Nigerian Stored Products Research Institute, P. M. B. 1489, Ilorin, Nigeria.

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**Abstract**: In tropical countries like Nigeria where seasonal variation in climate is usually experienced, the earth routes which usually compose of lateritic soil are not usually stable. There is an increase of moisture content during the rainy season, which tends to weaken the strength of the soil while in the dry season; the dust in such roads is a great menace to the comfort and well-being of road users and adjacent inhabitant. This study looks at the effect of lime variation on moisture content and dry density of lateritic soil in Ilorin, Nigeria. The lime concentrations used were 0%, 2.5%, 5%, and 7.5% respectively and a total of five specimens were used for each concentration to obtain moisture – density relation. British Standard (BS) 1377 method or procedure was used in carrying out the test. The results of analysis of variance (ANOVA) showed that there is significant variation (at 5 % level of significance) in moisture contents and dry densities with lime concentration. The maximum dry density ranges from 1.63 kg/dm$^3$ to 1.89 kg/dm$^3$ and the moisture content ranges from 2.2 % to 17.2 % for the samples under consideration. The dry density of the sample decreases with increase in lime concentration with the rate of reduction being more between 0 % and 2.5 % lime content while the moisture content increases with increase in lime content. The increase in the moisture content due to the addition of lime results into lower amount of compaction or less compactive effort and this could be achieved by addition of small amounts of lime to laterite.

**Keywords**: Lime, Moisture Content, Dry Density, Lateritic Soil, Soil Stabilization

## Introduction

Lime in the form of quicklime (calcium oxide-CaO), hydrated lime (Calcium hydroxide-$Ca(OH)_2$), or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonates (limestone-$CaCO_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. It is hydrated lime that reacts with clay particles and permanently transforms them into a strong cementitious matrix. Most lime used for soil treatment is ''high calcium'' lime, which contains no more than 5 percent magnesium oxide or hydroxide. On some occasions, however, ''dolomite'' lime is used. Dolomite lime contains 35 to 46 percent magnesium oxide or hydroxide. Dolomite lime can perform well in soil stabilization, although the magnesium fraction reacts more slowly than the calcium fraction according to National Lime Association (2004). It can permanently stabilize fine-grained soil employed as a sub-grade or sub-base to create a layer with structural value in the pavement system. The treated soils may be in-place (sub-grade) or borrow materials. It can also permanently stabilize sub-marginal base materials (such as clay-gravel, retained on a No. 4 screen). Base stabilization is used for new road construction and reconstruction of worn-out roads (Little, 1995).

When lime and water are added to a clay soil, chemical reactions begin to occur almost immediately. If quicklime is used, it immediately hydrates (i.e. chemically combines with water) and releases heat. Soils are dried, because water present in the soil participates in this reaction, and because the heat generated can evaporate additional moisture. The hydrated lime produced by these initial reactions will subsequently react with clay particles. These subsequent reactions will slowly produce additional drying because they reduce the soils moisture holding capacity. If hydrated lime or hydrated lime slurry is used instead of quicklime, drying occurs only through the chemical changes in the soil that reduce its capacity to hold water and increase its stability.

After initial mixing of lime and water with lateritic soil, the calcium ions ($Ca^{++}$) from hydrated lime migrate to the surface of the clay particles and displace water and other ions. The soil becomes friable and granular, making it easier to work and compact. At this stage the plasticity index of the soil decreases dramatically, as does its tendency to swell and shrink. The process, which is called ''flocculation and agglomeration,'' generally occurs in a matter of hours. When adequate quantities of lime and water are added, the PH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Silica and alumina are released and react with calcium from the lime to form calcium-silicate hydrates (CSH) and calcium-aluminate-hydrates (CAH). CSH and CAH are cementitious products similar to those formed in Portland cement. They form the matrix that contributes to the strength of lime-stabilized soil layers, as this matrix forms; the soil is transformed from a sandy, granular material to a hard, relatively impermeable layer with significant load bearing capacity (Little, 1999). The process begins within hours and can continue for years in a properly designed system. The matrix formed is permanent, durable, and significantly impermeable, producing a structural layer that is both strong and flexible. For soils with low amounts of clay, lime-pozzolan mixtures are used. Properly proportioned mixtures of lime and pozzolans can modify or stabilize nearly any soil, but are typically used for soils with low to medium plasticity. The additional silica and alumina from the pozzolan react with the lime to form the strong cementitious matrix that characterizes a lime-stabilized layer. Such ''pozzolans'' include fly ash and ground blast furnace slag (Petry, 2005).

The hardening of soil-lime is accelerated at higher temperatures and the process is thus more suitable for use in warm climates. The principal advantage of lime is the raising of the plastic limit of clayey soil, the soils becoming apparently drier, ensuring better pulverization and more uniform admixture of the stabilizing material.

## Materials and Methods

Lateritic soil sample was collected from borrow pit beside the department of Agricultural Engineering (now Agricultural & Biosystem Engineering) of University of Ilorin and was immediately stored in polythene bag prior to the experiment to prevent loss in moisture.

### Preparation of the Sample.

When the sample was taken to the laboratory, the deleterious materials such as roots and other foreign materials were removed. The sample was air-dried, lumps broken down, and graded through sieves analysis. Identification and classification test through the sieve analysis was carried out on the sample to determine the particle size distribution.

To compare relative effects of additives on the performance of sample, varying proportions of additives used are expressed as percentage of the dry weight of the sample. The lime concentrations used were 0%, 2.5%, 5%, and 7.5% respectively. Mixing of sample with additive was done manually at the optimum moisture content of natural samples as obtained from compaction tests.

Moulding of test specimens were as soon as possible after completion of mixing and the test were conducted according to the BS Standards. For each concentration, a total of five specimens were used to obtain the optimum moisture density relation.

**Experimental Procedures**

Identification and classification tests were carried out on the natural sample used to determine the particle size distribution and compaction tests. Lime is then added in proportions 0%, 2.5%, 5%, and 7.5% to the sample to determine its effect on moisture-density relations in compaction tests. The procedure used in carrying out the test was according to BS 1377 Standard methods which is as follows:

**Laboratory Compaction Test (BS 1377)**

In this method the soil sample was air-dried and passes through a 20mm sieve, the amount of gravel retained was noted. Next 3 kg of the soil passing the sieve was thoroughly mixed with water to give fairly low moisture content; the soil was put in airtight container for 2-3 hours so that the water could migrate through it. The soil was then compacted in a 101.6mm diameter mould by means of 2.5 kg hammer with 50.8mm diameter head falling freely from 305mm above the top of the soil.

Compaction was effected in 3 layers, each being given 25 blows. The compaction was considered satisfactory when the soil in the mould was not more than about 6mm above the top of the soil. The top of the soil was then trimmed level with the mould. The base was removed and the soil and mould were weighed. Moisture content samples were taken from the top, middle and base of the soil. The test was repeated using a fresh batch of soil mixed to optimum moisture content of the natural samples

The procedure was repeated until the weight of the soil in the mould passes the maximum value and begins to decrease. Once the moisture contents have been determined, the graph of moisture content and dry density variation with lime concentration could be plotted.

**Result and Discussion**

**Identification and Classification Test**

The result of the average particle size distribution of the sample is presented in Table 1. The soil sample is classified as inorganic silt of medium compressibility according to Casangrande and as A-2-6 of good rating as sub-grade material according to AASHTO classification.

**Table 1.** Average Particle Size Distribution of Sample

| Sample size | Percentage |
|---|---|
| Gravel | 16.4 |
| Sand | 58.4 |
| Clay | 25.2 |

**Compaction Results**

The result of compaction tests carried out on both the treated and untreated samples are shown in the Tables 2, 3, 4, 5 and summarized in Table 6.

**Table 2.** Compaction Test Using 0% Lime Concentration

| Test No. | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wt of cylinder + wet soil(g) | 6288 | | 6344 | | 6559 | | 6778 | | 6716 | |
| Wt of cylinder(g) | 4610 | | 4610 | | 4610 | | 4610 | | 4610 | |
| Wt of wet soil(g) | 1678 | | 1734 | | 1949 | | 2168 | | 2106 | |
| Wet density kg/dm$^3$ | 1.653 | | 1.708 | | 1.920 | | 2.135 | | 2.074 | |
| Moisture Content Determination | | | | | | | | | | |
| Container No. | 1A1 | 1A2 | 2A1 | 2A2 | 3A1 | 3A2 | 4A1 | 4A2 | 5A1 | 5A2 |
| Wt of soil +tin(g) | 99 | 117 | 89 | 75 | 49 | 53 | 51 | 54 | 74 | 50 |
| Wt of dried soil + tin (g) | 97 | 113 | 85 | 74 | 45 | 51 | 47 | 48 | 66 | 46 |
| Wt of tin(g) | 27 | 26 | 28 | 28 | 15 | 18 | 2 | 12 | 14 | 14 |
| Wt of dry soil(g) | 70 | 87 | 57 | 46 | 30 | 33 | 45 | 36 | 52 | 32 |
| Wt of moisture (g) | 2 | 4 | 4 | 1 | 4 | 2 | 4 | 6 | 8 | 4 |
| Moisture content(%) | 2.85 | 4.59 | 7.02 | 2.04 | 3.33 | 6.06 | 8.89 | 16.67 | 15.38 | 12.50 |
| Ave. M.C(%) | 3.72 | | 4.59 | | 9.69 | | 12.78 | | 13.94 | |
| Dry density kg/dm$^3$ | 1.59 | | 1.63 | | 1.75 | | 1.89 | | 1.82 | |

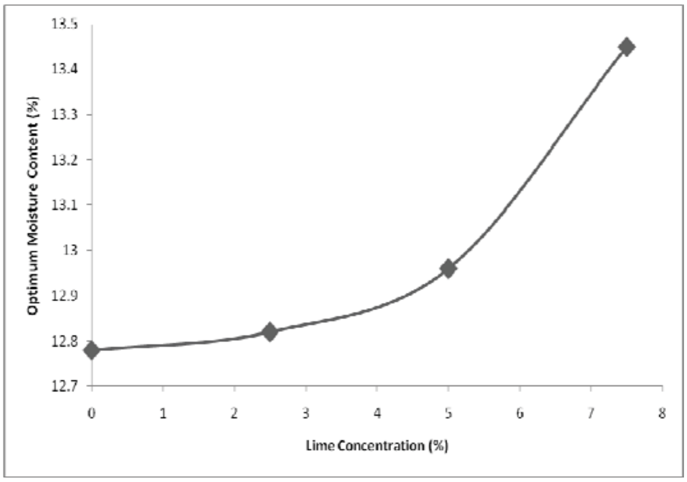


**Figure 1.** Variation of Moisture Content with Lime Concentration.

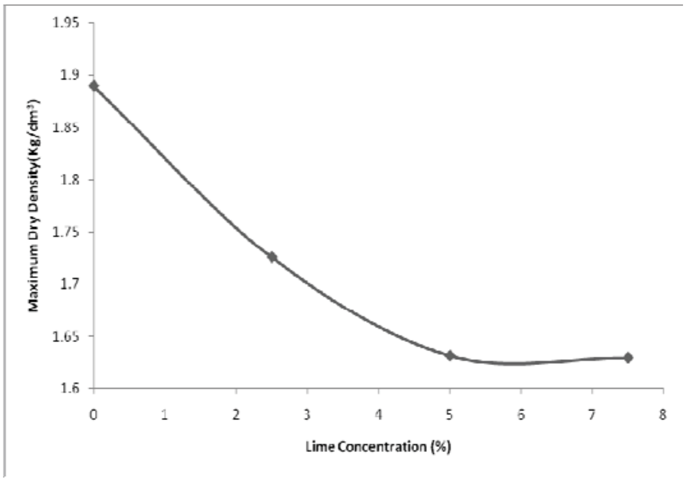


**Figure 2.** Variation of Dry Density with Lime Concentration.

**Table 3.** Compaction test Using 2.5% Lime Concentration

| Test No. | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wt of cylinder + wet soil(g) | 4586 | | 4622 | | 4761 | | 4963 | | 4938 | |
| Wt of cylinder(g) | 3031 | | 3031 | | 3031 | | 3031 | | 3031 | |
| Wt of wet soil(g) | 1555 | | 1591 | | 1730 | | 1932 | | 1907 | |
| Wet density kg/dm$^3$ | 1.555 | | 1.591 | | 1.730 | | 1.932 | | 1.907 | |
| Moisture Content Determination | | | | | | | | | | |
| Container No. | 1B1 | 1B2 | 2B1 | 2B2 | 3B1 | 3B2 | 4B1 | 4B2 | 5B1 | 5B2 |
| Wt of soil +tin(g) | 95 | 92 | 49 | 53 | 62 | 50 | 68 | 49 | 72 | 44 |
| Wt of dried soil + tin (g) | 93 | 90 | 47 | 52 | 57 | 47 | 62 | 46 | 64 | 40 |
| Wt of tin(g) | 28 | 30 | 18 | 15 | 19 | 18 | 18 | 21 | 19 | 15 |
| Wt of dry soil(g) | 65 | 60 | 29 | 38 | 38 | 29 | 44 | 25 | 45 | 25 |
| Wt of moisture (g) | 2 | 2 | 2 | 1 | 5 | 3 | 6 | 3 | 8 | 4 |
| Moisture content(%) | 3.00 | 3.33 | 6.89 | 2.63 | 13.20 | 10.30 | 13.64 | 12.00 | 17.80 | 16.00 |
| Ave. M.C(%) | 3.165 | | 4.761 | | 11.750 | | 12.820 | | 16.900 | |
| Dry density kg/dm$^3$ | 1.507 | | 1.519 | | 1.548 | | 1.726 | | 1.631 | |

**Table 4.** Compaction Test Using 5% Lime Concentration

| Test No. | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wt of cylinder + wet soil(g) | 4803 | | 4820 | | 4903 | | 5082 | | 5042 | |
| Wt of cylinder(g) | 3280 | | 3280 | | 3280 | | 3280 | | 3280 | |
| Wt of wet soil(g) | 1523 | | 1540 | | 1623 | | 1802 | | 1762 | |
| Wet density kg/dm$^3$ | 1.523 | | 1.540 | | 1.623 | | 1.802 | | 1.762 | |
| Moisture Content Determination | | | | | | | | | | |
| Container No. | 1C1 | 1C2 | 2C1 | 2C2 | 3C1 | 3C2 | 4C1 | 4C2 | 5C1 | 5C2 |
| Wt of soil +tin(g) | 112 | 117 | 100 | 92 | 70 | 62 | 73 | 83 | 54 | 42 |
| Wt of dried soil + tin (g) | 110 | 115 | 98 | 91 | 66 | 60 | 68 | 77 | 50 | 39 |
| Wt of tin(g) | 26 | 18 | 20 | 50 | 15 | 25 | 23 | 36 | 18 | 21 |
| Wt of dry soil(g) | 84 | 97 | 78 | 41 | 51 | 35 | 45 | 41 | 32 | 18 |
| Wt of moisture (g) | 2 | 2 | 2 | 1 | 4 | 2 | 5 | 6 | 4 | 3 |
| Moisture content(%) | 2.37 | 2.06 | 2.55 | 2.45 | 7.86 | 5.71 | 11.11 | 14.81 | 12.51 | 16.32 |
| Ave. M.C(%) | 2.215 | | 2.520 | | 6.786 | | 12.960 | | 14.416 | |
| Dry density kg/dm$^3$ | 1.490 | | 1.502 | | 1.520 | | 1.632 | | 1.540 | |

**Table 5.** Compaction test Using 7.5% Lime Concentration

| Test No. | 1 | | 2 | | 3 | | 4 | | 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Wt of cylinder + wet soil(g) | 3366 | | 3396 | | 3506 | | 3815 | | 3798 | |
| Wt of cylinder(g) | 1853 | | 1853 | | 1853 | | 1853 | | 1853 | |
| Wt of wet soil(g) | 1513 | | 1543 | | 1653 | | 1962 | | 1945 | |
| Wet density kg/dm$^3$ | 1.513 | | 1.543 | | 1.653 | | 1.932 | | 1.907 | |
| Moisture Content Determination | | | | | | | | | | |
| Container No. | 1D1 | 1D2 | 2D1 | 2D2 | 3D1 | 3D2 | 4D1 | 4D2 | 5D1 | 5D2 |
| Wt of soil +tin(g) | 62 | 53 | 62 | 72 | 57 | 60 | 53 | 68 | 71 | 74 |
| Wt of dried soil + tin (g) | 61 | 52 | 60 | 69 | 53 | 56 | 48 | 62 | 61 | 64 |
| Wt of tin(g) | 26 | 18 | 14 | 13 | 15 | 14 | 13 | 14 | 13 | 13 |
| Wt of dry soil(g) | 35 | 34 | 46 | 56 | 38 | 42 | 35 | 48 | 48 | 51 |
| Wt of moisture (g) | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 9 | 8 |
| Moisture content(%) | 2.86 | 2.94 | 4.35 | 5.36 | 10.53 | 9.52 | 14.28 | 12.67 | 18.75 | 15.69 |
| Ave. M.C(%) | 2.900 | | 4.855 | | 10.025 | | 13.450 | | 17.248 | |
| Dry density kg/dm$^3$ | 1.470 | | 1.472 | | 1.502 | | 1.630 | | 1.489 | |

The results of the compaction tests carried out on the sample show that the addition of lime to the natural sample resulted in the improvement in the characteristics of the natural sample. The samples have their maximum dry densities ranging from 1.630 kg/dm$^3$ to 1.890 kg/dm$^3$ and their optimum moisture content ranging from 2.215% to 17.248%. The addition of lime to the sample generally increases the optimum moisture content and reduces the maximum dry density as lime content increases with the rate of reduction more pronounced between 0% and 2.5% lime content as shown in the figures 1 below. However, the results of the compaction test show that the maximum dry density of the laterite decreases with increase in lime concentration while the optimum moisture content increases with increases in lime concentration.

**Table 6.** Summary of Compaction Results

| Sample | | 1 | 2 | 3 | 4 | 5 | OMC | MDD |
|---|---|---|---|---|---|---|---|---|
| 0% Lime Concentration | Moisture Content | 3.720 | 4.590 | 9.690 | 12.780 | 13.940 | 12.780 | 1.890 |
| | Dry Density | 1.590 | 1.630 | 1.750 | 1.890 | 1.820 | | |
| 2.5% Lime Concentration | Moisture Content | 3.165 | 4.761 | 11.750 | 12.820 | 16.900 | 12.820 | 1.726 |
| | Dry Density | 1.507 | 1.586 | 1.548 | 1.726 | 1.631 | | |
| 5% Lime concentration | Moisture Content | 2.215 | 2.520 | 6.786 | 12.960 | 14.416 | 12.960 | 1.632 |
| | Dry Density | 1.490 | 1.520 | 1.520 | 1.632 | 1.540 | | |
| 7.5% Lime concentration | Moisture Content | 2.900 | 4.855 | 10.025 | 13.450 | 17.248 | 13.450 | 1.630 |
| | Dry Density | 1.470 | 1.472 | 1.502 | 1.630 | 1.489 | | |

OMC – *Optimum Moisture Content* MDD – *Maximum Dry Density*.

The Figure 2 shows that the dry density reduces as the lime concentration increases with the rate of reduction more pronounced between 0% and 2.5%. The results of the compaction tests carried out on the sample show that the addition of lime the natural sample resulted in improvement in the characteristics of the natural sample. This is in accordance with the works of other investigation like Faluyi and Oluborode (2006).

**Analysis of Variance.**

The results of the compaction test were analyzed to determine the cause of variation of dry densities and moisture contents with lime concentrations. The result of the analysis is shown below:

**Table 7.** Analysis of Variance (ANOVA) showing the Variation of Dry Densities with Lime Concentrations.

| Source of Variation | Sum of Squares | Degree of Freedom | Mean Square | Variance Ratio, F |
|---|---|---|---|---|
| Between Samples | 0.150360 | 3 | 0.050120 | 6.542 |
| Within Samples | 0.122577 | 16 | 0.007661 | |
| Total | 0.272937 | 19 | | |

**Table 8.** Analysis of Variance (ANOVA) showing the variation of moisture contents with lime concentration.

| Source of Variation | Sum of Squares | Degrees of Freedom | Mean Square | Variance Ratio, F |
|---|---|---|---|---|
| Between Samples | 12.3520 | 3 | 4.1173 | 7.378 |
| Within Samples | 486.0319 | 16 | 30.3770 | |
| Total | 498.3839 | 19 | | |

Null Hypothesis: There is no significant variation in the dry densities and moisture contents with lime concentrations.

According to the analysis of variance (ANOVA) shown in Tables 7 and 8, Table value (Table 7) of **F** for $\mathbf{v}_1 = 3$ and $\mathbf{v}_2 = 16$ at 5% level of significance equals 3.24. Since the calculated value of F (6.542) is greater than the Table value, null hypothesis is rejected which implies that there is significant variations in the dry densities with lime concentrations. Also, Table value (Table 8) of **F** for $\mathbf{v}_1 = 3$ and $\mathbf{v}_2 = 16$ at 5% level of significance equals 3.24. Since the calculated value of F (7.378) is greater than the Table value, null hypothesis is rejected which implies that there is significant variations in the moisture contents with lime concentrations.

**Conclusion and Recommendation**

**Conclusion**

The results of this investigation have shown that beneficial effects are obtained by the addition of small amounts of lime to laterite. The dry density of the laterite decreases with increase in lime content with the rate of reduction being more between 0% and 2.5% lime concentration while the optimum moisture content increases with increase in lime concentration. The increase in the optimum moisture content due to the addition of lime result into lower amount of compaction or less compactive effort.

**Recommendations**

The followings are hereby recommended:

- **i.** Lime stabilization mixture design and testing procedure for different soil conditions and environmental exposures in Nigeria should be developed.
- **ii.** The use of lime for soil stabilization should be encouraged in Nigeria since its use favours the warm climate.
- **iii.** Lime manufacturing company should be established by government to reduce the cost of lime since there is large deposit of limestone in Nigeria.

**Acknowledgement**

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**References**

Faluyi, S.O; Adebayo, S.O; Oluborode, K.D. 2006. Moisture-Density Relation of Lime- treated Samples of Lateritic Soils in Ado-Ekiti, Nigeria. Journal of Applied Science. Engineering and Technology. Volume 6. Numbers 2: 56-61.

Little, Dallas N. 1995. Stabilization of Pavement Subgrades and Base Courses with Lime. Kendall/Hunt Publishing Company, Dubuque, Iowa

Little, Dallas N. 1999. Evaluation of Structural Properties of Lime Stabilized Soils. and Aggregates Volume 1: Summary of Findings Prepared for the National Lime Association, pp 1-97.

National Lime Association. 2004. Lime Treated Soil Construction Manual: Lime `Stabilization & Lime Modification.

Petry, Tom. 2005. The Effect of Organic Content on Lime Treatment of Highly Expansive Clay. Proceedings of the 2nd International Symposium of Treatment and Recycling of Materials for Transport Infrastructures. Paris. France. 24-26 October.