

Int. J. Forest, Soil and Erosion, 2012 2 (4): 165-168

ISSN 2251-6387 [PRINT] 2251-824X [Online]

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Research Paper

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

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Received: 2012-01-29

Accepted: 2012-03-22

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/dm³ to 1.89 kg/dm³ 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-CaCO₃) 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 Casagrande 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	

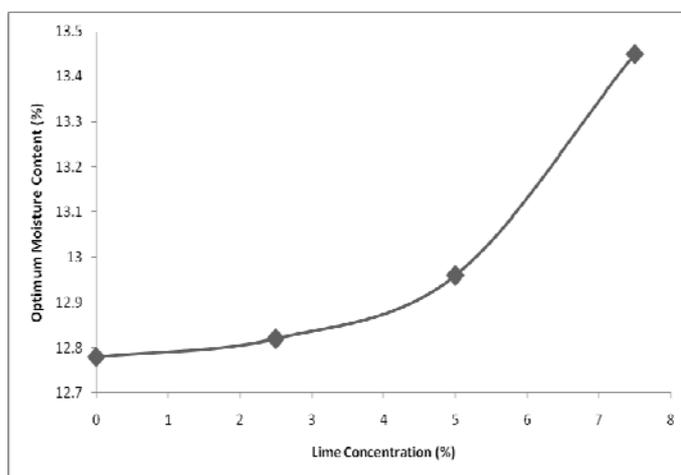


Figure 1. Variation of Moisture Content with Lime Concentration.

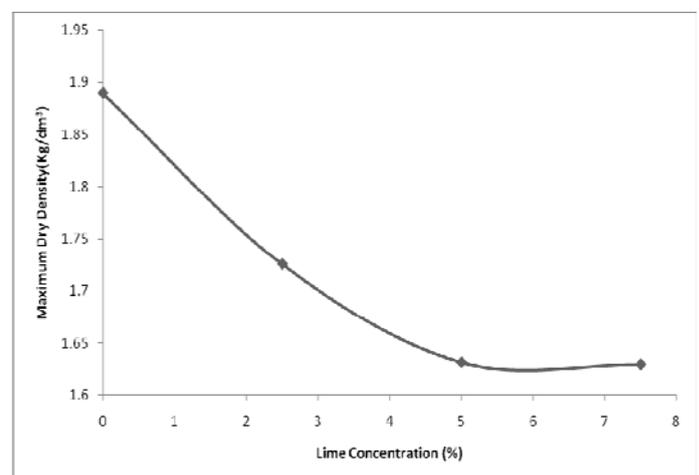


Figure 2. Variation of Dry Density with Lime Concentration.

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/dm³ to 1.890 kg/dm³ 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 $v_1 = 3$ and $v_2 = 16$ 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 $v_1 = 3$ and $v_2 = 16$ 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

The author acknowledge the efforts of the laboratory technologists in the department of Civil Engineering, Faculty of Engineering and Technology, University of Ilorin, Ilorin, Nigeria for their guidance and contributions in making available all the equipment used for this experiment.

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