DIFFERENTIAL MATURITY ACROSS LATERITIC PROFILES FROM ILORIN, NORTH CENTRAL NIGERIA.

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ABSTRACT

This study characterizes the three distinct horizons of the lateritic profiles within the study location with the view to determining their relative degrees of laterization. The three distinct horizons (the upper crustal, middle gravelly and basal less/non gravelly) were subjected to series of geotechnical tests to determine parameters such as Grain size distribution, Atterberg limits, Specific gravity, California bearing ratio, Compaction and Shear strength. The results of the tests elucidated a useful connection between the parameters determined and the degree of laterization. The middle horizon, which is the gravelly horizon, has the highest specific gravity out of the three horizons and a lower clay content than the basal less/non gravelly horizon, both of which are indicative of a higher degree of laterization.It also shows relatively improved and enhanced values for the other parameters such as California bearing ratio, Shear strength and Atterberg limits, which further indicates that the gravelly horizon has attained a higher degree of maturity compared to the others. It is thus expected to have the best engineering performance.

Keywords – Degree of Maturity, Degree of Laterization, Engineering Performance, Geotechnical Test, Lateritic Profile

Introduction

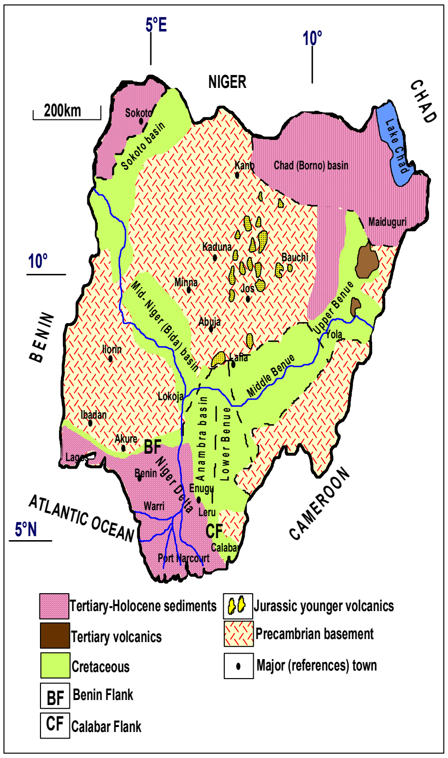
Since the discovery of laterite by Buchanan in India in the year 1807(Ollier and Galloway,1990), it has progressively become the most important construction material of the tropical world. It is widely used as foundation material and for other construction purposes in the subtropical and tropical regions where it is abundantly deposited. Although, laterite is ubiquitous, its properties and features vary from location to location. The variations have been established to depend on factors such as parent material, topography, climate, drainage among others. Consequently, the maturity and degree of laterization of laterite is also variable (Terzaghi, 1958; Vargas, 1993) cited in Eze*et al*.(2014). According to Tuncer and Lohnes (1977) cited in Adeyemi and Ogundero (2001), properties such as specific gravity, sesquioxide content, dry density, mineralogy and moisture content are good indicators of the degree of tropical weathering or laterization.

The location of this study is Ilorin, North central Nigeria, where the typical lateritic profile presents a peculiar distinct three horizon situation. The upper most horizon is the crust or hard pan, followed by a middle gravelly horizon and a basal horizon with lesser gravel than the middle horizon or no gravel at all. The unique three horizons across the profile conforms with the description of Alao (1983). The lateritic profile in Ilorin is essentially developed over the Migmatite – Gneiss – Quartzite complex, which is a unit of the Nigerian basement complex (Figure 1). This study seeks to characterize each of the three distinct horizons and also to determine their relative degrees of laterization.

Research Methods

The study location is situated along Asa – Dam road, Ilorin and it is essentially defined by Long. E 004^0 32^1 52.6^1 and Lat. 08^0 27^1 02.4^1 (Figure 2). It is a remnant of a road cut with well-defined horizons of the lateritic profile. Samples were collected across the profile from the three horizons at three different spots. The three horizons are designated as A, B and C representing the uppermost horizon of crust, the middle gravelly and the basal horizon with fewer or no gravel.

Samples were collected across the three distinct horizons designated as A (crust), B(Gravelly) and C (Non/Less Gravelly).The collected samples were appropriately prepared and subjected standard geotechnical tests. The tests carried out include the grain size analyses, atterberg limits tests, compaction test, density, specific gravity test, CBR test and the shear strength test. All the geotechnical tests were carried out according to procedures specified in the British Standard 1377 (BS, 1990). However, it must be noted that, where necessary, appropriate modifications were made to the suggested procedures because of the tropical nature of the samples as against the temperate nature of the soils on which the suggestions are made. Specifically, the samples were soaked in mild Calgon solution to ensure disaggregation subsequent to being air dried. Tests for the California Bearing Ratio (CBR), Compaction and the Shear Strength were also carried out at energies of both standard and modified proctors.



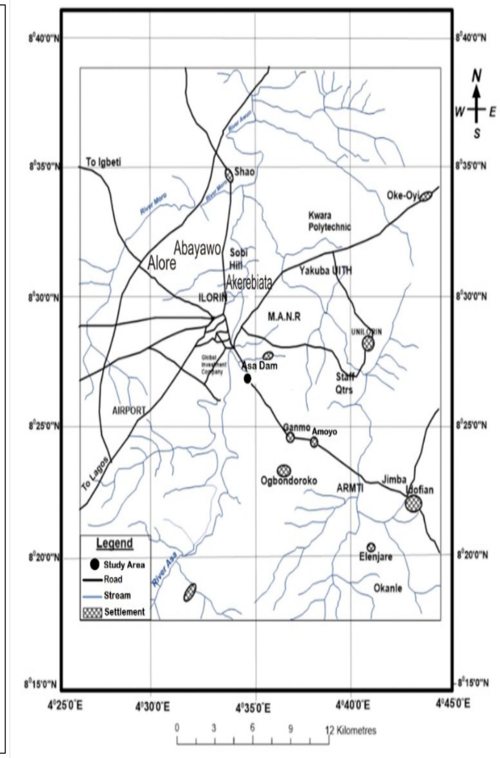


Figure 1: Geological Map of Nigeria showing the study area (Modified after(Obaje, 2009).

Figure 2: Map of Ilorin and Environs showing the location of the study area Olasehinde*etal.,* 1998)

Results and Discussion

The results of the geotechnical tests carried out on samples collected from three sampling points from the study location are presented in Tables 1,2 and 3.

Table 1: Results of Moisture Content, Specific Gravity, Grain Size Analysis and Atterberg Limits Tests

Horizon	*Sampling Point*			*Grain Size*				*Atterberg*			
		Moisture content(%)	**Specific Gravity**	**Gravel(%)**	**Sand(%)**	**Silt(%)**	**Clay(%)**	**LL(%)**	**PL(%)**	**SL(%)**	**PI**
A (Crust)	1	3.0	2.60								
	2	3.5	2.61								
	3	3.8	2.60								
	Mean	3.43	2.603								
B (Gravelly)	1	4.1	2.66	17	51	9	23	27.5	22.0	5.2	7.5
	2	4.6	2.64	12	45	14	29	31	18.6	5.3	12.4
	3	4.8	2.62	11	46	16	27	34	20.5	5.7	13.5
	Mean	4.5	2.640	13.33	47.33	13	26. 33	30.8	20.36	5.4	11.13
C (Non/Less Gravelly)	1	4.9	2.55	0	31	23	46	37	22	6.1	19.5
	2	5.2	2.52	6	30	16	48	42.5	15.5	6.5	27
	3	5.7	2.50	4	29	16	49	46.5	16.6	6.8	29
	Mean	5.26	2.523	3.33	30	18.33	47.66	42	16.53	6.46	25.16

Table 2: Results of CBR, Compaction and Shear Strength Tests

Horizon	***Sampling Point***	***CBR***				***Compaction***				***Shear Strength Parameters***			
		Standard Proctor		**Modified Proctor**		**Standard Proctor**		**Modified Proctor**		**Standard proctor**		**Modified Proctor**	
		Unsoaked	**Soaked**	**Unsoaked**	**Soaked**	**OMC (%)**	**MDD (g/cm³)**	**OMC (%)**	**MDD g/cm³**	**C(KPa)**	**Ø(⁰)**	**C(KPa)**	**Ø(⁰)**
A (Crust)	1												
	2												
	3												
	Mean												
B (Gravelly)	1	5	3	6	5	9.0	1.90	8.0	1.97	35	31	40	33
	2	4	3	5	4	13.5	1.73	12.5	1.80	30	28	43	32
	3	4	4	5	4	10.2	1.84	9.5	1.91	55	37	120	43
	Mean	4.33	3.33	5.33	4.33	10.9	1.82	10	1.89	40	32	67.66	36
C Non/Less Gravelly)	1	2	2	3	5	14.9	1.62	13.8	1.68	80	23	110	25
	2	2	1	3	1	15.0	1.69	13.0	1.78	60	20	100	30
	3	3	2	3	1	15.2	1.59	14.1	1.61	90	25	125	35
	Mean	2.33	1.66	3.66	1.66	15.03	1.63	13.63	1.69	76.66	22.66	111.66	30

Moisture Content

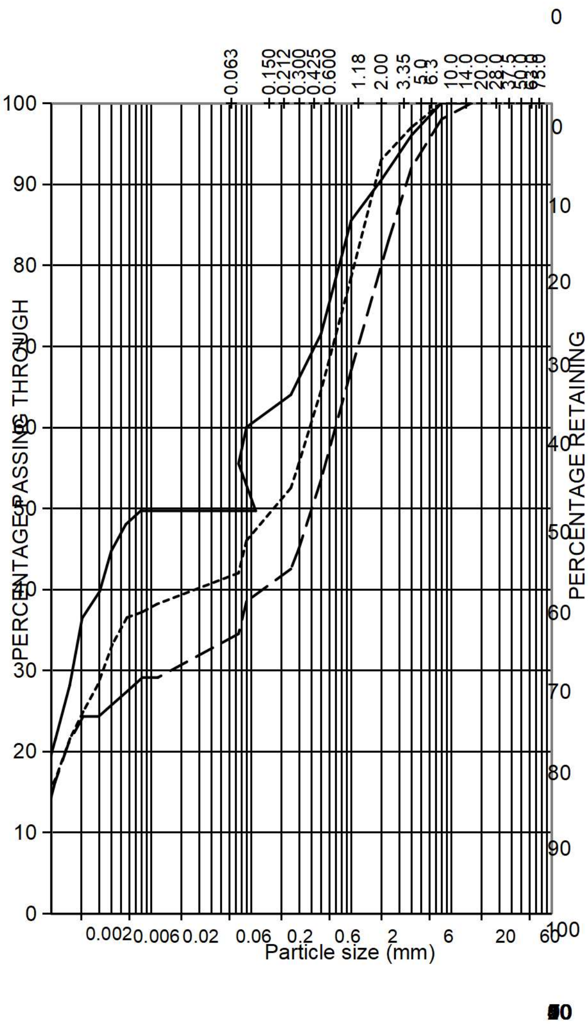
As presented in T able 1, Horizon C has the highest mean moisture content of 5.26%, Horizon B with 4.5% is intermediate, while Horizon A with 3.43% has the least moisture content. Moisture content essentially describes the natural propensity of soil for water (Adeyemi and Akinseli,1995), and it also indicates the potential for self-stabilization of a soil (Gidigasu, 1976). The lower the value, the higher the potential for self-stabilization. Excluding Horizon A that is crustal, the moisture contents of both Horizon B and C can be related to the amount of their clay size particles. This results from the high affinity for water by clay.Consequently, Horizon B with a lower moisture content than Horizon C equally has a lower amount of clay size particles than C. Since the degree of laterization has been established to increase as the amount of clay size particles reduces (Gidigasu, 1976), moisture content (which is lower in horizon B relative to horizon C) also suggests that horizon B is more laterised and more matured than Horizon C.

Specific Gravity

Table 1 presents the results of the specific gravity test. From the table, the mean specific gravity for horizons A, B and C are 2.603, 2.64 and 2.523 respectively. According to Akroyd (1963), the maturity of lateritic soil can be appraised by the specific gravity. Tuncer and Lohnes (1977) and De Graft – Johnson (1972) cited in Kamtchueng*et al*. (2015) similarly discovered a correlation between the degree of laterization and specific gravity. Invariably, according to the findings of this authors, the higher the specific gravity of a soil, the higher the degree of laterization and the stronger the soil for engineering purposes. Therefore, Horizon B (gravelly) has attained the highest degree of laterization cum maturity, followed by Horizon A (crust) while Horizon C (less/non gravelly) is least laterised, having the lowest specific gravity.

Textural Analysis

This essentially describes the relative abundance of the different grain sizes upon which the physical and engineering attributes of lateritic soils depends (Adeyemi*et al.,* 1997). Table 1 as well as Figures 2 and 3 show the results of the grain size analysis. The mean of the proportions of particle sizes for Horizon B are 13.33%, 47.33%, 13% and 26.33% for gravel, sand, silt and clay respectively. Accordingly, that of Horizon C are 3.33%, 30%, 18.33% and 47.66%. From the results, Horizon B is more granular than Horizon C, having higher content of both gravel and sand. Conversely, Horizon C has a higher content of fine particles (silt and clay) than horizon B. figure 2 and figure 3 show that Horizon B with a mean gravel content of 13 33% and sand content of 47.33% is more granular than Horizon C, while Horizon C with a clay content of 46.66%, conversely contains higher content of clay than Horizon B. Findings from studies on laterite (Gidigasu, (1976), Oyediran and Durojaiye (2011) have shown that the amount of clay size particles of laterite is related to its degree of laterization. They opined that, the lower the clay content, the higher the degree of laterization. Consequently, Horizon B, with lesser clay content relative to Horizon C, is dimmed to have attained a higher degree of laterization.



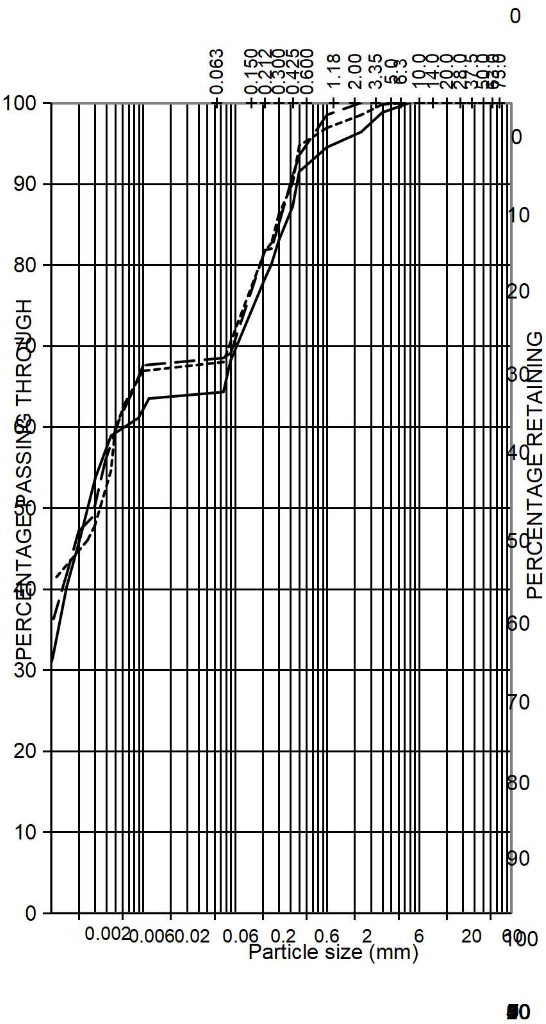


Figure 3: Particle Size Curves for Horizon B **Figure 4: Particle Size Curves for Horizon C**

Consistency Limits

The results of consistency limit tests are shown in Table 1 while the plasticity classification is shown in Figure 5. Soils of Horizon B have a lower mean plasticity (11.13%) than that of Horizon C (25.16%). Relative plasticity of a soil is related to relative amount of clay size particles, which is in turn a reflection of the degree of maturity and laterization. According to Madu (1977), a reducing trend in plasticity suggests an increasing degree of maturity. Consequently, the lower plasticity of the samplesfromHorizon B also implies its higher degree of laterization. Both the Horizon B and C however, plot as inorganic clay of medium plasticity on the Casagrande chart and also above the A- line (Figure 5). Having plotted above the A- line, the soils can be regarded as not being problematic for construction (Terzaghi, 1958).

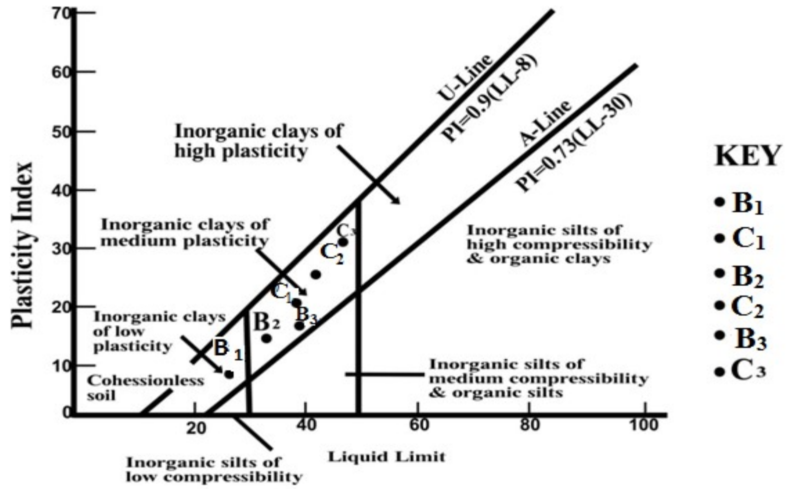


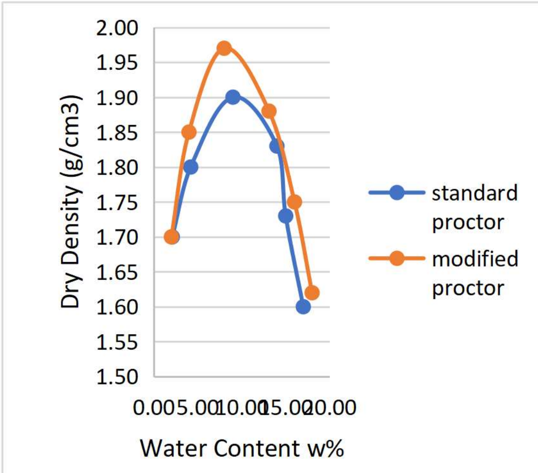
Figure 5: Casagrande Chart Classification of Studied Lateritic Soil Samples.

California Bearing Ratio (CBR)

The California bearing ratio essentially estimates the bearing capacity of soils for highway subgrade and sub base uses (Simon *et al.,* 1973; Gidigasu, 1980). According to Adeyemi(2003), CBR is enhanced by increasing degree of laterization. Also, Oyelami and Alimi (2015) suggest that CBR is impacted by the amount of clay content which in turn is a measure of the degree of latrerization. Expectedly as shown in Table 2, all the values for the modified proctor energy level are higher than those of the standard proctor energy level. Similarly, the values for the unsoaked specimens are also higher than the equivalent values for soaked specimens. Mean CBR values for Horizon B were 4.33 and 3.33 respectively for unsoaked and soaked specimens at the energy of standard proctor, while they were 5.33 and 4.33 for un soaked and soaked at the energy of modified proctor. For horizon C, 2.33 and 1.66 for unsoaked and soaked at energy of standard proctor and 3.66 and 1.66 respectively for unsoaked and soaked at the energy of modified proctor. Consequently, at both the standard and the modified proctor energy levels, whether soaked or unsoaked, Horizon B has higher CBR values than the corresponding values for Horizon C. This suggests a higher bearing capacity, higher engineering performance and a higher degree of laterization cum maturity.

Compaction

The results of the compaction tests are shown in table 2 and figures 3 and 4. Horizon B which is the gravelly Horizon, has a mean maximum dry density (MDD) of 1.82 g/cm^3 and a corresponding optimum moisture content (OMC) of 10.9 % when compacted at the energy of standard proctor. It also has a maximum dry density (MDD) of 1.89 g/cm^3 and optimum moisture content (OMC) of 10% when compacted at the energy of modified proctor. For the horizon with no or less gravel, Horizon C, the maximum dry densities (MDD) are 1.63 g/cm^3 and 1.69 g/cm^3 while the optimum moisture contents (OMC) are 15.03% and 14.1% when compacted at the energies of the standard and modified proctors respectively. Be it at the energy of the standard or modified proctor, Horizon B has better compaction characteristics compared to Horizon C. According to the findings of G/Medhin(2008), who worked on the compaction properties of lateritic soils of Assossa, Ethiopia, maximum dry density (MDD) increases while the optimum moisture content(OMC)reduces with increasing degree of laterization across a profile where the layers are developed over the same parent material. He also further opined that the layers at the top or close to the top of the profile will attain higher degree of laterization due to fluctuation of temperature and moisture at the surface, which is germane for tropical weathering or laterization. Similarly, Kamtchueng*et al*. (2015) also suggest that both maximum dry density (MDD) and optimum moisture content (OMC) are directly and inversely dependent on the degree of laterization respectively. This implies that, Horizon B (which has better compaction parameters) will exhibit a higher degree of laterization or maturity than Horizon C, and invariably, also a better engineering performance.



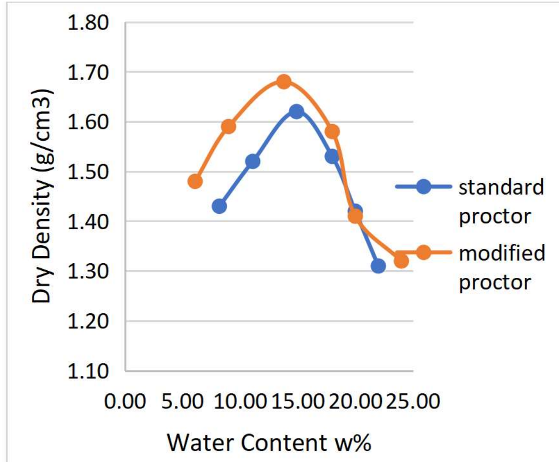


Figure 6:SampleCompaction Chart forFigure 7: Sample Compaction Chart for Horizon B Horizon C

Shear Strength

The Shear Strength of a soil essentially expresses the maximum internal resistance of a soil to the movement of its particles. According to Gidigasu (1976),cohesion is affected by degree of saturation while angle of internal friction is not. For both the standard and modified proctors, Horizon B shows better mean shear strength parameters than Horizon C (Table 2). The mean cohesions for Horizon B are 40 KPa and 66.67 KPa while that of Horizon C are 76.66 KPaand 111.66KPa for the standard and modified proctors respectively. For the angle of internal friction, it is 32^0 and 36^0 for Horizon B and 22.66^0 and 30^0 for Horizon C at the energies of standard and modified proctors respectively. The two shear strength parameters relate directly to the relative abundance of clay size and granular particles. The higher the amount of clay size particles, the higher the value of cohesion, while an enhanced quantity of granular materials will result in higher angle of internal friction. According to Baldovin (1976), the higher the degree of laterization,the more favourable the shear strength parameters. Horizon B is thus adjudged to be more matured.

Conclusion

Lateritic soil from the three distinct horizons, but developed over the same parent rock, have been investigated to determine their relative degrees of laterization. Due to the crustal nature of Horizon A, only its moisture content and specific gravity were determined. However, for Horizon B (gravelly) and C (non/less – gravelly), properties such as shear strength parameters, CBR, compaction parameters, Atterberg limits, grain size distribution as well as the specific gravity and moisture content were determined.

The relatively lower quantity of clay size particle Horizon B suggests an enhanced sesquioxide coating, thus a higher degree of maturity and laterization. This is further affirmed by its relative higher specific gravity and the other investigated parameters, such as c ompaction parameters, plasticity, calafornia bearing ratio and shear strength parameters, all of which have been positively enhanced compared to the horizons A and C. Of the three horizons, Horizon B, based on its characteristic features, which suggests highest level of maturity, will therefore perform better as an engineering material.

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