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PERMEANT PROPERTIES OF FOUNDATION SOILS IN THE BASEMENT COMPLEX TERRAIN OF SOUTHWESTERN NIGERIA

N. O. ADEBISI

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ABSTRACT

Previous investigations on foundation soils of the Basement Complex Terrain of Southwestern Nigeria revealed a wide range variation in coefficient of permeability (K) due to grain sizes. Compared to findings on geotechnical properties of foundation soils in general, permeant properties due to grain-size distribution in relation to the rate of settlement, has not been discussed. This study focuses on the concept of permeant properties to clarify the relationship between K and grain-size distribution for the purpose of rate of foundation settlement. Grain-size distribution of the soils was carried out by sieve analysis method and hydrometer test for coarse and fine soils respectively following the British Standard. The effective size (D_{10}) and a constant of 0.015 were employed in the estimation of K, based on Hazen formula.

Inverse relationship exist between K and amount of clay (r = -0.34), K and amount of silt (r = -0.29) as well as exists between K and amount of sand (r = - 0.015). It follows that the amount of clay in the soils decreases with K, and rate at which water flows in the soil will rather influence the rate and amount of foundation settlement. However, fairly strong positive correlation (r = 0,58) exists between K and amount of gravel with line of best fit *K = 0.006 %Gravel + 0.047*. This study has shown that the permeability of the foundation soils increases with amount of gravel.

KEYWORDS: Grain-size, soils, permeability, foundation and settlement.

INTRODUCTION

The study area covers parts of Southwestern Nigeria where gneiss, quartz-schist and granites constitute the major bedrocks (Adebisi 2010). It stretches between longitude range 3^0 30'E - 3^0 55'E and latitude range 7^0 14'N - 7^0 27'N (Fig. 1). The rocks have witnessed varying degrees of weathering through the action of water and other agents to form laterised profiles of soil with various thicknesses (Faniran and Jeje, 1983). Tropical climate, which is characterised by alternating dry and wet seasons, as reiterated by Adeyemi, (1992), Elueze et al. (2004) and Ige et al. (2005) features prominently in the formation of the lateritic soils. The laterised profiles in Southwestern Nigeria widely serve as foundation materials for structures. The suitability of such soils; as foundation materials is expected to depend strongly on their rate and amount of consolidation.

N. O. Adebisi, Department of Earth Sciences, Faculty of Science. Olabisi Onabanjo University, Ago-Iwoye, Nigeria.

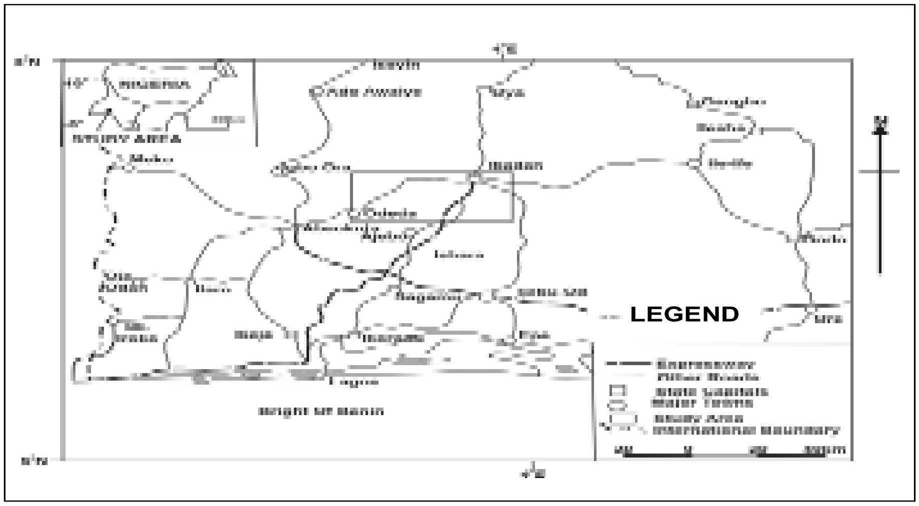

Figure 1: Map of Southwestern Nigeria showing the study area

Fukuda et al (1997) studied the role of grain-size distribution on the permeability of a marine clay, with emphasis on consolidation analysis. Evaluation of permeant properties of laterized soil developed over crystalline rocks in the Basement Complex terrain of Southwestern Nigeria, seems to remain a relatively minor investigated field. Oloruntola (2002) noticed variation above 80% with depth in permeability of lateritic soils from southwestern Nigeria. Adebisi (2010) made mention of wide range of permeability coefficient from consolidation assessment of foundation soils from parts of the Basement Complex Terrain in Southwestern Nigeria. So far, most studies related to soil properties utilized in road and highway construction in the study area have been well-published (Malomo et al. 1983; Ogunsanwo, 1989a; Adeyemi, 1992).

The present study is tailored towards how relative sizes of particles will influence the variance of permeant properties of lateritic soils. Information obtained from this study will enable categorical statements to be made on the permeability of foundation soils and rate of settlement as far as site conditions are concerned.

Method of Study

In accordance with BS (1990), about 500 grams each of 30 air-dried soils samples obtained from 6 test pits at depths of 1.0m 1.5m, 2.0m, 2.5m and 3.0m in profiles of soils developed over crystalline bedrocks, were soaked in sodium hexametaphosphate solution (10 grams in 4 liters of water) for a period of 24 hours. Shaking and squeezing of samples were made at regular intervals to effect thorough separation of the soil particles. Soil fractions retained on the British standard sieve no. 230 (0.063mm) were weighed, after wet sieving, and oven-dried before subjecting them to mechanical analysis by means of mechanical shaker. After the mechanical shaking, the weight on each sieve was recorded; and the percentage of the total sample passing each of the sieves was calculated.

Fine fractions were passed through sieve no. 230 for hydrometer tests for a period of 24 hours. The hydrometer analysis was based on Stoke's law. Particle sizes were determined from the settling velocity and times recorded, with percentages between sizes calculated from density differences. Record of hydrometer reading was taken at various times. Calculation of suspension in grams/liter was done, followed by the summation presentation.

The percentage passing of soil grains from depths of 1.0m, 1.5m, 2.0m, 2.5m and 3.0, were plotted on the sand and fines fractions of a semi logarithm papers. Coefficient of permeability (K) was estimated from the theoretical equation relating K to effective size (Hazen, 1895; Taylor, 1948)

$$K = C.D_{10} \qquad (1)$$

Where C is a constant and equals 0.015, being the maximum recommended (Holtz and Kovacs, 1980). The effective diameter (D_{10}) is usually taken to be 10% of the size of the percentage finer.

Discussion of Results

Grading curves for the studied foundation soils as shown in figure (2a-f), cover several log cycles of the semi-log paper This implies that a variety of particle sizes exist in the soils. The soils can be adjudged well-graded. The grading characteristics of the studied soils are numerically summarized in table 1. It is obvious that sand and silt fractions dominate the composition of the studied soils, in comparison to gravel and clay fractions. Effective size (D_{10}) ranges between 0.0021 mm and 0.035 mm with an overall average of 0.0093 mm. Estimated coefficient of permeability (K) also ranges from 0.012 m/s to 0.53 m/s with an overall average of 0.14 m/s. This is consistent with the established variation in the permeability values of lateritic soils.

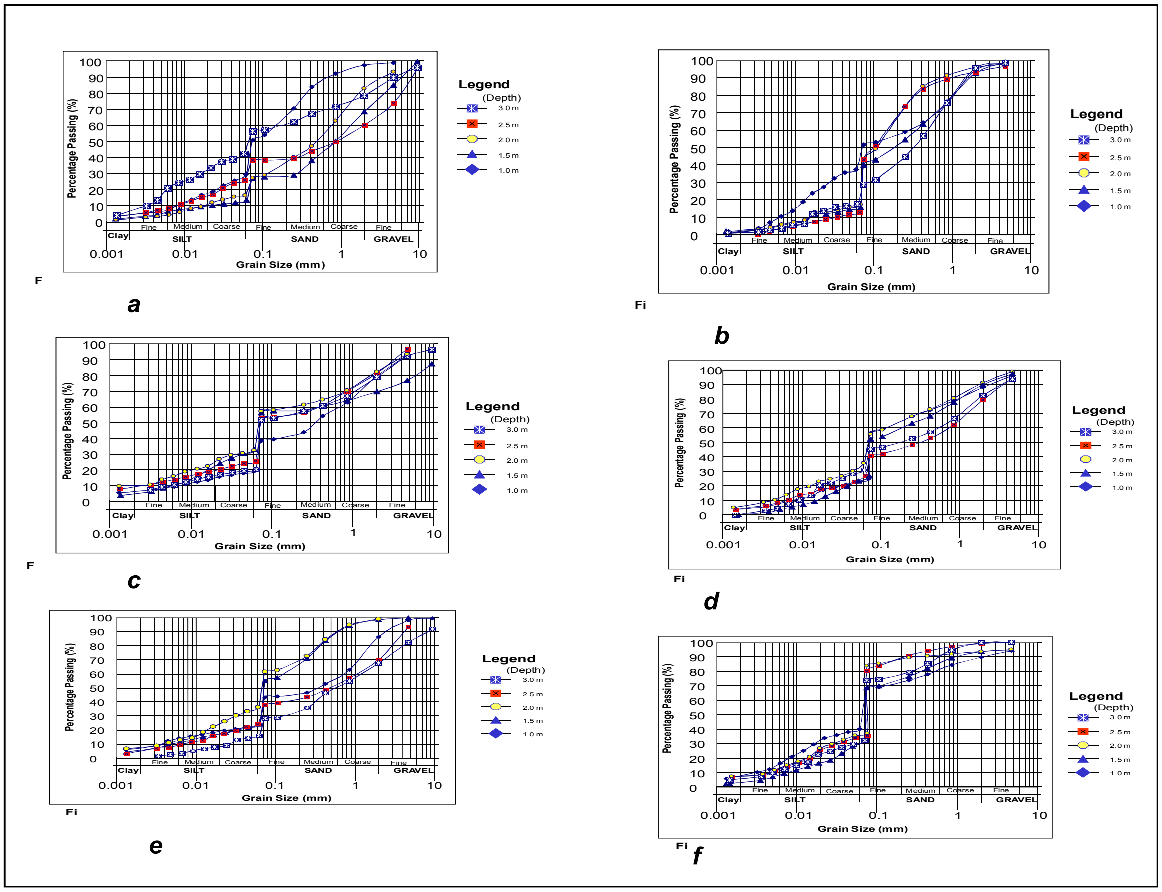

Figure 2: Grading curves of the studied soils

Table 1: Grain-size distribution and permeant parameters of the studied soils.

SOIL SAMPLES	DEPTH (m)	GRAIN-SIZE DISTRIBUTION					PARAMETERS	
		% Clay-sized particles	% Silt-sized Particles	% Fines	% Sand-sized particles	% Gravel-sized particles	Effective size, D_{10} (mm)	Coefficient of permeability (K) m/s
PIT 1	1.0	6.0	30.0	36	59.0	5.0	0.0065	0.098
	1.5	5.0	35.0	40	53.0	7.0	0.023	0.35
	2.0	4.0	12.0	16	78.0	5.0	0.018	0.27
	2.5	3.0	8.0	11	82.0	7.0	0.008	0.012
	3.0	5.0	13.0	18	77.0	5.0	0.003	0.045
PIT 2	1.0	12.0	18.0	30	67.0	3.0	0.0062	0.093
	1.5	4.0	9.0	14	54.0	32.0	0.017	0.26
	2.0	5.0	10.0	15	68.0	17.0	0.017	0.26
	2.5	5.0	12.0	17	43.0	40.0	0.035	0.53
	3.0	7.0	35.0	42	36.0	22.0	0.017	0.26
PIT 3	1.0	5.0	23.0	28	85.0	12.0	0.006	0.09
	1.5	2.0	20.0	22	68.0	10.0	0.006	0.09
	2.0	5.0	28 .0	33	59.0	8.0	0.0032	0.048
	2.5	6.0	18.0	24	54.2	22.0	0.0042	0.063
	3.0	3.0	37.0	40	38.0	22.0	0.006	0.09
PIT 4	1.0	4.0	26.0	30	60.0	10.0	0.007	0.11
	1.5	7.0	24.0	31	37.0	32.0	0.0071	0.11
	2.0	7.0	24.0	31	51.0	18.0	0.0045	0.068
	2.5	7.0	19.0	26	56.0	18.0	0.0061	0.092
	3.0	5.0	15.0	20	58.0	21.0	0.01	0.15
PIT 5	1.0	10.0	23.0	33	64.0	3.0	0.0035	0.053
	1.5	5.0	39.0	45	54.0	1.0	0.0035	0.053
	2.0	8.0	39.0	47	51.0	2.0	0.0035	0.053
	2.5	5.0	37.0	42	28.0	30.0	0.006	0.09
	3.0	2.0	14.0	16	51.0	33.0	0.028	0.42
PIT 6	1.0	9.0	30.0	40	50.0	10.0	0.0021	0.032
	1.5	6.0	22.0	28	61.0	11.0	0.008	0.12
	2.0	9.0	69.0	78	15.0	7.0	0.0045	0.068
	2.5	8.0	21.0	29	65.0	2.0	0.0045	0.068
	3.0	8.0	23.0	31	68.0	1.0	0.0045	0.068

Regression analyses between coefficient of permeability and each of the grain sizes are presented in figure 3(a-d). Weak inverse relationship exist between K and amount of clay, between K and amount of silt and between K and amount of sand with coefficient of correlations (r) of - 0.34, - 0.29 and r = -0.015 respectively. It can be seen that the degree of correlation of K decreases with increase in grain size.

Permeability of a soil is not expected to decrease with increase in amount of sand, this situation is characteristic of consolidated sand (March and Kennny, 1966). Very weak inverse relationship (r = -0.015) which exists between K and amount of sand indicates that the effect of sand-sized particles on reduction in permeability of the soils is insignificant. It is logical to remark that sand fraction dominates the composition of the studied soils, and finer particles filled the voids between sand and gravel.

Fairly strong positive correlation (r = 0.58) exists between coefficient of permeability and amount of gravel with line of best fit given as K = 0.006 %Gravel + 0.047. The implication is that the permeability of the studied soils increases with amount of gravel. Since r is low, the coefficient of permeability of the foundation soils cannot be reliably estimated on the basis of their gravel fraction.

Various relationships established between the coefficient of permeability and grain components of the studied foundation soils are forming useful basis in explaining voids proportion and the ease with which ground water flows in the soil.

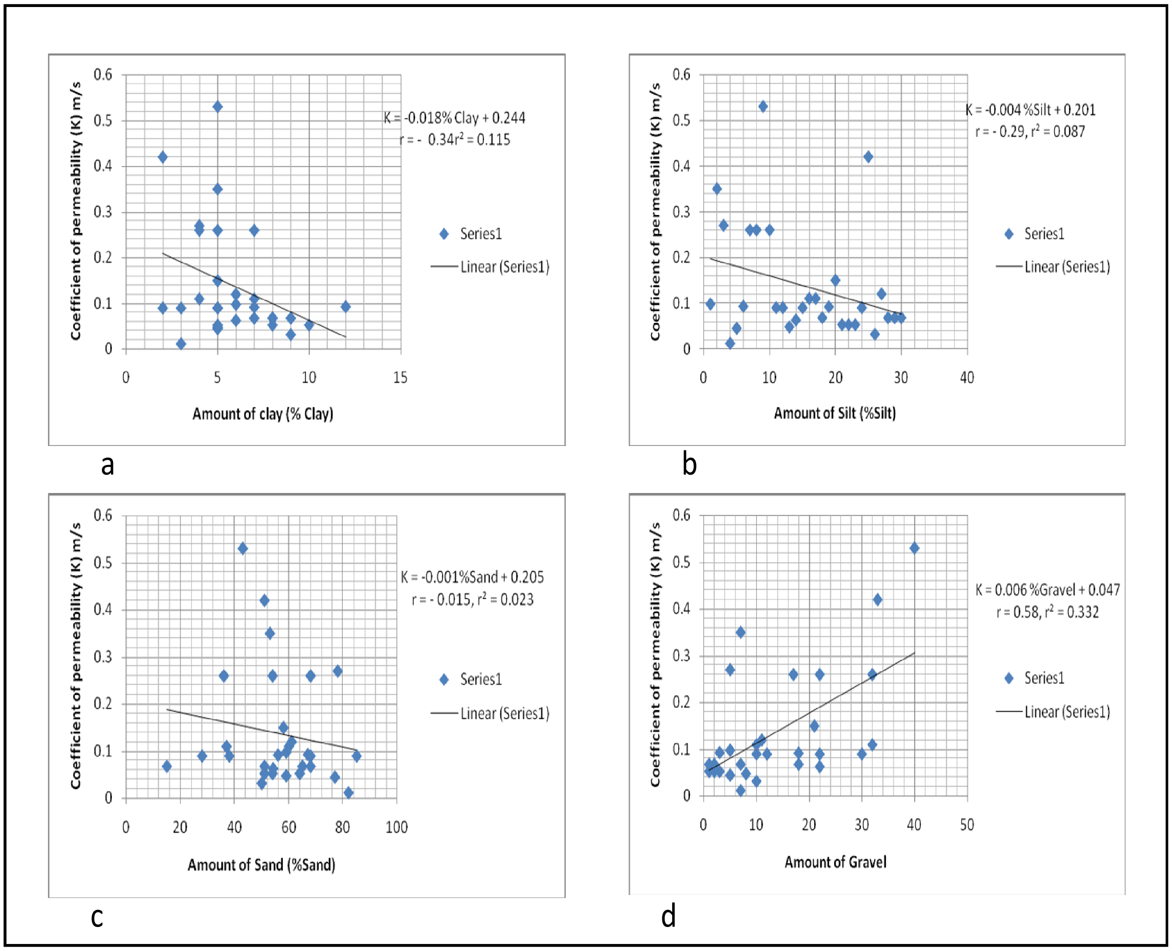

Figure 3: Regression plots of coefficient of permeability and grain sizes

In this situation where the proportion of gravel within the soil is relatively low, the size of the individual void will be extremely large. Bear (1972) affirms the fact that the proportion and size of voids affect the flow of water through a soil. Permeability will definitely increase with increase in amount gravel present in a soil.

The various ranges of particle sizes present in the residual lateritic soils which serve as foundation materials, and the ease with which water flows in them enable settlement prediction to be more reliable. According to Carter and Bently (1991), specific correlation exists between coefficient of permeability and grain-size distribution of a soil. The proportion and size of voids within a soil are therefore expected to determine the ease with which water flows through the soil. It follows that the coefficient of permeability of the soil will depend on the rate of settlement which can be related to coefficient of consolidation (Cv) and amount of settlement which defines coefficient of compressibility (Mv) of the soils.

CONCLUSIONS

The laterised profiles in Southwestern Nigeria are widely employed as foundation materials for structures. The suitability of soils for this purpose is expected to be influenced by the grain sizes and the ease with which water flows through the soils. Sand and silt fractions form the dominate particle sizes in the soils with subordinate amounts of gravel and clay Compared to other soil fractions, most interesting relationship exists between permeability coefficient and amount of gravels in the soils.

Wide ranges of permeabilities will exist within the studied soils because permeant properties have directly expressed their foundation settlement. From this study, grain size distribution is the principal factor responsible for variation in the soils' permeability. It influences the consolidation parameters of the studied foundation soils in the Basement Complex Terrain of Southwestern Nigeria.

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