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Effect of multicyclic compaction on cohesion in lateritic soils

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ABSTRACT

Lateritic soils occur in the flat plains of Niger Delta. Deltaic lateritic soils are known to be relatively immature compared to those of Southwestern Nigeria. Lateritic soils are the major road construction materials in the Niger Delta region. They are however, subject to rapid deterioration as a result of continuous vehicular loading. The effect of vehicular loading on cohesion is simulated in the laboratory by subjecting the soils to repeated compaction cycles. The results indicate different degrees of particle breakdown with increasing compaction cycles. Quantitative relationships between the number of compaction cycles and cohesion of soils are developed. The polynomial relationships best explain the effect of multi-cyclic compaction on cohesion of the soil.

Keywords: Compaction cycles, correlation coefficient, Niger Delta.

INTRODUCTION

Soil improvement is generally defined as the alteration of any property of the soil to improve its engineering performance. The most common and important method of soil improvement is densification using compaction tests [1].

Lateritic soils have been found to develop over different geologic materials. Laterite soils in the Niger Delta are superficial soils of varying thickness from 1m to above 25m.They were most likely derived from and also overlie the Benin Formation .The Niger Delta lateritic soils have been observed to possess some distinct engineering characteristics when compared with other types of lateritic soils. These lateritic soils possess very low to medium proportion of fines and rock forming minerals such as feldspars, micas and they occur in a flat or near – flat terrain [2].

Lateritic soil appears as coarse but loosely bound micro – clusters. These loosely bound micro – clusters are very sensitive to any form of manipulation such as remoulding, drying and wetting [3, 4, 5]. The effect of multi-cyclic compaction should therefore be expected in lateritic soils.
Multi-cyclic compaction (compacting and re – compacting a soil sample for several times) has been used to assess soil quality for pavement construction. Lateritic soils deteriorate when subjected to cyclic compaction [6, 7, 8, 9].

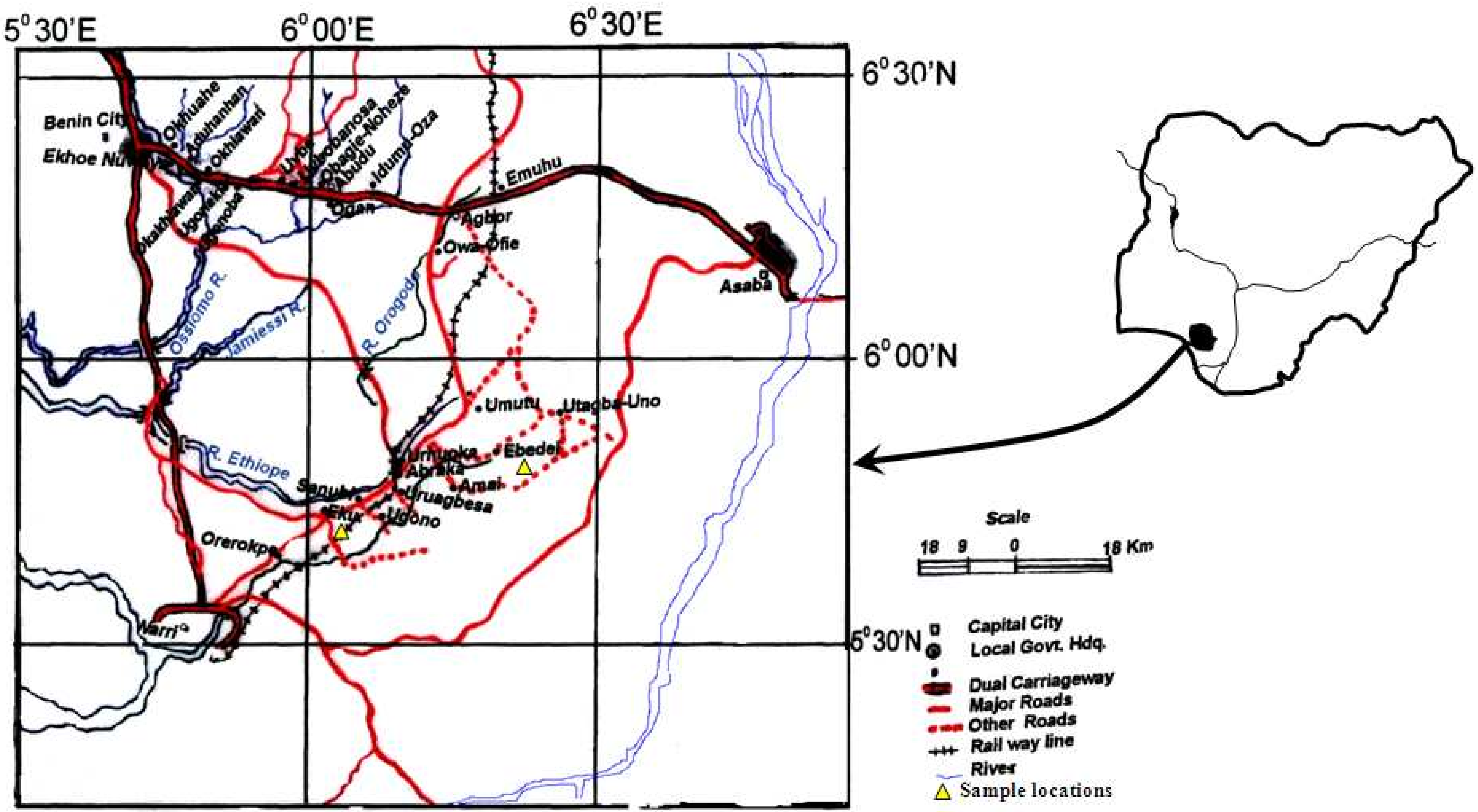


Fig. 1: Study Location Map

In the field multi-cyclic compaction process is associated with series of compaction arising from vehicular loading whenever a vehicle passes the road. The effects of multi-cyclic compaction on some geotechnical properties of relatively matured lateritic soils of southwestern Nigeria have been investigated [10, 11].

[12] have investigated the effect of compaction cycles on index properties of Niger Delta lateritic soils. Shear strength parameters are quite important engineering properties of soils. The stability of a road depends on the shear strength parameters of the soil. No study has so far been carried out to establish the effect of compaction cycles on shear strength parameters. Cohesion being one of the shear strength parameters has been found to be the major factor determining shear strength in lateritic soils [13]. The objective of this study therefore is to establish the quantitative relationship between the number of compaction cycles and cohesion in deltaic lateritic soils.

The soil samples were obtained from two active burrow pits from Ebedei and Eku with longitude 06^{0} 20^{1} 00^{11} E and latitude 05^{0} 52^{1} 00^{11} N and longitude 06^{0} 04^{1} 00^{11} E and latitude 05^{0} 45^{1} 00^{11} N (Figure 1).

The general geology for the study area consists of relatively simple diverse types of Quaternary deposits overlying thick Tertiary sandy and clayey deltaic deposits. Three main subsurface lithostratigraphic units (Table 1) have been recognized [14] in the Niger Delta. From the oldest to the youngest, they are Akata, Agbada and Benin Formations. Detailed studies of Quaternary deposits of the Niger Delta by [15] revealed that the sediments were deposited under the influence of fluctuating Pleistocene eustatic sea level.

Table 1: Geologic Units of the Niger Delta [14]

Geologic Unit	Lithology	Age
Alluvium (general)	Gravel, sand, clay, salt	Quaternary
Freshwater backswamp, meander belt	Sand, clay, some silt and gravel	
Mangrove and salt water/ backswamps	Medium-fine sands, clay and some silt	
Active/abandoned beach ridges	Sand, clay, and some silt	
Sombreiro-Warri deltaic plain	Sand, clay, and some silt	
Benin Formation (Coastal Plain Sand)	Coarse to medium sand with subordinate silt and clay tenses	Miocene
Agbada Formation	Mixture of sand, clay and silt	Eocene
Akata Formation	Clay	Paleocene

MATERIALS AND METHODS

The samples were obtained from two major active burrows pits at Ebedei and Eku. The bulk samples were first air – dried before subjecting them to basic geotechnical index property tests in accordance with British Standards Procedures [16]. The average basic geotechnical index properties of the soils are presented in Table 2.

In the compaction cycle test, the soil samples were mixed at about the standard proctor OMC and allowed to homogenize for twenty four hours. The soil samples were thereafter compacted for many cycles (ranging from 1 – 15) breaking down each compacted soil before re – compacting. After each compaction cycle, the soils were subjected to triaxial test to determine their shear strength parameters.

Table 2: Soils classification Characteristics

SOIL CHARACTERISTICS	SAMPLE LOCATION	
	EKU	EBEDEI
Percentage Fines %	52	27
Liquid limit %	44	25
Plastic limit %	18	14
Plasticity %	26	11
MDD % kg/m^3	1770	2080
OMC %	18	11
CLASSIFICATION (AASHO)	A – 7	A - 2

RESULTS AND DISCUSSION

In the A – 2 type soils, the cohesion values range between 46 KN/m^2 and 48.5 KN/m^2 (Table 3). This represents 2.5 KN/m^2 increase over the fifteen compaction cycles. This is as a result of low 27% fines percent in the soils. There soils consist of medium to fine grained sands [17]. Since the soil has 73% sand, the effect of particle breakdown will be that the medium sands are reduced to fine sands with increasing number of compaction cycles. These fine sands will not play any significant role in increasing cohesion since they are not fines. This is the reason why for fifteen compaction cycle cohesion increases only by 2.5 KN/m^2.

Table 3: Multicyclic Compaction Tests Results

A - 2 TYPE		A - 7 TYPE	
Cycle	Cohesion (KN/m^2)	Cycle	Cohesion (KN/m^2)
1	46	1	52
2	47	2	53
3	47	3	54
4	47	4	55
5	47	5	57
6	48	6	57
7	48.3	7	57
8	48	8	57.4
9	48.2	9	58.8
10	48.5	10	59.3
11	48.6	11	59.8
12	48.4	12	60.3
13	48	13	60.7
14	48.4	14	61.2
15	48.5	15	61.5

On the other hand, A – 7 types soils, have cohesion values ranging from 52 KN/m^2 to 61.5 KN/m^2. This represents 9.5 KN/m^2 increases over fifteen compaction cycles. The fines percent is 52% in this soil type. It is therefore the high fines percent that accounts for this 9.5 KN/m^2 increase over the fifteen compaction cycle.

Comparing the two soil types, it is obvious that the fines percent in A – 7 soils is almost twice that of the A – 2 soils. This also accounts for an increase of about 380% of cohesion values in A – 7 over A – 2 soils in fifteen compaction cycle. [17] classified the A – 7 soils as sandy clays and A – 2 soil as clayey sands. Since A – 7 soils are essentially clays their cohesion values are expected to be higher than those of A – 2 types because cohesion is majorly dependent on clay content in soils. An attempt to correlate the number of compaction cycle with angle of internal friction did not give any significant trend. This is because the soils have sand grain of medium to fine sizes. With multi-cyclic compaction the angles of friction within the grains do not change significantly but remain almost constant throughout the fifteen compaction cycles.

Table 4: Equations representing relation between cohesion and number of compaction cycles

	A-2	A-7
Cohesion KN/m^2		
Linear	Y = 0.1507x + 46.588; R^2 0.7336	Y = 0.6614x + 52.309; R^2 = 0.96
Logarithm	Y = 0.9229Ln(x) + 46.056; R^2 0.8613	Y = 3.7587Ln(x) + 50.609; R^2 = 0.9478
Exponential	Y = 46.59$e^{0.0032x}$; R^2 0.7318	Y = 52.432$e^{0.0116x}$; R^2 = 0.952
Polynomial	Y = -0.0177x^2 + 0.4336x; R^2 = 0.8824	Y = -0.0269x^2 + 1.0912x + 51.091; R^2 0.9833

A – 2 Type

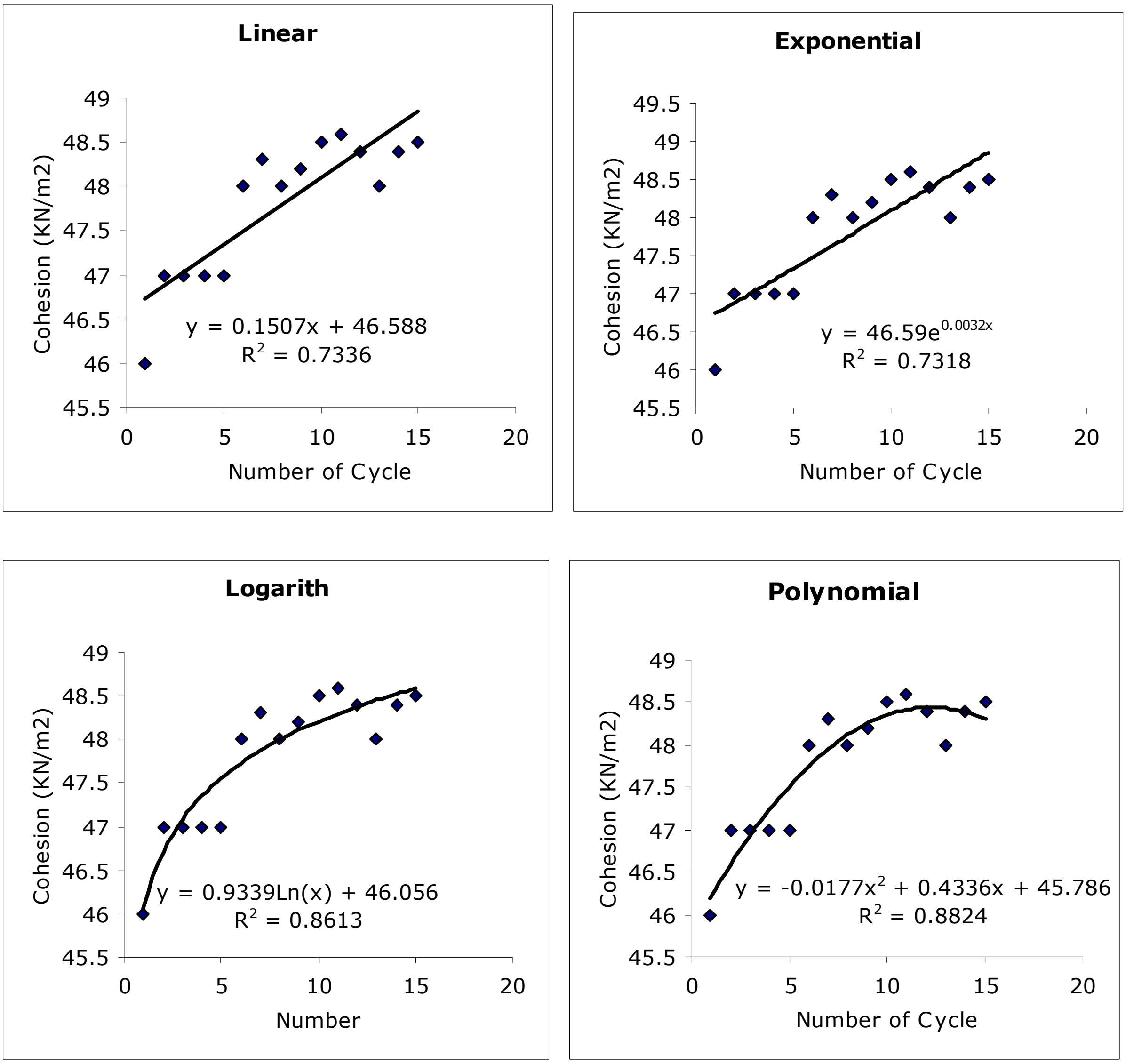
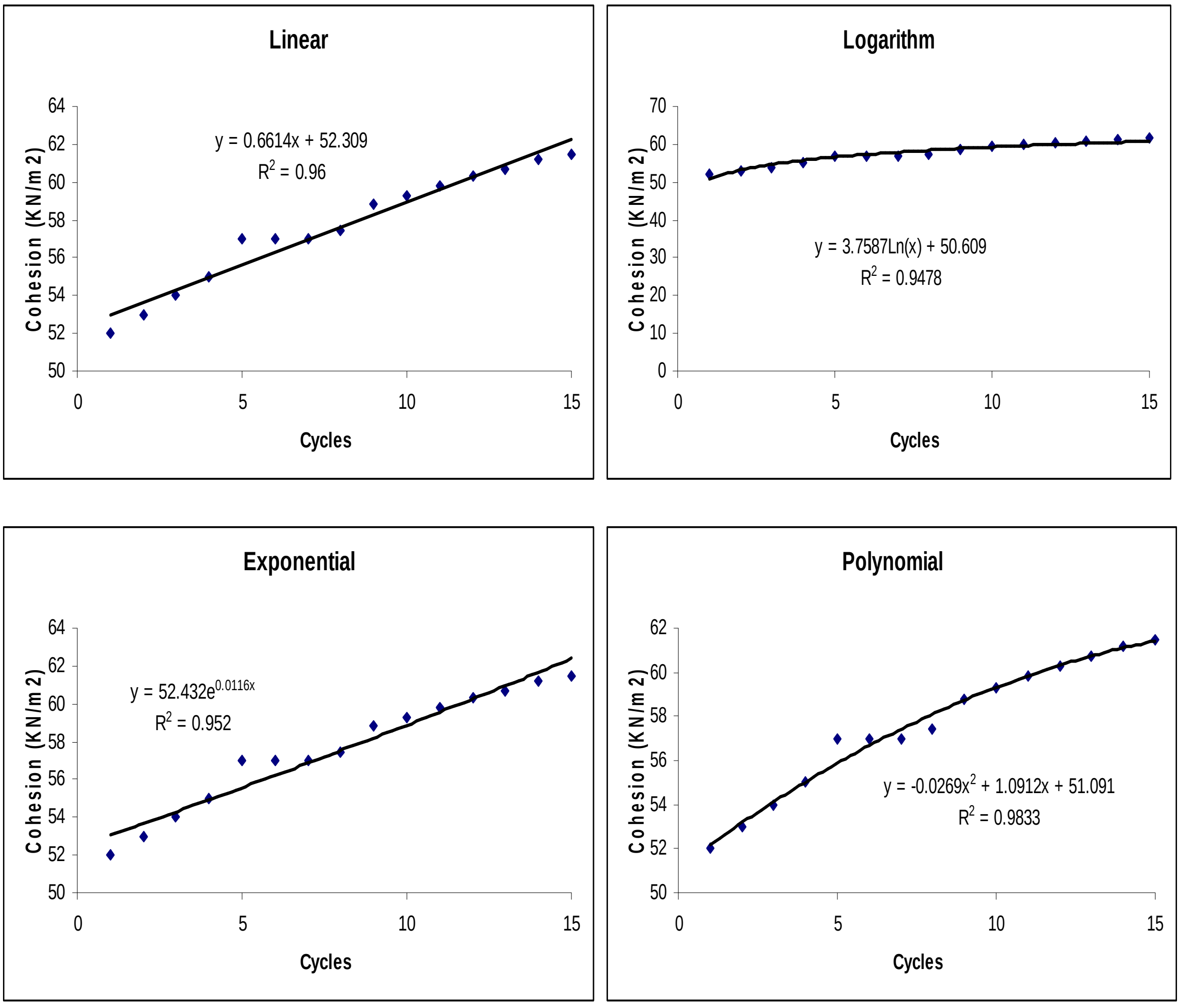


Fig. 2: ***Cohesion Versus Number of Compaction Cycles***

A-7 Type



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