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EFFECT OF COMPACTION CYCLES ON INDEX PROPERTIES OF SOILS FROM WESTERN NIGER DELTA

UGBE[1], F.C. AND AKPOKODJE[2], Enuvie.G.
[1]*Department of Geology, Delta State University, Abraka*
[2]*Department of Geology, University of Port Harcourt, Port Harcourt, Nigeria*

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Abstract
Lateritic soils of Western Niger Delta have been classified as immature laterites. Repeated vehicular loading on soils tends to result in deterioration of soil construction qualities. In this study, lateritic soils from the Western Niger Delta were investigated to determine the effects of vehicular loading which was simulated by subjecting the soils to series of repeated laboratory compaction cycles. The engineering index properties were determined after the specified cycles. The results of the study on A-2 and A-7 soil types from the area revealed that there were different degrees of particle breakdown with increasing compaction cycles. The polynomial equation best explains the effects of compaction cycles on the percentage of fines and liquid limit. Different equations have been developed to relate the effects of compaction cycles on percent fines and liquid limit.

INTRODUCTION

Lateritic soils and concretionary gravels have been observed to deteriorate when subjected to cyclic compaction (Newill 1961; Fukumoto, 1972; Alam and Sridharam, 1981; Akpokodje and Hudec, 1992). Although some studies have been undertaken on the effect of compaction cycles on some index properties of more matured lateritic soils of South-Western Nigeria (Akinmusuru et al 1984; Omotosho and Akinmusuru, 1992), no attempt have been made to investigate the effect of compaction cycles on the relatively immatured lateritic soils of the Niger Delta. The objective of this paper therefore is to establish quantitative relationships between the number of compaction cycles and the values of some geotechnical index properties of deltaic lateritic soils.

LOCATION OF STUDY AREA

The soil samples were obtained from two active borrow pits from Umutu and Sanubi with longitude 06° 13' 00'E and Latitude 05° 54' 00'N and Longitude 06° 02' 00'E and Latitude 05° 40' 00'N respectively (Fig. 1).

GEOLOGY

The general geology of the study area consists of relatively simple diverse types of Quaternary deposits overlying thick Tertiary sandy and clayey deltaic deposit. Three main subsurface lithostratigraphic units (Table 1) have been recognized (Short and Stauble, 1967) in the Niger Delta. From the oldest to the youngest, they are Akata, Agbada and Benin Formation.

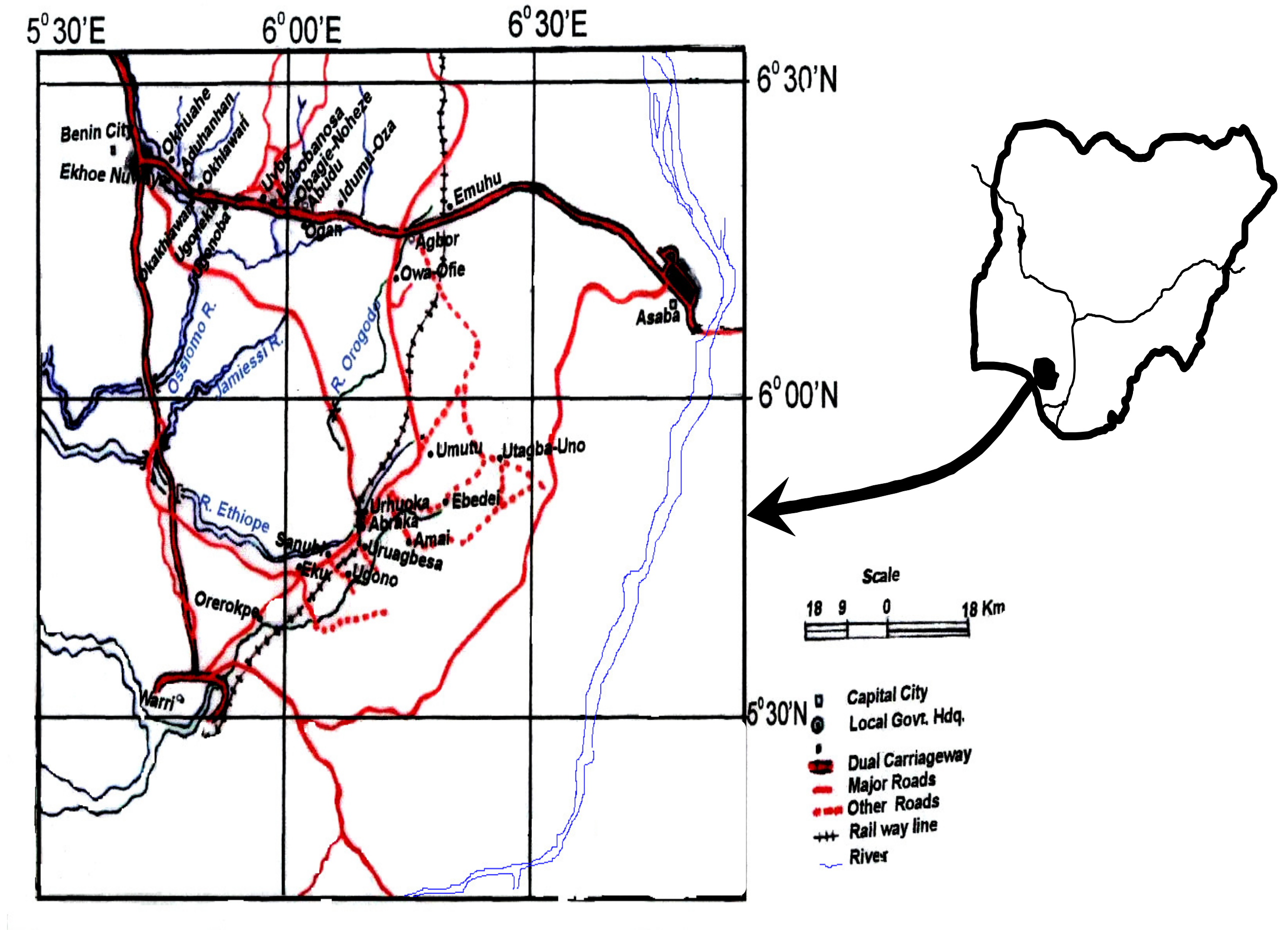

Fig. 1 Map of Study Area

Detailed studies of the Quaternary deposits of the Niger Delta by Allen (1964, 1965) revealed that the sediments were deposited under the influence of fluctuating Pleistocene ecstatic sea levels.

MATERIALS AND METHODS

The samples were obtained from two major borrow pits at Sanubi and Umutu within the study area. The soil samples were first air-dried before subjecting them to basic geotechnical index property tests in accordance with American Society for Testing Material (ASTM) and British Standard (BS) procedures. The average basic geotechnical index properties if these two soil groups are presented in Table 2.

In the compaction cycle test, the soil samples were mixed at about the standard OMC and allowed for 24 hours to homogenize. The soil samples were thereafter compacted for many cycles (ranging from 1-15) breaking down each compacted soil before re-compacting. After the required compaction cycles, the soils were subjected to two basic geotechnical tests namely:

(i) Particle size distribution and
(ii) Atterberg limit (liquid limit).

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Table 1: Geologic Units of the Niger Delta (Short Stauble, 1967)

Geology 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/bandone beach ridge`s	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
Agbala Formation	Mixture of sand, clay and silt	Eocene
Akata Formation	Clay	Paleocene

Table 2: Soils Classification Characteristics

SOIL CHARACTERISTICS	SAMPLE LOCATION	
	SANUBI	UMUTU
Percentage Fines %	35	28
Liquid Limit %	35	23
Plastic Limit %	42	14
Plasticity Index %	26	9
MDD kg/m^3	1760	2060
OMC %	18	11.2
CLASSIFICATION (AASHO)	A-7	A-2

RESULTS AND DISCUSSION

The results of the multiple compaction tests presented in table revealed increases in the percentage of fines by about 5% in A-7 soil types compacted for 15 cycles whilst the increase in fines of for A-2 soil types compacted for the same 15 cycles was about 18%. This represents a greater particle breakdown in A-2 soil type than A-7 soil type. As expected, the particle breakdown is more pronounced in A-2 soil type because they have coarser fractions of gravels and sands. With increase in compaction cycles, these particles tend to break down to finer fractions. The significant particle breakdown could cause serious deterioration of the soil quality when used for pavement construction. The relationship between fines and the number of compaction cycles is illustrated graphically in Fig. 2. There are linear, logarithm, exponential and polynomial relationships.

The relationship between liquid limit and the number of compaction cycles is illustrated graphically in Figs. 3 and 4. In the case of A-2 soils, the liquid limit increased by 2.3% for 15 compaction cycles while for A-7 soils, the liquid limit increased by about 12%. The greater increase in A-7 soil type is most likely due to increased surface area of the silt and clay particles. However, increased compaction cycles in A-2 soils tend to cause breakdown to fine sand fractions which have minimal affinity for water, hence the slight increase of liquid limit.

Table 3: Multicyclic Compaction Tests Results

A - 2 TYPE	
Cycle	**Fines (%)**
1	29
2	30
3	31
4	32
5	33.5
6	34.5
7	35
8	36
9	36
10	36
11	36
12	36
13	36
14	36
15	36
A - 2 TYPE	
Cycle	**LL (%)**
1	30.7
2	30.8
3	31.2
4	31.4
5	31.7
6	31.7
7	31.8
8	31.9
9	32.1

A - 7 TYPE	
Cycle	**Fines (%)**
1	34
2	34
3	34
4	34
5	34
6	34
7	34
8	34
9	34
10	39
11	39
12	39
13	39
14	39
15	39
A - 7 TYPE	
Cycle	**LL (%)**
1	35.2
2	35.2
3	35.2
4	42.5
5	42.5
6	42.5
7	42.5
8	44
9	44

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10	32.3
11	32.4
12	32.5
13	32.7
14	33.0
15	33.0
A - 2 TYPE	
Cycle	**Cohesion (KN/m²)**
1	46
2	47
3	47
4	47
5	47
6	48
7	48.3
8	48
9	48.2
10	48.5
11	48.6
12	48.4
13	48
14	48.4
15	48.5

10	47
11	47
12	47
13	47
14	47
15	47
A - 7 TYPE	
Cycle	**Cohesion (KN/m²)**
1	52
2	53
3	54
4	55
5	57
6	57
7	57
8	57.4
9	58.8
10	59.3
11	59.8
12	60.3
13	60.7
14	61.2
15	61.5

The respective derivable equations representing relation between various geotechnical Index properties and the number of compaction cycles are presented in Table 4. As can be observed from the table, all the correlation coefficients are above 0.5 and they tend to have the highest values in the polynomial equations. In all cases, the polynomial relationship best explains the effects of compaction cycles on percent fines and liquid limit.

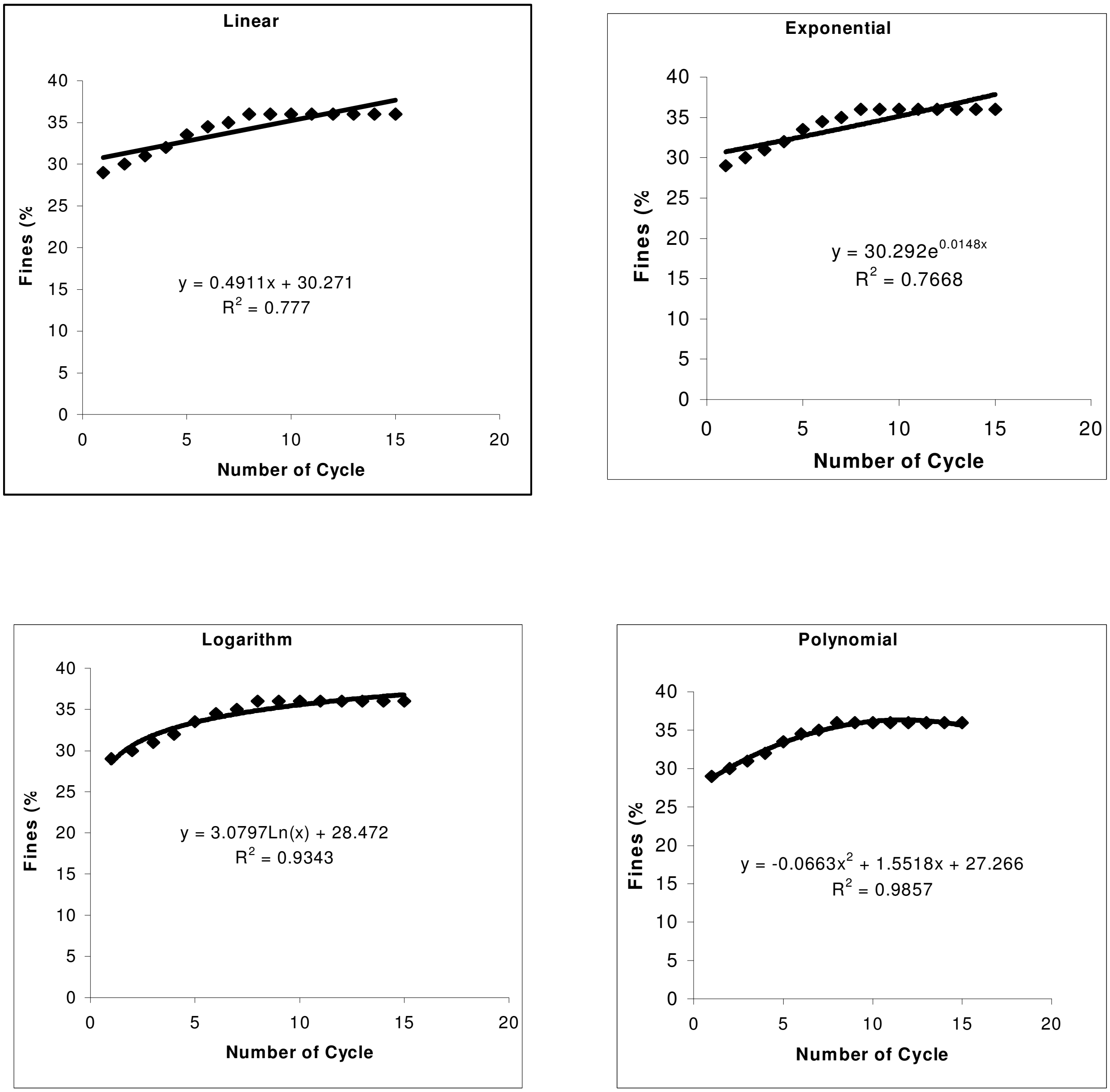

Fig. 3.10: *Fines Percent Versus Number of Compaction Cycles*

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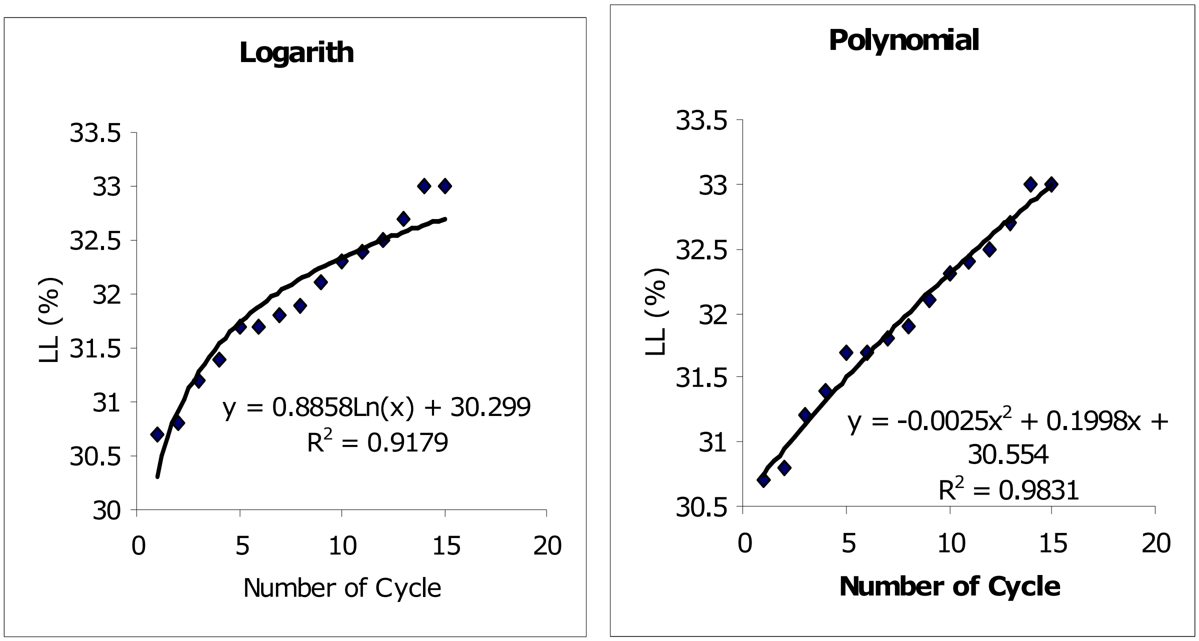
A-2 soil type



A-2 soil type

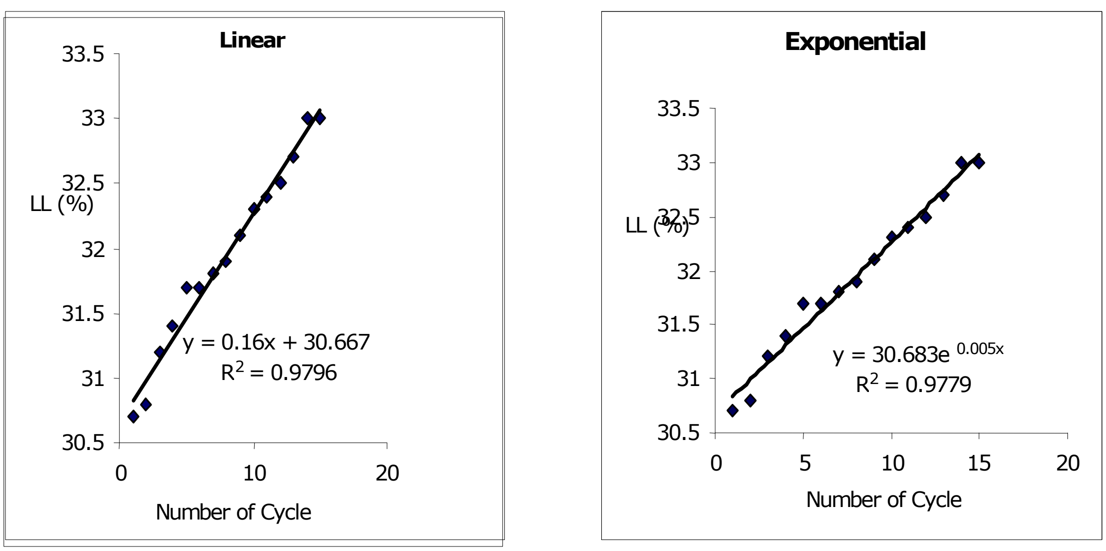


Fig 3. Liquid limit versus number of compaction cycles

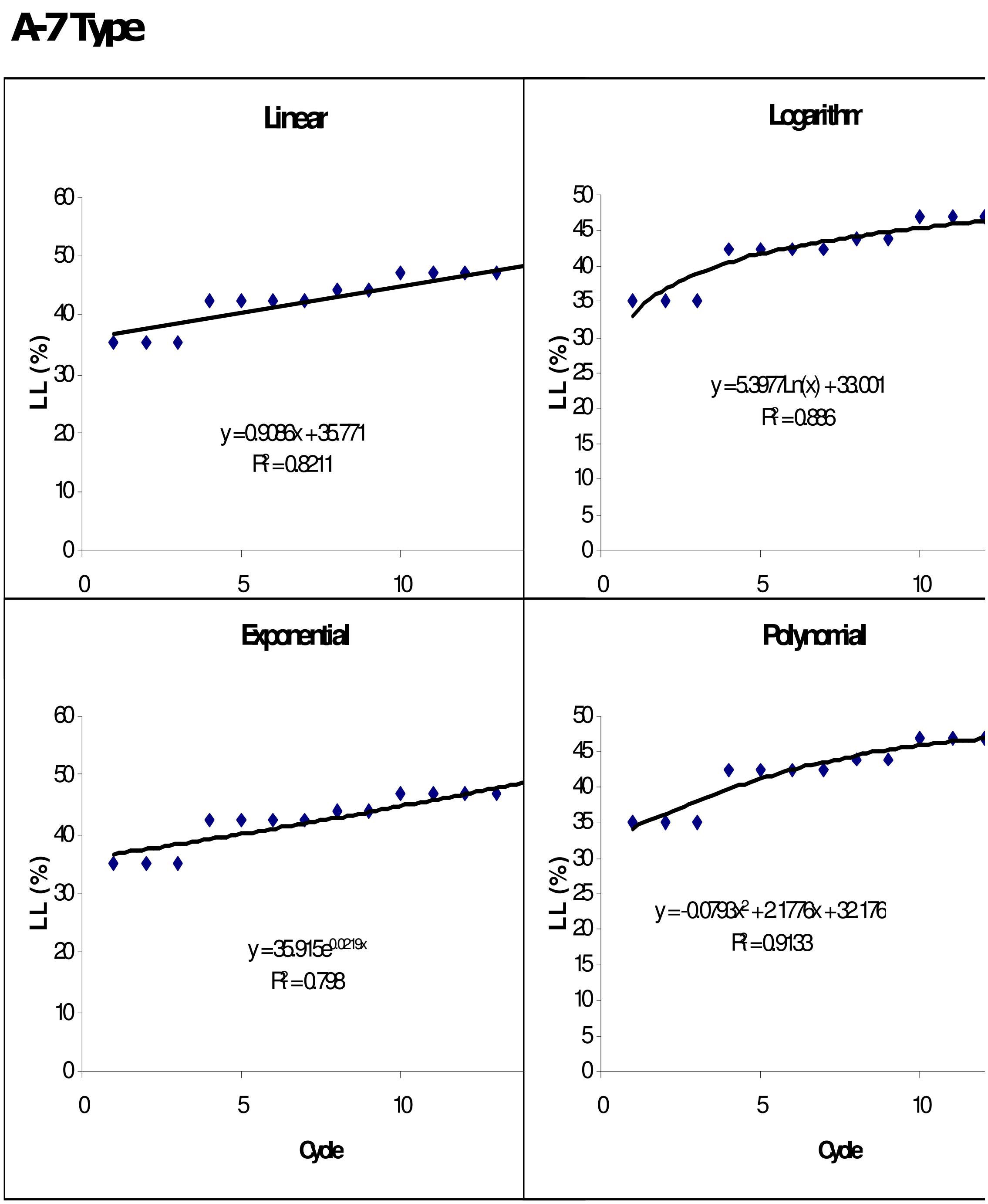


Fig 4. Liquid limit versus number of compaction cycles

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Table 4: *Equations representing relation between various geotechnical Index properties with number of compaction cycles*

	A-2	A-7
Fines (%)		
Linear	Y = 0.4911x + 30.271; R^2 = 0.777	Y = 0.4821x + 32.143; R^2 0.7232
Logarithm	Y = 3.0797Ln(x) + 28.472; R^2 = 0.9343	Y = 2.2999Ln(x) + 31.722; R^2 = 0.5031
Exponential	Y = $30.292e^{-0.0148x}$; R^2 0.7668	Y = $32.311e^{0.0132x}$; R^2 0.7232
Polynomial	Y = -0.663x2 + 1.5518x + 27.266; R^2 0.9857	Y = $0.0327x^2$ – 0.0415x + 33.626; R^2 0.7723
LiquidL. (%)		
Linear	Y = 0.16x + 30.667; R^2 0.9796	Y = 0.9086x + 35.771; R^2 0.8211
Logarithm	Y = 0.8858Ln(x)+30.299; R^2 0.9179	Y = 5.3977Ln(x) + 33.001; R^2 0.886
Exponential	Y = $30.683e^{0.005x}$; R^2 0.9779	Y = $35.915e^{0.0219x}$; R^2 = 0.798
Polynomial	Y = $-0.0025x^2$+0.1998x+30.554; R^2 = 0.9831	Y = $-0.00793x^2$+ 2.1776+32.176; R^2 =0.9133

CONCLUSIONS

In this study, deltaic lateritic soils have been subjected to laboratory multi-cyclic compaction test. The effect of compaction cycles of A-2 and A-7 materials indicate different degrees of particle breakdown with increasing number of compaction cycles. The polynomial equations best explain the effects of compaction cycles on the percent of fines and liquid limit. Different equations have been developed to relate the effects of compaction cycles on fines and liquid limit in both a-2 and A-7 materials.

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