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Pavement Design of Ilaro- Papa Alanto Highway, Ogun State, Nigeria

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Abstract:- The Ilaro to Papa Alanto highway is a major transportation route in the industrial complex of Portland cement manufacturing axis of Ogun State, Nigeria. Several years of studies and the observation of the rate and mode of the highways destabilization or failures prompted the necessityto carry out series geotechnical investigation of the various factor causing the failure, in order tooffer appropriate solutions for the failures and utilize the results of the investigation as credible basis for assisting the evolution of Nigeria standards for highway design. At present, no reliable standards exist in Nigeria, as current standards are generally considered inadequate. The Ilaro - Papa Alanto highway is a typical example of this unfortunate scenario. The present axle load is 505 heavy vehicle traffic which cannot be supported by the road pavement thickness of 120mm. Papa Alanto subbase has high Liquid Limit of 40% and Plasticity Index of 25% while Ilaro 50 %and 15% respectively. Both fall below the minimum requirement for road pavement of 35% for liquid limit and 12% for Plasticity Index. The soaked CBR of the Ilaro and Papa Alanto subgradeand subbase are 6.29% and 8.99% and 3.08% and 9.32% respectively. The increase in CBR reduced the required pavement thickness from 550mm to 50mm (1100% decrease) and reduced the cost of pavement construction from ₦8billion to ₦753million.

***Keywords**:- Road failures, Highway, Geotechnical, Techniques, Engineering Properties and Terralite.*

I. INTRODUCTION

Lateritic clays have shown credible evidence that they are not the optimistic, excellent road construction usually ascribed to them by engineers all over the tropical world, [14]. The physical and engineering properties of lateritic clays are characterized by extreme variations, resulting in very disappointing magnitudes of destabilization of virtually all Nigeria roads and highways soonest after completion. This unfortunate condition has afflicted the Papa Alanto -Ilaro highway since its completion over 20 years ago. The highway is an important communication linkamong cement producing industries in Ogun State of Nigeria, and its incessant failure has posed an important threat to the industrial development of the region.

This study is conceived to utilize engineering geotechnics to design a road pavement that will be able to withstand the heavy traffic wheel load.

II. GEOLOGICAL SETTING OF THE STUDY AREA

The Ilaro to Papa Alanto highway which is the object of this research traverses two prominent geological formations, namely the Ilaro formation and Ewekoro formation of South Western Nigeria.[11], have summarized the respective geological characteristics of the formation, highlighting their sedimentary, stratigraphic and major mineralogical characteristics (Figure 1).

This is generally underlain also by variable thickness of calcareous shale and limestone, to depthsgreater than 40m in thickness. The Ilaro to Papa Alanto highway was constructed over the overlying calcareous clays and sandy clays. This mean that the clays and sandy clays constitute the subgrade of the highway. This, specifically is the major practical reason for the highways instability. Geotechnically, the engineering properties of the clays and sandy clays requireconsiderable study prior to the design and construction of the highway. The Ilaro to Papa-Alanto highway, lies over a distance of 15 km from Ilaro towards Papa-Alanto. The remaining 4 km lies over the Ewekoro formation.

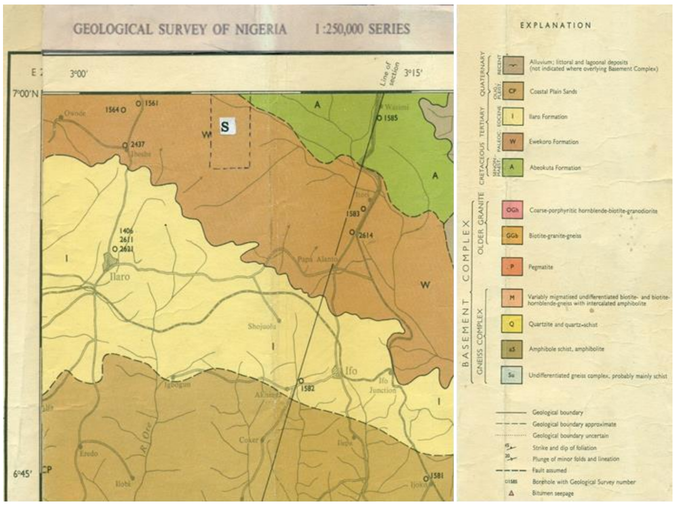

Fig 1: Geological Map of a Part of Southwestern Nigeria (Jones and Hockey, 1957).

III. METHODS AND MATERIALS

This aspect describes the details of materials, methods and experiments carried out on thespecimens.

➢ *Clay Soil*

Soil samples were collected at failed sections of the 20km Ilaro – Papa Alanto highway using hand Auger boring tools for both the Geotechnical and Geochemical laboratory analysis at about eight (8) traverses. Samples of Asphalt concrete were equally cored using a coring machine for highway analysis.

➢ *Field Tests*

Field tests carried out include the following:

Traffic Count: Personnel were stationed at the carriageway of the studied highway with tally sheets, stopwatch and pen for recording. The number of vehicles plying each carriageway was observed and recorded on the tally data sheets on 12 hours (7am – 7pm daily) basis for a particular vehicle category. The exercise was repeated for one full year, from 01 June, 2012 – 31 May, 2013.

Cone Penetrometer Test (CPT): CPT is a reliable means of exploring soils for pavement subgrades and bridge foundations. CPT readings permit clear delineations of various soil strata.

Auger Boring: Auger Boring is an excavation technique using a rotating auger chain/flight fitted with a cutter head. It involves boring and installation of a casing pipe into the ground.

➢ *Laboratory Test on Soil Samples:*

The following tests were carried out in accordance with British Standards, BS 1377 (1990):**Atterberg Limits Tests**: Atterberg limits are used to distinguish the boundary between each soil state based on their water content. It can distinguish between different types of silt and clays.

Particle Size Distribution Test: The Sieve Analysis determines the distribution of aggregate particles, by size in order to determine compliance with design and specifications.

Specific Gravity (Gs): Specific gravity of soils is the ratio of the weight in air of a given volume of soil particles to the weight in air of an equal volume of distilled water at a stated temperature (40ºC).

Compaction Test: Standard Compaction Test was used to determine the Optimum Moisture Content (OMC) and the Maximum Dry Density (MDD) for the various samples collected.

California Bearing Ratio (CBR) Test: Specimens for CBR tests were prepared at their OMC and MDD. The specimens were soaked in water for 24hrs to allow free access of water to both the top and bottom. The top and bottom surfaces of the specimen were then tested. The CBR is the ratio of force per unit area required to penetrate a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm /min. CBR-value is an index of soil strength. It is used in design of road pavements.

➢ *Laboratory Tests on Pavement Samples:*

Bitumen Extraction Test: Bitumen extraction test involves coring portions of the asphaltconcrete and soaking it in a quantity of tricholene (trichloroethylene). Bitumen, the active cementing portion of the Asphaltic concrete is soluble in trichloroethylene [3]. The process dissolves the bitumen in the asphaltic concrete. The bitumen is then extracted with a machine.

Sieve Analysis: Gradation test refers to the quantity expressed in percentage by weight ofvarious particle sizes. This is determined by separating the aggregates into portions, whichare retained on a number of sieves. The results obtained may be expressed as a total percentage.

Marshall Stability and Flow Test: Marshall Stability is the load carrying capacity of a bituminous mixture at 60ºC and it is measured in kilogram. It measures the maximum load sustained by the bituminous material at a loading rate of 50.8mm/min. It is the resistance to plastic flow of cylindrical samples of a bituminous mixture loaded on the lateral surface. Flow value is the vertical deformation at the maximum load.

➢ *Additives used for StabilizationLateralite*

Lateralite is a flux of several minerals with an electrically induced activity in the soils matrix which produces a pozzolanic reaction with the sesquioxides. It induces some level of cementation with the sesquioxides and forms a very strong bond that is insoluble in water[13].

➢ *Cement*

Ordinary Portland cement manufactured by Lafarge was obtained from the open market and used for the research work. Ordinary Portland cement is a fine powder produced by heating materials in a kiln to form what is called clinker, grinding the clinker, and adding small amounts of other materials. It is grey in color.

➢ *Lime*

The lime used for this research work was obtained from retail shop in Ojota, Lagos. Lime provides an economical way of soil stabilization. Lime modification describes an increase in strength brought by cation exchanged rather than cementing effect brought by pozzolanic reaction [17]. Lime reacts with wet clay minerals which results into increased pH which favors solubility of siliceous and aluminous components. These compounds react with Calcium to form Calcium silica and Calcium alumina (hydrated), a Cementous productsimilar to those of cement paste.

➢ *Ant House*

The ant-house samples were collected at about 10Km From Papalanto Junction, along the Papalanto – Ilaro Road at latitude 06º 53. 608’ N; Longitude 003º 02. 061’ E (at an elevation of 86m above sea level). Ant house (Termite clay) is obtained from termite mound. Mound is a pile of earth made by termite resembling a small hill it is made of clay whose elasticity has further been improved by the secretion from the termite while being used in building the mound [15]. It is considered to be a better materialthan the ordinary brick in terms of utilization for molding lateritic bricks [16];[15] Ant house has been reported to perform better than ordinary clay indam construction, [18]. The ant-house was pulverized into fine powder and added in 8%, 10% and 12% to the laterite by weight to assess its effect on the CBR of thesoil.

IV. RESULTS AND DISCUSSIONS

➢ *Traffic Count Analysis*

The result of the Traffic count analysis along the Ilaro – road is shown in Table 1. The traffic countfor the design is determined under the Federal Ministry of Works and Housing Manual (1973). The number of vehicles per day excluding 3 tonnes along Ilaro- Papa Alanto road is 505. Hence, the design traffic count for the road is 505.

Table 1: Traffic Count Results for the Road under Investigation Ilaro-Papa Alanto

Vehicle Classification Time (hrs.)	Number of Carsand Light Vehicles	Number of Light Commercial Vehicles	Number of Heavy Commercial Vehicles	Total Vehicles	Total Passenger Car Unit
7-8	109	17	47	173	64
8-9	130	27	41	198	68
9-10	127	73	45	245	118
10-11	98	55	47	200	102
11-12	82	67	50	199	117
12-1	95	51	57	203	108
1-2	87	63	47	197	110
2-3	93	67	45	205	112
3-4	97	73	41	211	114
4-5	105	69	33	207	102
5-6	129	77	29	235	106
6-7	130	33	23	186	56
12hr – volume	1282	672	505	2459	1177
					1530

➢ *Pavement Design*

The pavement thickness of the existing Ilaro – Papa Alanto Road is 120mm. The CBR value of the subsoil samples at Ilaro and Papa Alanto are 3.08% and 9.32% respectively (Table 2). The CBR values of the subsoil samples at Ilaro and Papa Alanto both fall below the minimum CBR value of 30% of the Federal Republic of Nigeria Highway Manual (1973), Table 3. Using the Federal Ministry of Works and Housing Design Manual (Figure 2), a flexible pavement design curve was generated (Figure 3). The pavement design analysis carried out showed that the requiredpavement thickness of Ilaro subsoil, (CBR=3.08%), is 580mm (22’’) while the pavement thicknessrequired for Papa Alanto subsoil, (CBR=9.32%), is 320mm (12’’), Table 2. The existing Ilaro – Papa Alanto Road pavement thickness of 120mm is therefore grossly inadequate for a subsoil CBRof 3.08% and Traffic count of 505. Road pavement should neither be too thick nor thin. If it is toothin, it will fail to protect the underlying unbound layers, causing rutting at formation level, [12]. A thick road pavement will be expensive and un-economical.

Table 2: Pavement Characteristics of Ilaro and Papa Alanto

Location	Subbase CBR, % (24 hrs)	Average Pavement ThicknessRequired Inches (millimeters)
Ilaro	3.08	22.0" (580)
Papa Alanto	9.32	12.80" (320)

Table 3: General Requirements for Subgrade, Subbase and Base course materials in Nigeria by Federal Republic of Nigeria Highway Manual (1992)

Property	Subgrade	Subbase	Base Course
Fines Content (%)	35	35	35
Liquid Limit (%)	80	35	35
Plasticity Index (%)	55	12	12
Soaked CBR (24hrs) (%)	10	30	80
Relative Compaction (%)	100	100	100

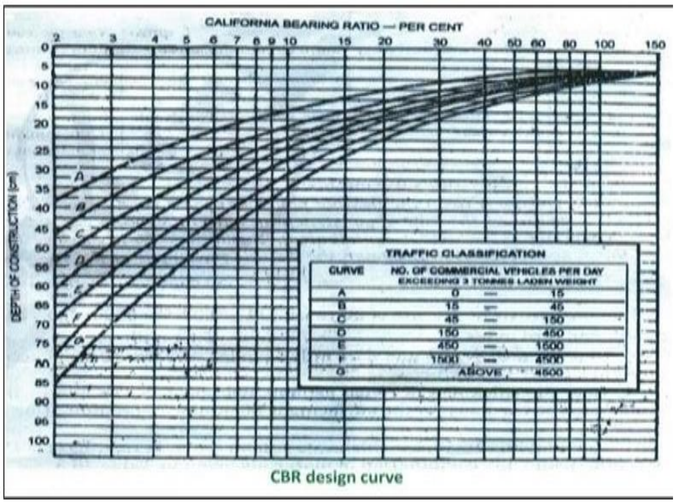

Fig 2: Flexible Pavement Design Curve, Federal Ministry of Works and Housing Design Manual (1973)

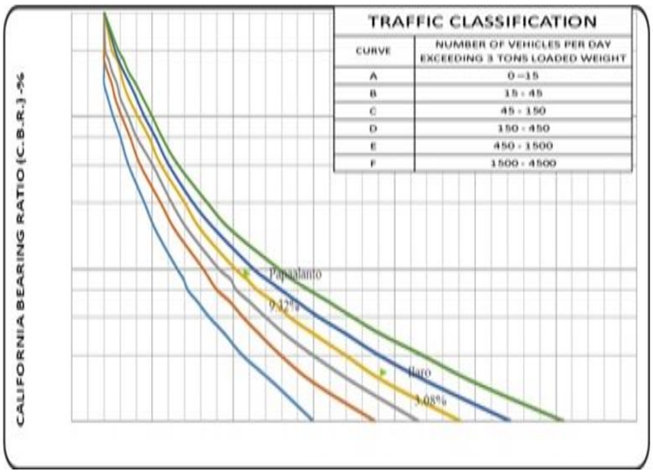

Fig 3: Generated Results for Flexible Pavement Design Curve, CBR and pavement thickness

➢ *Bitumen extraction*

Aggregate Gradation

A detailed result of sieve analysis for some of the aggregate samples recovered from the hot mixasphalt (HMA) for Papa Alanto and Ilaro are presented in Table 4 and Table 5 respectively. A summary of the results is presented in Table 6. Figures 4 and 5 show the graphical representationof the aggregate graduation curves for HMA wearing course from Papa Alanto and Ilarorespectively. The curves were superimposed on the FMW gradation envelope for wearing courseshown in Table 7. The wearing course samples from Papa Alanto did not meet the FMW specifications, while samples from Ilaro conform to FWM specifications for wearing course.

Table 4: Bituminous Mix Extraction Analysis (Papa Alanto)

SIEVES ANALYSIS OF AGGREGATE					
SIEVE SIZES		WEIGH T RETAINED (g)	% RETAINED	% PASSING	% SPECIFICATIO N
Inches	mm				
¾	19	0	0.00	100	100
½	12.5	42.14	5.82	94.18	87-100
3/8	9.5	14.68	2.03	92.15	75-93
¼	6.3	36.31	5.01	87.14	65-84
3/16	4.7	42.61	5.88	81.26	60-76
No.7	2.36	161.25	22.26	59.00	50-64
No.14	1.18	140.07	19.34	39.66	36-50
No.25	0.6	92.16	12.72	26.93	26-40
No.52	0.3	70.04	9.67	17.26	18-30
No.100	0.15	55.57	7.67	9.59	13-24
No.200	0.08	40.63	5.61	3.98	8-15
Pan		28.82	3.98	0.00	-
TOTAL		724.3	100		

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Table 5: Bituminous Mix Extraction Analysis (Ilaro)

SIEVES ANALYSIS OF AGGREGATE					
SIEVE SIZES		**WEIGHT RETAINED (g)**	**% RETAINED**	**% PASSING**	**% SPECIFICATION**
Inches	**Mm**				
¾	19	0	0.00	100	100
½	12.5	29.41	2.31	97.69	87-100
3/8	9.5	104.13	8.17	89.52	75-93
¼	6.3	134.9	10.58	78.94	65-84
3/16	4.7	45.26	3.55	75.39	60-76
No.7	2.36	150	11.77	63.62	50-64
No.14	1.18	182	14.28	49.34	36-50
No.25	0.6	150	11.77	37.57	26-40
No.52	0.3	140.5	11.02	26.54	18-30
No.100	0.15	100.8	7.91	18.63	13-24
No.200	0.08	140.5	11.02	7.61	8-15
Pan		97	7.61	0.00	-
TOTAL		1275	100		

Table 6: Gradation Values for Recovered Aggregates

BS Sieve Size (inches)	**Sieve Opening (mm)**	**Wearing Course (mm)**	
1¼’’	31.5	Papa Alanto	Ilaro
1’’	25		
¾’’	19		90.32
½’’	12.5	94.18	82.49
3/8’’	9.5	92.15	74.25
¼’’	6.3	87.14	65.92
3/16’’	4.75	81.26	58.69
7.0	2.25	59.00	39.26
14.0	1.18	39.66	29.83
25.0	0.6	26.94	23.8
52.0	0.3	17.27	17.29
100.0	0.15	9.6	11.51
200.0	0.075	3.99	5.92

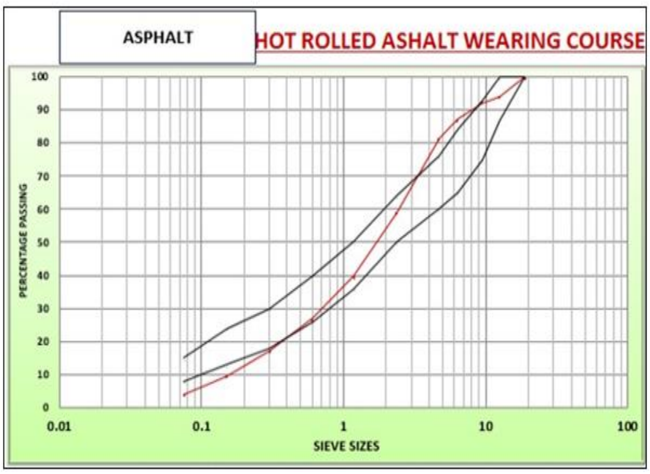

Fig 4: Gradation Curves for HMA Wearing Course (Papa Alanto)

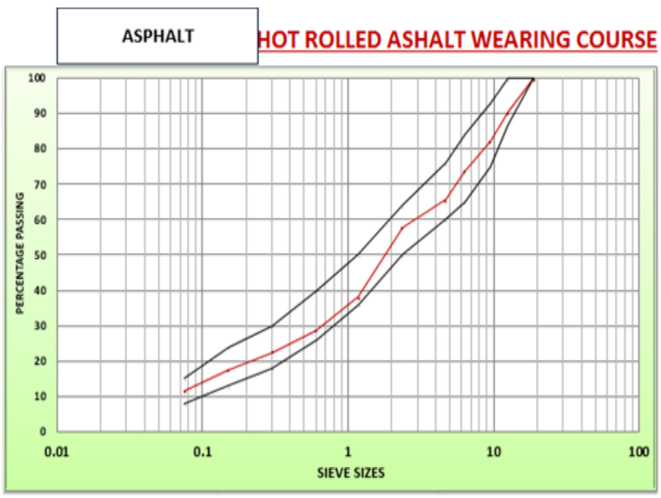

Fig 5 Gradation Curve for HMA Wearing Curves (Ilaro)

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Table 7: Grading Envelopes for Wearing Course (Source: FMW, 1997)

Sieve Size (mm)	Weight Passing (%)
31	100
25	100
19	100
12.5	85 – 100
9.5	75 – 92
6.4	65 – 82
2.8	50 – 65
1.25	36 – 51
0.600	26 – 40
0.300	18 – 30
0.150	13 – 24
0.075	7 – 14
Bitumen content, %by weight of aggregate	5 – 8.0

- *Marshall Stability and Flow Test Results*

Table 8 shows the results of the Marshall Stability test carried out on Papa Alanto and Ilaro samples. Tables 9 shows the requirements of asphalt concrete of the FMW while Table 10 shows the Marshall Mix Design Criteria. The average stability value from the two samples is 6.35kN. The samples from both Papa Alanto and Ilaro conform to the FWM specification for wearing course, but the Papa Alanto samples fail the Marshall Mix Design Criteria for heavy traffic surface and base. Papa Alanto sample has a value of 5.4kN as against the 6.6kN standard from Asphalt Institute. These low values indicate that the sample will crack under heavy traffic, which is evidentfrom physical observation of the road. Ilaro sample has a value of 7.3 kN which meets both FWMand Asphalt Institute standards. These were noted from physical observation of the road, as the stable section of the road.

Table 8: Test Results for Hot Mix Asphalt Samples

HMA Type	Wearing Course		
Property	Papa Alanto	Ilaro	Standard
Bitumen Content (%)	4.6	6.2	(5.0 – 8.0)
Stability (kN)	5.4	7.3	(6.6)
Flow (0.25mm)	6.0	8.7	(8 - 16)
Voids in Total Mixture (%)	4.2	4.2	(3 - 5)
Voids filled with Bitumen(%)	77.5	74.80	(65 - 78)
Specific gravity	2.36	2.42	
Density (g/cc)	2.40	2.36	

Table 9: Properties of Compacted Asphalt Concrete (Source: FMWH, 1997)

Property	Base Course	Wearing Course
Optimum bitumen content, %	4.5 -6.5	5.0 -8.0
Stability , not less than, kN	3.5	3.5
Flow , 0.25mm (mm)	8 – 24	8 – 16
Voids in total mixture, %	3 – 8	3 -5
Voids filled with bitumen, %	65 – 72	75 – 82

Table 10: Marshall Mix Design Criteria

Property	Light Traffic: Surface and Base		Medium Traffic:Surface and Base		Heavy Traffic: Surface and Base	
	Min.	Max.	Min.	Max.	Min.	Max.
Compaction: No ofblows each end of specimen	35		50		75	
Stability, kN	2224		3336		66	72
Flow, 0.25mm	8	20	8	18	8	16
Air Voids (%)	3	5	3	5	3	5
Voids Filled withBitumen (%)	70	80	65	78	65	78
Voids in Mineral Aggregate (VMA) (%)	20	30	20	30	20	30

Source: Asphalt Institute, 1984.

- *Binder Content*

The bitumen contents for Papa Alanto is 4.6% while that of Ilaro is 6.2% (Table 8). This just meets the FMW requirements (Table 9), but falls below the 5-8% requirements of the Asphalt Institute (Table 8). The bitumen contents for Ilaro (6.2%) meets both the FMW requirements (Table 9) and the requirements of the Asphalt Institute (Table 10). The Papa Alanto asphalt samplehas a stability value of 5.4kN as against the 6.6kN standard from Asphalt Institute. The low valueindicates that the sample will crack under heavy traffic, which is evident from physical observation of the road. The Ilaro Asphalt sample has a stability value of 7.3kN which meets bothFWM and Asphalt Institute standards.

➢ *Suitability of the Mixtures*

The properties of the mixtures evaluated in this study are presented in Table 8. The Ilaro sample has a relatively high stability and flow values which meet requirements; hence it is satisfactory. Papa Alanto sample has relatively low stability and flow values, hence, it is not satisfactory for construction purposes. Mixes with abnormally high values of Marshall Stability and abnormally low flow values are less desirable because pavements of such mixes tend to be more rigid or brittleand may crack under heavy traffic [3]. This situation is especially critical if the sub-base and sub-grade materials are weak and permit moderate to relatively high deflectionsunder the actual traffic [19].

The mix design criteria will produce a narrow range of acceptable bitumen contents that pass all the guidelines, (Table 8). The bitumen content selection is then adjusted within this narrow rangeto achieve a mix property that will satisfy the needs of a specific project as shown in Figure 6.

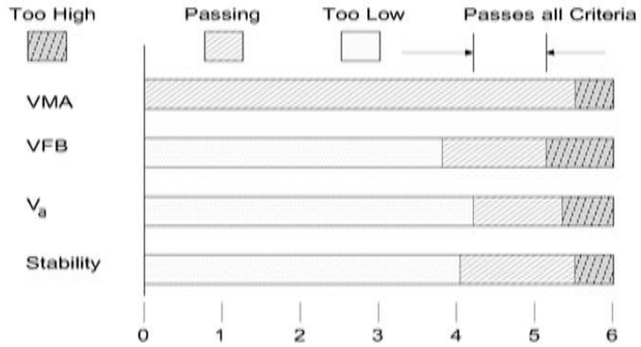

Fig 6: Range of Acceptable Bitumen Contents from the Marshall Test (Source: Zooro, 2002)

➢ *Geotechnical Characteristics*

The soil index properties of the subbase materials at Papa Alanto and Ilaro are presented in Table 11. The soil index properties of the subgrade materials at Papa Alanto and Ilaro are presented in Table 12. The general requirements for subgrade, sub-base and base course materials are listed in Table 13.

Table 11: Engineering Index Properties of Subbase Materials

S/N		PAPA ALANTO						ILARO	
	Location	L1	L2	L3	L4	L5	L6	L7	L8
1	% Passing2mm	93.08	93.00	88.57	95.77	90.40	86.05	74.62	73.33
2	% Passing 0.425mm	58.40	23.65	51.92	44.87	35.52	44.74	29.82	28.26
3	% Passing 0.075mm	7.23	1.72	13.95	8.63	4.88	3.99	4.52	4.71
4	LL	56	37	22	39	42	43	74	42
5	PL	24	18	15	15	37	26	51	37
6	PI	32	19	7	24	5	17	23	5
7	SG	3.06	2.84	2.31	2.20	2.66	2.26	2.50	2.51
8	NMC (%)	12.83	5.8	1.74	7.63	12.16	5.84	5.08	5.46
9	USCS	CH	CL	CL	CL	CL	CL	CH	ML

Table 12: Engineering Index Properties of Subgrade Materials

S/N		PAPA ALANTO						ILARO	
	Location	L1	L2	L3	L4	L5	L6	L7	L8
1	% Passing 2mm	92.83	92.27	83.51	92.96	95.16	81.15	96.04	91.16
2	% Passing 0.425mm	56.35	45.08	44.43	50.98	36.58	37.07	42.40	36.13
3	% Passing 0.075mm	9.09	1.78	12.57	13.72	6.87	4.12	4.00	8.79
4	Liquid Limit, %	50	31	29	31	42	66	66	49
5	Plastic Limit, %	21	10	10	06	18	26	51	11
6	Plasticity Index, %	29	21	19	25	24	40	15	38
7	Group Index	5	5	3	5	5	2	5	4
8	Specific Gravity	2.43	3.53	2.40	2.95	2.66	2.98	2.01	2.07
9	NMC (%)	17.20	12.83	4.90	5.62	14.82	7.35	5.79	7.35
10	USCS	SP	SP	SP-CL	SP-CL	SP	SP	SW	SW
11	AASHTO	A-7-6[b]	A-6	A-6	A-6	A-7-6[b]	A-7-6[b]	A-7-5[a]	A-7-6[b]
12	Subgrade Rating	Fair to Poor							

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Table 13: General Requirements for Road Pavement Materials in Nigeria, Federal Republic of Nigeria HighwayManual (1973)

Property	Subgrade	Sub-base	Base Course
Fines content (%)	35	35	35
Liquid Limit (%)	80	35	35
Plasticity Index (%)	55	12	12
Soaked CBR (24hrs) (%)	10	30	80
Relative compaction (%)	100	100	100

➢ *Particle Size Distribution*

Tables 11 and 12 show the results of the sieve analysis carried out on soil samples from Ilaro –Papa Alanto highway subbase and subgrade. The soil can be classified as an A-7 soil according to AASHTO (1986) soil classification. This is a soil, which consists of fine grains having medium plasticity.

➢ *Atterberg Limit*

From Tables 11 and 12, under the USCS soil classification system, soil samples from both Papa Alanto Subbase have high Liquid Limit (an average of 40%) and very high Plasticity Index (an average of 25%) which falls below the specification of the Federal Ministry of Works for Subbase,Table 13. Ilaro subbase soil samples have very high Liquid Limit (an average of 50 %) and high Plasticity Index (an average of 15%). These are also below the specification of the Federal Ministry of Works for Subbase, Table 13. Therefore, both Ilaro and Papa Alanto subbase soil samples do not meet the required standard for road construction. The soil samples obtained from Papa Alanto subgrade, have Liquid Limit and Plasticity Index values of (29-66%) and (19-40%) respectively while Ilaro subgrade soil samples have LL and PI values of (49-66%) and (16-38%) respectively.This value fall within the specification for subgrade materials, Table 13. This situation is especiallycritical if the sub-base and sub-grade materials beneath the pavement are weak and permit moderate to relatively high deflections under the actual traffic, [19]

V. STABILIZATION WITH CEMENT, LIME, ANT HOUSE AND TERRALITE

➢ *Effects of Stabilizer on the Compaction Characteristics*

The results of compaction test on samples mixed with 0, 8, 12 and 15% by volume of cement, lime, ant house and Terralite are presented in Tables 14 – 17. The addition of cement, lime, ant- house and lateralite decreased the maximum dry density (MDD) of the subbase and subgrade materials of Papa Alanto and Ilaro while the optimum moisture content (OMC) increased.Additives such as lime and cement have been recorded to decrease the density of the compacted soil, [9]. Terralite has also been proven to reduce the density of compacted soils [13]. The MDD decreased with increase in stabilizer content for Ilaro subbase material from 2070kg/m^3 to 1880kg/m^3, 1900kg/m^3, 1960kg/m^3 and 1950kg/m^3 with cement, lime, ant-house and Terralite respectively. The OMC increased with increase in stabilizer content from 12.43% to 14.48%, 14.25%, 14.10% and 14.55% with cement, lime, ant-house and Terralite respectively.

Table 14: Variation of Compaction Characteristics with Stabilizer for Papa Alanto Subbase Material

Property	**Laterite**	**Cement**		**Lime**			**Ant House**				**Terralite**		
	0%	**8%**	**12%**	**15%**	**8%**	**12%**	**15%**	**8%**	**12%**	**15%**	**8%**	**12%**	**15%**
MDD (kg/m^3)	2070	1960	1910	1880	1990	1940	1900	1970	1967	1960	2020	1970	1950
OMC (%)	12.43	13.6	14.29	14.48	13.21	14.11	14.25	13.11	13.72	14.10	13.53	14.32	14.55
Degree of Saturation (%)	71.86	89.7	90.9	91.8	70.8	74.0	74.5	68.3	70.3	73.6	150.	161.	164
Air Voids (%)	**28.14**	**10.2**	**9.1**	**8.2**	**29.1**	**25.9**	**25.4**	**31.6**	**29.6**	**26.3**	**50.2**	**61.8**	**64.4**

Table 15: Variation of Compaction Characteristics with Stabilizer content for Ilaro Subbase Material

Property	**Laterite**	**Cement**			**Lime**		**Ant House**			**Terralite**			
	0%	8%	12%	15%	8%	12%	15%	8%	12%	15%	8%	12%	15%
MDD (kg/m^3)	2250	2130	1980	1950	2090	1960	1950	2210	1990	1960	2201	1989	1976
OMC (m %)	10.7	12.3	13.7	13.7	12.3	13.8	13.7	12.1	12.9	13.4	12.6	13.2	**13.76**
Degree of Saturation (%)	62.95	60.9	60.8	68.2	69.0	78.0	77.2	60.0	64.1	67.0	127.7	134.4	140.9
Air Voids(%)	**37.05**	**39.1**	**39.2**	**31.8**	**31.0**	**22.0**	**22.7**	**40.0**	**35.9**	**33.0**	**-27.7**	**-34.4**	**-40.94**

Table 16: Variation of Compaction Characteristics with Stabilizer for Papa Alanto Subgrade Materials

Property	Laterite	Cement			Lime			Ant House			Terralite		
	0%	8%	12%	15%	8%	12%	15%	8%	12%	15%	8%	12%	15%
MDD (kg/m^3)	2140	2060	1980	1930	2040	1970	1940	2030	1960	1920	2060	2020	1950
OMC (m%)	12.04	13.33	14.49	14.75	12.76	13.65	13.88	12.74	13.11	13.79	13.45	14.37	**14.79**
Degree of Saturation (%)	73.70	66.3	72.5	75.1	71.6	77.1	78.5	63.2	65.2	68.95	137.52	147.68	152.32
Air Voids (%)	26.30	33.6	27.4	24.9	28.3	22.9	21.4	36.7	34.0	31.0	37.52	47.68	**52.32**

Table 17: Variation of Compaction Characteristics with Stabilizer for Ilaro Subgrade Materials

Property	Laterite	Cement			Lime			Ant House			Terralite		
	0%	8%	12%	15%	8%	12%	15%	8%	12%	15%	8%	12%	15%
MDD (kg/m^3)	2250	2160	2040	1960	2170	2010	1980	2115	2024	1997	2180	2046	1987
OMC (m %)	9.89	11.79	12.99	14.00	11.74	12.87	13.94	11.69	12.76	13.89	11.86	13.01	14.50
Degree of Saturation (%)	59.35	58.04	64.49	69.93	65.46	72.35	78.87	57.63	63.40	69.49	119.95	132.66	149.11
Air Voids (%)	40.65	41.96	35.51	30.07	34.54	27.65	21.13	42.37	36.60	30.51	-19.95	-32.66	-49.11

- *Effects of Stabilizer on the Air voids*

The addition of cement, lime, ant-house and lateralite decreased the air voids in the subbase and subgrade materials of Papa Alanto and Ilaro. The Air voids decreased with increase in stabilizercontent from 28.14% for Papa Alanto subbase to 8.2%, 25.48%, 26.32% and -64.45S% with cement, lime, ant-house and Terralite respectively. The addition of 8% Terralite gave a negativeAir void which indicates that there are no air void present in the compacted soil mixture. Thisphenomenon is called 'cold-sintering' of the mixture [2]. Terralite is very effective inimproving the strength characteristics of lateritic soils and it can be used to improve the subgradeand subbase layers of heavily trafficked roads.

- *Effects of Stabilizer Content on the California Bearing Ratio (CBR).*

For the design of road pavement, the thickness of the various layers of the pavement (base and wearing course) is determined majorly by the strength of the subgrade material (expressed as the California Bearing Ratio). The higher the CBR of the subgrade the thinner the pavement thickness.The thickness of the subbase/capping layer is dependent on the CBR of the subgrade and is determined in accordance with HD 25/94, [5].The CBR is an indirect index of the bearing capacity of soils in highway construction. It is the most significant soil index affected by Terralitestabilization, [13]. The CBR of the subgrade and subbase soils from Ilaro and Papa Alanto are presented in (Tables 18 and 19). The natural soil from Ilaro and Papa Alanto subgrade have low CBR values of 13.42 and 16.56 which reduced by 47% and 54% respectively after soaking for 24 hrs and 48 hrs.

The 24hr soaked CBR of the subgrade soil at Ilaro and Papa Alanto are 6.29% and 8.99% respectively; both are below the minimum requirement of 10% for subgrade (Table 13). The 24hrsoaked CBR of Ilaro and Papa Alanto subbase are 3.08% and 9.32%; both are below the minimum requirement of 30% for subbase (Table 13).

The addition of ant-house, lime, cement and Terralite increased the soaked CBR of Ilaro subgradefrom 6.29% to 9.32%, 94.3%, 135.9% and 289.21% respectively. The increase in soaked CBR meets the minimum requirement of 10% for subgrade. The addition of ant-house, lime, cement and Terralite increased the soaked CBR of Papa Alanto subgrade from 8.99% to 13.41%, 104.8%, 140.4% and 275.32% respectively. The increase in soaked CBR meets the minimum requirementof 10% for subgrade, except for Ilaro subgrade with ant-house. The increase in soaked CBR with lime, cement and Terralite satisfies the soaked CBR requirement of 80% for Base courses. The results revealed that the cement stabilized samples reduce in CBR values after 24hours of soaking (between 95% and 86%) and furtherby 79% and 82% when soaked for 48 hours while Terralite stabilized samples gained strength after 24hour soaking. This shows that Un-stabilized laterite soil, Ant House stabilized, lime stabilized and cement stabilized soil are not satisfactory for prolonged raining season. Terralite-soil samples that shows a significant increase in CBR values (within the range of (336% - 374%) even after 96 hours of soaking.

Table 18: Subgrade CBR Value

	Laterite			Ant House			Lime			Cement			Teralite		
Location	Un	S (24hrs)	S (48hrs)	Un	S (24hrs)	S (48hrs)	Un	S (24hrs)	S (48hrs)	Un	S (24hrs)	S (48hrs)	Un	S (24hrs)	S (48hrs)
Ilaro	13.42	6.29	5.00	24.84	9.32	4.34	106.5	94.3	84.5	178.0	135.9	117.7	142.41	289.21	484.82
Papa-Alanto	16.56	8.99	9.65	45.21	13.41	15.01	117.7	104.8	92.4	164.8	140.4	119.8	123.61	275.32	486.17

Table 19: Subbase CBR Value

	Laterite			Ant House			Lime			Cement			Teralite			
Location	Un	S (48hrs)	S (48hrs)	U	S (24hrs)	S (48hrs)	Un	S (24hrs)	S (48hrs)	Un	S (24hrs)	S (48hrs)	Un	S (24hrs)	S (48hrs)	S (96hrs)
Ilaro	60.5	3.08	2.09	60.5	20.95	10.32	80.2	57.4	50.2	155.8	148.47	117.1	148.47	294.32	495.39	490
Papa-Alanto	12.99	9.32	2.65	41.2	10.78	5.87	77.8	74.4	65.9	148.8	127.5	104.9	130.73	268.15	486.12	490

UN = Unsoaked S = Soaked

➢ *Pavement Thickness, Design and Cost Analysis*

The traffic count analysis showed that the road which was originally designed for medium trafficis now being used for heavy traffic load of 505. The pavement thickness of the existing Ilaro – Papa Alanto Road is 120mm. The CBR value of the subsoil samples at Ilaro and Papa Alanto are3.08% and 9.32% respectively (Table 2). These are below the minimum CBR value of 30% of the Federal Republic of Nigeria Highway Manual (1992), Table 3. The pavement design analysis carried out showed that the required pavement thickness of Ilaro subsoil, (CBR=3.08%), is 580mm (22'') while the pavement thickness required for Papa Alanto subsoil, (CBR=9.32%), is 320mm (12''), Table 2. The existing Ilaro – Papa Alanto Road pavement failed because it is grossly inadequate to sustain the imposed heavy axle traffic load of 505.

Table 20 shows the required pavement thickness for unstabilized and stabilized soil using lime, cement, ant-house and Teralite and the cost of construction. Pavement thickness required for un- stabilized soil is 580mm and for stabilized soil are: 295mm (laterite with ant House), 103mm (laterite with lime), 57.5mm (laterite with cement) and 50mm (laterite with Teralite stabilized soil.The cost of road pavement using un-stabilized soil is more than #8 billion. The cost of road pavement using stabilized soil is about #5 billion (soil with Ant-house), #2 billion (soil with lime),#900 million (soil with cement) and about #700 million for soil stabilized with Teralite.

Table 20: The Cost of Construction of Road using Various Types of Stabilizing Agents

StabilizingAgent	Road Width (m)	Road Thickness (mm)	Volume/Kmm^3/Km	Cost/Km (N)	Cost/19.5Km (N)
Laterite	11.25	550	6,187.5m^3	425,040,000.00	8,288,280,000.00
Anthouse	11.25	295	3318.75 m^3	227,976,000.00	4,445,532,000.00
Lime	11.25	102.5	1153.13 m^3	79,212,343.47	1,544,640,698.00
Cement	11.25	57.5	646.89 m^3	44,437,030.40	866,522,092.80
Teralite	11.25	50	562.5 m^3	38,640,000.00	753,480,000.00

NO	OBJECTIVES	RESULTS
i.	Determine the axle loads on the road due to vehicular volume.	The present axle load is 505 heavy vehicle traffic which cannot be supported by the road pavement thickness of 120mm. The average CBR of 6.16% requires a pavement thickness of about 550mm to withstand the present axle load of 505 heavy vehicle traffic.
ii.	Investigate the geotechnical properties of the soil	Papa Alanto and Ilaro subbase and subgrade have poor geotechnical properties. The CBR of the subsoil at Ilaro (3.08%) and Papa Alanto (9.32%) fall below the minimum CBR value of 10% (Subgrade) and 30% (Subbase) of the Federal Republic of Nigeria Highway Manual (1992). The natural soil requires stabilization. Stabilization with Teralite increased the CBR to 275% and decreased pavement thickness to 50mm.

VI. CONCLUSIONS

From the results of the investigation conducted on Ilaro – Papa Alanto highway, the followingconclusions can be made:

- ➢ The number of vehicles per day excluding 3 tonnes along Ilaro - Papa Alanto road is 505. Hence,the design traffic count for the road is 505. This is a heavy axle traffic. The CBR values of the subsoil samples at Ilaro (3.08%) and Papa Alanto (9.32%) both fall below the minimum CBR value of 30% of the Federal Republic of Nigeria Highway Manual (1992).
- ➢ The pavement design analysis carried out showed that the required pavement thickness of Ilaro subsoil, (CBR=3.08%), is 580mm (22'') while the pavement thickness required for Papa Alantosubsoil, (CBR=9.32%), is 320mm (12''). The existing road pavement thickness of 120mm is grossly inadequate for a subsoil CBR of 3.08% and Traffic count of 505.
- ➢ The Bitumen aggregate graduation showed that the wearing course samples from Papa Alanto did not meet the FMW specifications, while samples from Ilaro conform to FWM specificationsfor wearing course. Papa Alanto samples also failed the Marshall Mix Design Criteria for heavytraffic surface and base. Papa Alanto

sample has a value of 5.4kN as against the 6.6kN standard from Asphalt Institute. This low value indicates that the sample will crack under heavy traffic.Ilaro sample has a value of 7.3 kN which meets both FWM and Asphalt Institute standards. ThePapa Alanto section of the road failed to meet the stability and flow specification for heavy traffic.

- Both Ilaro and Papa Alanto subgrade soil samples have poor geotechnical properties which fall within the AASHTO subgrade rating of 'poor to fair'. Papa Alanto Subbase soil have high Liquid Limit (40%) and high Plasticity Index (25%). Ilaro subbase soil have high Liquid Limit(50 %) and high Plasticity Index (15%). Both Ilaro and Papa Alanto subbase soil samples do not meet the Federal Ministry of Works standard requirement for Subbase (Liquid Limit of 35%, Plasticity Index of 12%) for road construction.
- The 24hr soaked CBR of the subgrade soil at Ilaro and Papa Alanto are 6.29% and 8.99% respectively, both are below the minimum requirement of 10% for subgrade. The 24hr soaked CBR of Ilaro and Papa Alanto subbase are 3.08% and 9.32% respectively, both are below the minimum requirement of 30% for subbase. The subgrade and subbase soil at Ilaro and Papa Alanto both requie soil stabilization.
- Soil stabilization with the addition of ant-house, lime, cement and Terralite increased the soakedCBR of Ilaro subgrade from 6.29% to 9.32%, 94.3%, 135.9% and 289.21% respectively. The addition of ant-house, lime, cement and Terralite increased the soaked CBR of Papa Alanto subgrade from 8.99% to 13.41%, 104.8%, 140.4% and 275.32% respectively. The increase in soaked CBR with lime, cement and Terralite satisfies the soaked CBR requirement of 80% for Base courses.
- Soaked CBR of Cement stabilized samples reduced after 24hours of soaking (by 95% to 86%)and further by 79% and 82% when soaked for 48 hours. Terralite stabilized samples gained strength after 24hour soaking. This shows that Ant House stabilized, lime stabilized and cement stabilized soil are not good for prolonged raining season. Terralite stabilized soils showsignificant increase in CBR (336% - 374%) even after 48 hours of soaking.

RECOMMENDATIONS

- Open drainage system is recommended to facilitate the removal of run-off water as theaccumulation of water threatens the stability of the underlying soil and pavement.
- Establishment of at least one well equipped functional road pavement evaluation unit in each state of the federation to ensure periodic evaluation of road pavements.
- Multi-disciplinary approach by integrating highway and geotechnical investigation methods should be adopted in the design, construction and maintenance of road pavements and solving road pavement problems.
- It is expedient to establish a functional pavement evaluation unit in all state of Nigeria to compliment the inadequacy of the only one in Kaduna for periodic road evaluation.

REFERENCES

[1]. **AASHTO. (1986).** Standard specification for transportation materials and methods of sampling and testing, 14th Ed., Washington, D.C.

[2]. **Alayaki F.M. (2001).** An Examination of the Engineering Characteristics of Lime, Cement and Terralite Stabilized Laterite Base Courses; Unpublished M.Sc. Project, Department of Civil Engineering, University of Lagos, Akoka, Nigeria.

[3]. **Asphalt Institute (1984).** Asphalt Paving Manual, Manual Series No. 8 3rd edition, The Asphalt Institute, Maryland, USA, 61 - 130.

[4]. **British Standard Institute (BS). (1990a)** Methods of testing soils for civil engineering purposes, BS1377, London.

[5]. **Dot (1994).** Skidding resistance, HD 28/94. Design manual for roads and bridges, volume 7: Pavement Design and Maintenance. The stationary office, London, UK.

[6]. **Federal Republic of Nigeria Highway manual (1992):** General specification requirements for roads and bridges. Clause 6102 and 6122 Vol II

[7]. **Federal Ministry of Works and Housing Design Manual (1973):** Highway Manual Road Design Part1: 200-220

[8]. **Federal Ministry of Works and Housing (FMW) (1997)**: General Specification (Roads And Bridges), Vol. II, Federal Ministry of Works and Housing, Abuja: 230 – 232

[9]. **Gidigasu M.D. (1976):** Laterite soil Engineering, Pedogenesis and Engineering Principles. Elsevier Scientific Publishing Company Amsterdam Oxford New York.

[10]. **Jones, H.A. and Hockey, R.D. (1957).** The Geological Map of Part of South-Western Nigeria, *Geological Survey Nigeria Bulletin,* 31.

[11]. **Jones, H.A. and Hockey, R.D. (1964).** The Geology of Part of South-Western Nigeria, *Geological Survey Nigeria Bulletin,* **31**: 56 - 86.

[12]. **Martin Rogers (2003).** Highway Engineering, Blackwell Publishing Limited, Oxford, USA.

[13]. **Meshida, E.A. (2005).** Terralite: A New Stabilizer for Fine Grained Lateritic Soils for Road Works, Proceedings of the 2nd International Conference in Engineering, University of Lagos, Nigeria, May 23 - 26, 183 - 193.

[14]. **Meshida, E.A. (2006a).** Highway Failure over Talc-Tremolite Schist Terrain: A Case Study of the Ife-Ilesha Highway, South-Western Nigeria, *Bulletin of Engineering, Geology and Environment,* **65**: 457 - 461.

[15]. **Mijinyawa Y., Lucas, E.B. and Adegunioye, F.O. (2007)** Termite Mound Clay as Material for Grain Silo Construction. Agricultural Engineering International: the CIGR E journalmanuscript BC 07 002. Vol. IX.

[16]. **Odumodu, R.C. (1999)** Clay bricks Industry in Nigeria, problem and prospects. Engineering focus3:6:37-40.

[17]. **Sherwood. P. (1993).** Soil stabilization with cement and lime. State of the Art Review. London: Transport Research Laboratory, HMSO.

[18]. **Yohanna, J.K., Fulani, U. Azagaku, E.D. and Anda, A.D. (2003).** Prospect of using anthill materials for the control of seepage in earthdam. Proceeding of the Nigerian Institution of Agricultural Engineering. 25: 135-143.

[19]. **Zooro, S.E (2002).** Design and Construction of Hot-Mix Bituminous Surfacing and Road Basses.In Highways: The location, Design, Construction and Maintenance of Road Pavements byO' Flaherty, C.A., Heinemann, 4th edition.