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Soil-Cement Stabilization Using Papalanto to Sagamu Road in Ogun State, Nigeria as Case Study

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---***ABSTRACT***---

The road from Papalanto to Sagamu located inOgun State of Nigeria is a very busy route. Daily a minimum of 300 fully loaded articulated vehiclescarrying up to 90 tons of cementeach;usethe route as a transit point to distribute products from factories of Dangote Industries Ltd (DIL)and Lafarge Plc. located at Ibese and Ewekoro in Ogun State of Nigeria respectively to other parts of the country. The road however is in a state of constant distress as a result of the heavy load plying the route and this is further worsened by poor maintenance culture of roads across the country. To curb this menace, arrangement was made by Dangote industry limited (DIL) and Lafarge Plc.to explore ways of carrying out palliatives that will ease hardship road users facebymaking the road motorable albeit temporarily until a permanent solution is put in place by the Federal Government of Nigeria. The palliative involved improving the strength of the road base course by stabilization with 5% Cement by weight of soil to enable the layer perform as a road riding surface for at least 12 months pending when a permanent solution will be put in place by government. The exerciseled to an increase in the California Bearing Ratio (CBR) of the base course by as much as 300%; however, the increase in CBR did not translate to a satisfactory Compressive Strength for the stabilized section and as a result, the stabilization exercise could not achieve the aim for which it was carried out as the sections stabilized could not perform satisfactorily as riding surface for the projected one (1) year anticipated in the original plan. Details of the method employed for the soil-Cement Stabilization exercise, challenges encountered, possible reasons why the sections did not perform satisfactorily including summaries of laboratory and field controltest are presented in this paper.

Keywords: *Articulated Vehicles, Base Course, California Bearing Ratio, Stabilization, Compressive Strength, Soil-Cement*

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I. INTRODUCTION

The road from Papalanto to Sagamu is approximately 43 km South of Abeokuta and almost 80 km throughAgbara to Sagamu interchange inOgun State of Nigeria (Adebayo and Adigun, 2018). This road is a very important transit route for transportation of goods and services across Nigeria. Just like most busy routes in Nigeria, several sections of the road have failed making movement on the route an unpleasant experience for vehicles and road users.According to a study done by Ede in 2014, Starting from an Average Daily Traffic (ADT) of 48,311 vehicles per day for the Lagos-Sagamu axis in 2009, the traffic projection over 20 years at 4% growth rate on same axis stands as 71,513 for 2019, 87,006 for 2024 and 105,856 for 2029. The road from Papalanto to Sagamu was constructed across relatively stable and some predominantly low-lying areas threatened by influx of water which rises up to the carriageway during wet season (Adebayo and Adigun, 2018). The road is a flexible pavement comprising of a subgrade, sub base, base course and asphalt surface course. Failures observed on the road between the period of January 2019 to December 2019 include; Rutting, Shear failure, Cracking (longitudinal and edge), Pumping, Potholes and Slippage. Several factors such as geotechnical properties of soils, topography and drainage, climate, geology, poor design, poor construction materials and poor construction techniques are responsible for road failure in Nigeria (Osadebe and Omage, 2005). Most of theimportant road networks in Nigeria were built over 30 years ago and with the exponential increase in the country's population; the number of road users has increased considerably (Ede, 2014). This situation is putting the roads in a state of perpetual distress. Current state of the road infrastructural decay in Nigeria is related to the poor road maintenance culture obtained in the country this is further worsened by the excessive stresses caused by heavy vehicular loads on the road networks (Ede, 2014). Road pavements provide traction for vehiclesto travel as well as transfer normal stresses from the vehicle to the underlying soils. The functionof pavement is to reduce stress on the subgrade such that there is no subgrade deformation under traffic action (Rolt, 2014). For structural design of pavements, vehicles with unlading weight exceeding 1500kg and their axle loading are considered for design. Road pavements are arranged in order of descending load bearing capacity with the highest load bearing capacity material on top and lower load bearing capacity material below (Mathew and Rao, 2006). Pavement structure design and maintenance requires a quantification of all expected loads on the pavement using the equivalent single axle loads and this approach converts axle configuration and axle loads of various magnitudes and repetitions into an equivalent number of standard loads of 80KN (Ede,2014).

The presence of the factories of the two leading producers of cement in Nigeria, Dangote Cement Plc. and Lafarge Cement Plc. have contributed largely to the increase in the number of vehicular loads that ply the route as the Papalanto to Sagamu road serves as a major transit route to connect to other parts of the country for delivery of products. To address the deteriorating state of the road, the two companies undertook the task of providing palliative measures to ease the challenges faced by road users and also enhance mobility of vehicles plying the road. The measure involved providing a soil cement layer in failed portions of theroad so as to improve the load carrying capacity. The sections where soil cement is introduced are to serve as the final riding surface for vehicular movement. The aim of the exercise is to provide a surface that will perform the function of a pavement satisfactorily for a projected period of 1 year before a permanent solution is provided by the Federal Government.

II. LITERATURE REVIEW

Soil Cement is a compacted mixture of pulverized soil, Portland cement and water used for construction of base courses and sub bases for streets, roads, highways, shoulders, airfield pavements and parking areas to provide a firm, durable pavement layer with considerable bearing strength which distributes imposed traffic loads to the underlying weaker subgrade(Nussbaum and Larsen, 1963) Nussbaum and Larsen listed some advantages of soil cement to include;

1. Protection from failure within the sub grade layer is provided by the load spreading capability of soil-cement
2. Volume changes within the base due to freezing and thawing or wetting and drying are minimized
3. The strength of soil-cementbase provides a stable working platform for construction operations

Soil stabilization improves soil strength and increases resistance to softening by water through bonding of the soil particles, water proofing the particles or combination of both (Sherwood, 1993). The principal purpose of soil stabilization with cement is to achieve increase in strength and this occurs as a result of increase in cohesion (Bell, 1995). Factors that affect strength of stabilized soil include presence of organic matters, sulphates, sulphides and carbon dioxide in stabilized soils may contribute to undesirable strength of stabilized materials (Netterberg and Paige-Green, 1984). The strength of soil-cement is affected by the character of the soil, the type and amount of cement added and the length of time available for curing (Bell, 1995). During soil-cement stabilization, chemical hydration of cement takes place which results in formation of calcium hydroxide and this increases the PH value of the aqueous phase to approximately 12.2 (Bell, 1994) According to Sherwood, (1993) if the PH value of a soil-cement mix is 12 or above when tested 15 minutes after addition of water; the soil will develop required strength. Sufficient moisture is required during soil cement stabilization process to enhance the process of hydration and also for efficient compaction (Makusa, 2012). For a given degree of compaction, stabilized mixture has lower maximum dry density than that of un-stabilized soil (Makusa, 2012). Typical flexible road pavement comprise of the following layers; Wearing Course, Binder Course, Base Course, Sub Base and the Subgrade. The use of the different layers is however based on either necessity or economy as some layers can be omitted (Ede, 2014). Subgrade is the upper layer of the natural soil which maybe undisturbed local material or maybe soil excavated elsewhere and placed (Ede, 2014). The Sub base on the other hand helps to reduce traffic stresses to acceptable limits within the subgrade and provides suitable platform for construction purpose (Ede, 2014). As mentioned earlier, the scope of contract investigated is to stabilize the base course layer at failed portions with cement so as to make the road motorable

III. METHODOLOGY

A road condition survey was undertaken to assess the condition of the existing pavement from Km 0+ 000 at Papalanto to Km 40 +000 by Sagamu express interchange. Based on observations made during a reconnaissance survey, a rehabilitation/maintenance program was drawn up to address challenges at the various sections with the aim of repairing the failed sections prior to stabilization. The kind of repairs from section to section varied because some failures were only partial affecting the existing asphalt surface while others required complete repair of the various earthworks layers. The condition survey revealed that out of the 300,000m^2 (40,000x7.5) length of finished road, 40km and width of carriageway 7.5m, 75,000m^2have failed at different levels of failure and require stabilization to make the road motorable.

Table 1- Condition Survey

S/No	Chainages	Condition of Carriageway	Remarks
1	0+000-1+994	Bad	Repair Base
2	1+994-3+055	Fair	Repair base
3	3+055-3+113	Good	Ok
4	3+113-3+860	Good	Ok
5	3++886-4+006	Good	Ok
6	4+006-4+118	Bad	Repair sub base and base
7	4+118-4+182	Fair	Repair Base
8	4+182-4+208	Fair	Repair Base
9	4+208-4+376	Good	Ok
10	4+376-4+434	Good	Ok
11	4+434-4+507	Good	Ok
12	4+507-4+532	Fair	Repair Base
13	4+532-4+554	Fair	Repair Base
14	4+554-4+627	Fair	Repair Base
15	4+627-4+664	Fair	Repair Base
16	4+664-4+806	fair	Repair Base
17	4+806-5+322	Good	Ok
18	5+322-5+473	Fair	Repair base course
19	5+473-8+328	Fair	Repair base course
20	7+241-7+818	Very Bad	Repair subgrade & sub base
21	8+328-8+866	Very Bad	Repair Base
22	8+900-10+039	Bad	Repair Base
23	10+039-10+127	Bad	Repair Base
24	10+127-10+200	Good	Ok
25	10+200-10+300	Bad	Repair Base
26	10+300-10+469	Bad	Repair Base
27	10+469-10+529	Bad	Repair Base
28	10+529-10+657	Good	Ok
29	10+657-10+709	Bad	Repair Base
30	10+709-10+736	Bad	Repair Base
31	10+740-10+866	Bad	Repair Base
32	10+866-10+894	Bad	Repair Base
33	10+894-10+989	Good	Ok
34	10+989-11+231	Good	Ok
35	11+231-11+298	Bad	Repair Base
36	11+298-11+678	Bad	Repair Base
37	11+678-11+798	Bad	Repair Base
38	11+798-12+131	Good	Ok
39	12+131-12+153	Bad	Repair Base
40	12+153-12+377	Bad	Repair Base
41	12+377-12+467	Bad	Repair Base
42	12+467-12+604	Good	Ok
43	12+604-12+987	Bad	Repair Base
44	12+987-13+084	Bad	Repair Base
45	13+084-13+259	Good	Ok
46	13+259-13+408	Bad	Repair Base
47	13+408-13+739	Bad	Repair Base
48	13+739-14+468	Good	Ok
49	14+468-14+596	Bad	Repair Base
50	14+915-15+271	Good	Ok
51	15+271-15+462	Good	Ok
52	15+462-16+188	Bad	Repair Base
53	16+188-16+239	Bad	Repair Base
54	16+491-16+530	Very Bad	Repair subgrade & sub base
55	16+530-16+678	Bad	Repair Base
56	16+678-16+897	Bad	Repair Base
57	16+897-17+145	Very Bad	Repair subgrade & sub base
58	17+145-17+537	Good	Ok
59	17+800-18+207	Bad	Repair Base
60	18+207-18+321	Bad	Repair Base
61	18+321-19+533	Very Bad	Repair subgrade & sub base
62	20+803-20+957	Bad	Repair Base
63	20+957-21+163	Bridge	Structurally stable
64	21+163-21+289	Fair	Repair Base
65	21+514-22+165	Very Bad	Repair subgrade & sub base
66	24+200-24+700	Bad	Repair Base
67	24+700-26+850	Bad	Repair Base
68	27+000-227+200	Very Bad	Repair subgrade & sub base

69	27+700-28+400	Bad	Repair Base
70	28+400-29+400	Very Bad	Repair subgrade & sub base
71	29+400-30+450	Very Bad	Repair subgrade & sub base
72	31+500-33+100	Bad	Repair Base
74	33+800-40+200	Good condition	Good Condition

Pictorials of Existing Condition

CHAINAGE: 7+241 – 7+818

CHAINAGE:8+328-8+866

28+400-29+400

Description

Four (4) No borrow pits were identified as possible sources for base course and two(2) No borrow pits were identified for use as sub base. The borrow pits were located off the road alignment. The borrow pits however did not meet specifications of the Federal Ministry for Works and Housing for use as Base course and Sub base respectively but were adjudged suitable for the exercise along the alignment since they bared closest resemblance out of the borrow pits checked in the course of investigation. This was confirmed after running series of laboratory tests on samples collected from trial pits at proposed borrow pit sites. Tests carried out on the samples include sieve analysis, consistency limit tests, and CBR and compaction tests to determine the maximum dry density at optimum moisture content. In particular, the CBR of the soils were found to be particularly low as none was able to meet the 80% CBR value after 48 hours soaking period as recommended by the Federal Ministry of Works manual (Nigeria, 2013)

Table 2- Summary of Base Course Borrow Pit Test Results

Pit No	BP1 (Baale)	BP2 (Lukosi)	BP3 (Ayegunle)	BP4 (Agbawo)
Compaction Properties and CBR				
MDD (Tons/m3)	1.99	1.95	1.97	1.98
OMC (%)	10	11	12	11
CBR(soak)	22	20	18	25
Atteberg Limit				
LL (%)	48	42	45	50
PL (%)	31	30	30	34
PI (%)	17	12	15	16
Sieve Analysis				
No10	96	90	92	92
No 40	49	52	50	46
No 200	38	40	35	34

Stabilization

Soil stabilized with cement is known as Soil-Cement. The cementing action is achieved as a result of chemical reaction of cement with soil during hydration reaction. Factors that affect Soil-Cement Stabilization include nature of soil, condition of mixing, compaction, curing and admixtures. For a layer of soil having surface area A $=1m^2$ (1x1), thickness H (m) and density Y ton/m^3 stabilized by P% of cement by weight, the weight of cement required per square meters will be (A x H x Y) x (P/100)

Equipment Required

1. Grader
2. Pulverizer
3. Sheep foot roller
4. Smooth wheel roller

5. Water tanker

Materials

- Laterite from borrow pits along the Papalanto-Sagamu way.
- Cement is Dangote brand delivered to site in bags of 50kg. Before carrying out stabilization tests, appropriate weights of the combinations shall be worked theoretically prior to physical application of the stabilizing agent in this case cement to laterite soil as specified.
- Water suitable for construction purpose sourced from streams along the road and delivered to site in water boozer

Compaction Properties

Laboratory tests conducted on the soils from borrow pitsrevealed the following average properties

- Maximum Dry Density 1.98 Ton/m^3
- OMC 10.8%

Other relevant laboratory tests such as sieve analysis and consistency limit tests were also conducted.Cement (Dangote brand)was delivered in 50 kg bags for the exercise. Stabilization was carried out by Mechanical means using Pulverizer and Grader. The work area wasgridded into appropriate measurable area on ground and the cement spread manually ensuring there is an even distribution over the entire work area.

Mixing and Compaction

Pulverizer was deployed to ensure thorough mixing between the soil and cement is achieved after which a grader carried out the final mixing and grading to fit cross section. Mixing and compaction was carried out at optimum moisture content

Calculations

Working with the prescribed dosageof 5% Cement by weight of laterite soil and a sand density of 1.98 Tons/cum

For a depth of 0.2m, Volume of soil in 1m^2 is 0.2m^3

Weight of soil is therefore 0.2x1.98 which is 0.396 Tons

5% by weight of Soil in 1m^2 is 0.198 Tons which is 19.8Kg of cement, approximately 20Kg

Curing Period

The Stabilized section was allowed for a minimum of 14 days to achieve maximum strength through curing. Within this period, no vehicle shall be allowed to ply the route and sufficient moisture will be applied to enhance the process

Quality Control

Cored samples shall be recovered from the site using appropriate recovery method and relevant tests such as CBR and Compressive Strength test were conducted on the specimen.

The soil-cement stabilization was done in half width and barricaded to allow curing of the section for 14 days before it was opened for traffic to ply. Cored samples were recovered from various sections after 28 days using a mechanically driven cylindrical tube with the following dimensions; height 15cm and diameter 10cm. CBR test and Compression tests were performed on the cored samples to get empirical values that can be used to assess the performance of the stabilization exercise.

Pictorials of Stabilization Papalanto – Sagamu Road

IV. RESULTS

There was an appreciable increase in the CBR values of remolded samples and for all the 15 samples tested, the CBR values recorded increased by at least 300% compared to the CBR of the un-stabilized sections and materials from various borrow pits. Compression tests performed on cored samples ranged from 3-10 N/mm^2 at point of failure.

Table 3 - Compressive Strength and CBR Test Result

S/NO	Thickness	Surface Area (m^2)	Dial Reading (KN)	Stress (N/mm2)	CBR (%)
1	4	0.008	25	3.1	80
2	4	0.008	30	3.8	90
3	6	0.008	35	4.4	90
4	10	0.008	70	8.8	130
5	8	0.008	60	7.5	120
6	7	0.008	60	7.5	125
7	8	0.008	65	8.1	135
8	10	0.008	80	10	155
9	10	0.008	75	9.4	160
10	5	0.008	30	3.8	80
11	4	0.008	30	3.8	95
12	8	0.008	45	5.6	132
13	9	0.008	70	8.8	130
14	10	0.008	65	9.4	135
15	8	0.008	60	7.5	130

V. CONCLUSION AND RECOMMENDATIONS

The performance of soil-cement stabilization exercise carried out on the Papalanto – Sagamu road was investigated. Though the stabilization exercise was carried out successfully in line with laid down procedures, the aim of the exercise was not achieved since the stabilized sections did not perform satisfactorily for the projected period of one (1) year. Test results showed that even though there was a considerable increase in the CBR of the base course by over 300% and the stabilized base course met CBR requirement recommended by Federal Ministry of Works manual. Results of compressive strength test performed on the cored samples however were not impressive even though the manual did not specify a specific range for judgment of the compressive strength of stabilized sections.However there was a positive correlation between increase in CBR and increase in Compressive strength. Problemwas encountered during extraction of samples (Coring) for test using the cylindrical tube as the mechanically driven tube could only recover a maximum of 10cm thick sample in the best case. It is very clear that pending when a permanent measure will be put in place by the Federal Government to make the road motorable, the use of stabilized base course as a riding surface is not feasible as the compressive strengths of the sections cannot withstand the heavy vehicular load plying the route. It is however recommended that giving appreciable increase in the CBR values of the stabilized section, the use of an additional layer of 150-200mm thick 0-50mm stone base will improve the load carrying capacity of the sections to make them perform better under the palliative arrangements.

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