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Rigid Pavement as an Alternative to Flexible Pavement Failure in Ogbaru Swampy Area

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Abstract
The study deals on the influence of rural road construction and connectivity as one of the key components of Millennium Development goals, that creates access to economic and social service, promoting poverty alleviation by generating increased agricultural produce and employment opportunities in the rural areas. Rigid pavement stops the incessant incident of non accessibility of agricultural produce by deplorable state of flexible pavement of rural roads in Ogbaru Swampy area.
Keywords: Rigid, flexible pavement, highway base course, subgrade

Introduction

A good road network in the rural areas is one of the key components of Millennium Development Goals, stated Collins and Hart (1992), because it promotes access to economic and social services, like increase in agricultural productivity, employment opportunities and poverty alleviation.

Moreover, FRN (1973) asserted in her book on Highway manual that rural roads are the basic infrastructure requirement and plays a vital role in social-economic promotion of the rural communities in Nigeria .

Anambra state government in her bid to transform the rural areas, started the interconnectivity of rural roads which is the key components of rural development in the declaration of Millennium Development Goals.

Oglesby (1975) defined precisely in his highway Engineering that the road pavement is the actual surface in which the vehicles travel, also has two fold purpose of providing functional road for vehicles and transferring normal stresses to the underlying soil. Therefore, he noted that researchers in construction industries confirmed that there are two defined categories of pavement currently in use, namely Flexible and Rigid pavement.

Kadiyali and Lai (2011) in their principles and practical of highway engineering, are of opinion that flexible pavement structure is typically composed of several layers of material with better quality material on top where the intensity of stress from traffic loads is high and lower quality materials at the bottom where stress intensity is low. Moreso, it is a multilayer system under loading arrangement, according by Vaxirani and Chandola (1984) in their highway and Soil Engineering.

Afser (2012) describe a typical flexible pavement in his book Road Pavement, as a structure that consist of surface course underlying base and subbase courses, and each of these layers contributes to structural supports and the pavement having sufficient low bending resistance to maintain intimate contact with underlying structure yet having the required stability furnished by aggregates interlock, particle friction and surface tension to support the traffic.

Bruce and Oglesby (2000) proposed and developed the use of hot mix asphalt as surface course, the stiffest layer and contributed the most to pavement strength. They also maintained that the underlying layers are less stiff but are still important to pavement strength as well as drainage system. In flexible pavement when a seal coat is used as the surfaces course, the base generally contributes most to the structural stiffness and the layers gradually decreases in material quality with depth Gupta and Gupta (2004) in concrete Technology gave the importance of Rigid pavement as consist of a relatively rich mixture of Portland cement (0.14m^3, sand (0.29m^3) and course aggregate (0.57) land as a single course. Rigid pavement is a pavement that possesses enough flexural strength or flexural rigid. Also, Gupta and Gupta were of view that stresses are not transferred from top to the lower layer as in the case of flexible pavement.

The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resist the load from traffic. It has a rigidity to distribute the load over a relativity wide area of soil and a minor variation in subgrade strength, has little or no influence on the structural capacity of a rigid pavement. Highway engineering construction has Highway Research board system that mostly regarded in the determination of pavement thickness and materials for base course gives yearly report on highway. Ogbaru having high liquid limit and plasticity indice of more than 14 reflect poor stability condition and needs strong pavement.

Afser (2012) asserted that flexural strength of concrete is the major factor in rigid pavement design, not the strength of the subgrade. He further emphasized that concrete slab of rigid pavement, bridges over the localized failure and areas of inadequate support from subgrade in the course of deflection beneath it, because of concrete slab action. Kadiyali and Lai (2011) in their principles, and practice of highway Engineering provided an overview of rigid pavement structure, being composed of hydraulic cement concrete surface course, underlying base and subbase course and provides the majority of strength. The subbase and the base layers are in the order of magnitude less stiff than the concrete surface but still contributes importantly to pavement drainage and provide a working platform for construction equipment.

H.R.B (1987) on the final report of committee on maintenance of concrete pavement compared the performance of rigid to flexible pavement in the swampy soil as it contains sufficient rigidity and has high modulus of elasticity cable of bridging over any localized subgrade failure or areas of inadequate support. Rigid pavement, with a relatively small thickness, distributes wheel load upon the subgrade, and bridges minor inequalities in subgrade support, by virtue of flexural strength and load transfer capacity in shear, Maclean et al (1979). The reaction of concrete pavement slab to environment and loading depends of properties of the concrete of which they are cast and those of underlying subgrade and base course

Aim and Objectives

The purpose of a good road pavement design is to effectively dissipate/spread the load from the tyre foot print of the vehicle over under area of existing natural surface so that the strength of the natural ground will be sufficient to carry the reduce loading without causing any type of failure over the proposed route of the load. Therefore the aim and objectives of the paper are to

(i) ascertain alternative and suitability of rigid pavement over flexible pavement
(ii) show advantage of rigid pavement over flexible pavement
(iii) show life cycle cost of rigid pavement is less than that of flexile pavement
(iv) show that rigid pavement is a solution to low “Califonia Bear Ratio” (CBR) Subgrade.

Causes of Pavement Failure

Lack of highway maintenance funds is a typical phenomenon in some local governments of Anambra State of Nigeria like Ogbaru local government area, Really, the situation is worsened as many access roads are dilapidated and impassible. Consequence to the effect most pavement are generally deteriorated in the area, FRN (1973). The deteriorated pavement cause serious economic losses to the nation at large. Therefore the following are the causes of road pavement failure

(i) traffic with heavy axle’s load and climate effect
(ii) environmental factors affecting the subgrade for the determination of bearing capacity
(iii) inefficient drainage systems
(iv) lack of good qualitative and quantitative design
(v) lack of maintenance culture and poorly managed net work structure
(vi) lack of systematic planning leading to uncoordinated efforts
(vii) water causing principally premature pavement failure

Study Area

Ogbaru local government area council of Anambra state and headquarter in Atani, consist of sixteen committees. The entire local government which is situated in a large wet land zone, and located in the south western part of Anambra state, and lies between latitudes $5^{0}42'$ 6^{0}SOE. She is bounded in the north by Onitsha south local government area, in the east by Idemili South, Ekwusigo and Ihiala local government areas, in the west by Delta state and in the south by Rivers and Imo States.

The relief is a plain land characterized by swampy condition as a result of its alluvial mud content.

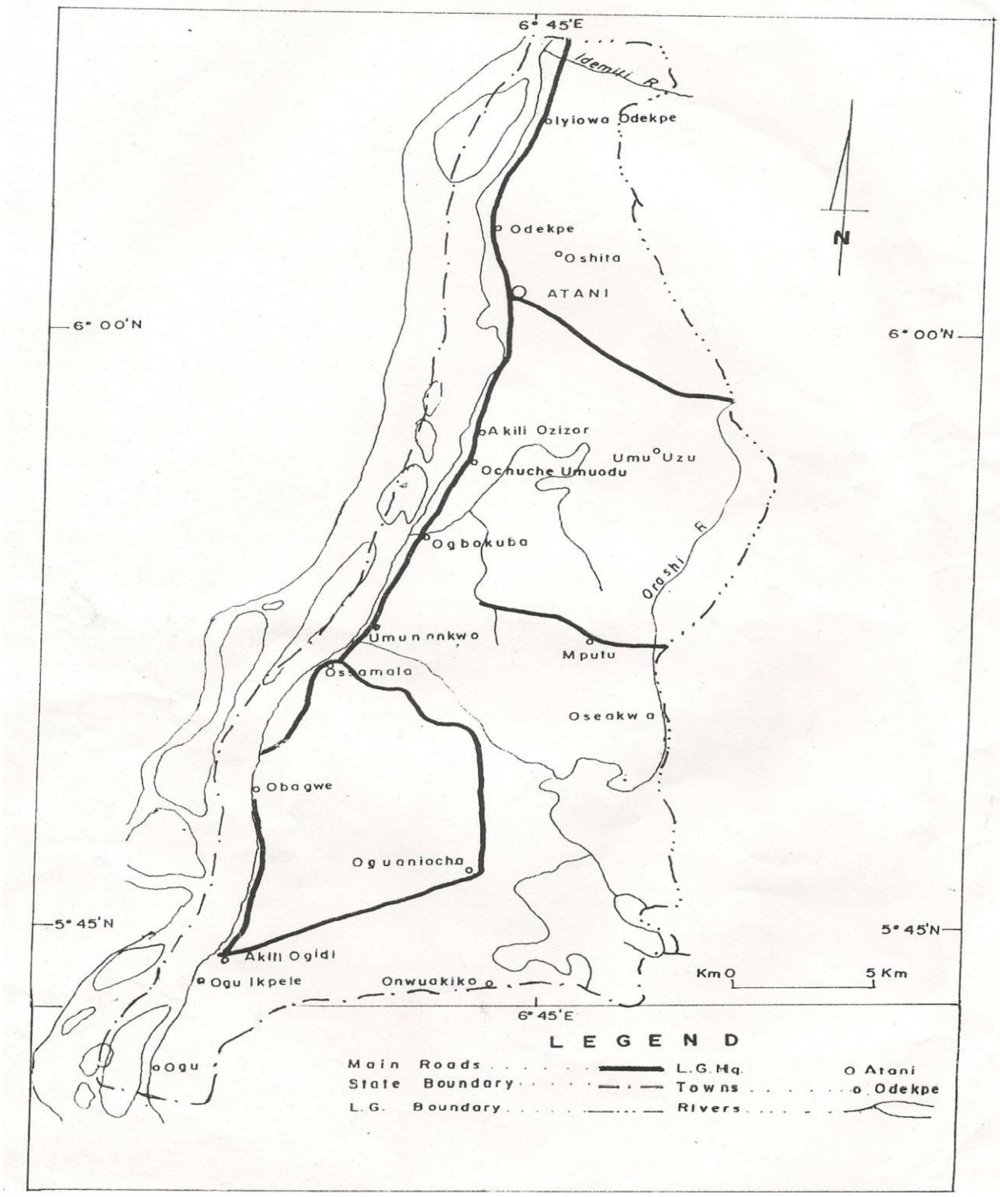

Figure 1: Map of Ogbaru Local Gov

Plastic Limit

Test Sample	Sub grade				Sub base				Base	
	1200mm		900mm		600mm		450mm		300mm	
Container	C	L	A	B	G	1	K	U	P	E
Mass of wet soil +container, M_2 (g)	7779	7729	74.99	75.49	79.50	79-50	78.50	76.50	77.50	7720
Mass of dry soil + container, M_2g (g)	76.70	76.44	73.98	74.54	73.60	74.50	77.60	75.50	76.60	76.20
Mass of moisture	1.09	0.85	1.01	0.92	0.90	1.00	0.90	1.00	0.90	1.00
Mass of container (g)	63	63	61	62.00	64.00	61.00	64.00	61.00	63.00	64.0
Mass of dry soil (g)	13.70		12.98	12.57	14.60	13.50	13.60	14.50	13.60	12.20
Moist Lire content	7.95	6.32	7.78	7.32	6.16	7.40	6.60	6.90	6.62	8.20
Average	7.14	7.55	6.78	6.75	7.41					

Liquid Limit

DEPTH: 1200MM **SUB GRADE**

Trial No	1		2		3		4		5	
Cone penetration initial reading (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cone penetration	87.00	86.56	87.50	80.00	140.00	139.00	158.50	158.00	185.00	184.60
final reading (mm)										
Container	A	B2	B	H	K	F	1	J	F2	D
Mass of wet soil + mass of container (g)	73.00	83.98	74.01	77.00	75.47	77.45	72.21	81.30	77.35	79.26
Mass of dry soil + mass of container (g)	72.10	83.09	72.51	75.49	73.49	75.50	69.88	78.86	74.61	76.55
Mass of moisture	0.90	0.89	1.50	1.51	1.98	1.95	2.33	2.44	2.74	2.71
Mass of container (g)	61.00	72.0	62.00	65.00	64-00	66.00	61.00	70.00	66.00	68.00
Mass of dry soil	11.10	11.09	10.51	10.49	9.49	9.50	8.88	8.86	8.61	8.55
Moisture content	8.10	8.02	14.27	14.39	20.86	20.52	26.23	27.53	31.82	31.69
Average	8.06	14.33	20.69	26.88	31.75					

DEPTH: 900MM **SUB GRADE**

Trial No	1		2		3		4		5	
Cone penetration initial reading [mm]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cone penetration	87.00	86.56	87.50	80.00	140.00	139.00	158.50	158.00	185.00	184.60
final reading(mm)										
Container	D	H	K	E	J	G	1	C	L	F
Mass of wet soil -t-	80.00	77.02	75.46	75.05	80.55	74.48	70.81	79.81	72.04	74.87
mass of container (g)										
Mass of moisture (g)	1-03	1.04	10.5	1.46	1.72	1.60	2.01	2.06	2.50	2.46
Mass of container (g)	68.00	65.00	64.00	64.00	70.00	64.00	61,00	63.00	63.00	66.00
Mass of dry soil (g)	12.00	12.02	11.46	11.05	10.55	10.48	9.81	9.85	9.04	8.87
Moisture	8.58	8.65	13.08	13.21	16.30	15.26	20.48	20.91	27.65	27.73
Average	8.61	13.4	15.78	20.69	27.69					

DEPTH: 600MM **SUB BASE**

Trial No	1		2		3		4		5	
Cone penetration initial reading (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cone penetration final reading (mm)	25.50	25.20	60.5	60.00	85.50	85.30	856.20	84.90	158.00	158.40
Container	K	C	J	E	L	F	K	A	g	D
Mass of wet soil + mass of container (g)	75.42	74.41	81.94	75.91	74.88	77.78	76.00	73.15	74.04	79.95
Mass of dry soil + mass of container [g]	74.50	73.48	80.44	74.40	72.89	75.78	73.35	70.40	70.99	76.86
Mass of moisture	0.92	0.93	1.50	1.51	1.99	2.01	2.65	2.75	3.05	3.09
Mass of container (g)	64.00	63.00	70.00	64.00	63.00	66.00	64.00	61.00	62.00	68.00
Mass of dry soil	10.5	10.48	10.44	9.89	9.78	9.35	9.40	8.99	9.04	8.86
Moisture content	8.76	8.87	14.36	14.51	20.12	20.55	28.34	29.25	33.92	34.87
Average	8.81	14.43	20.33	28.79	34.39					

DEPTH: 450MM **SUB BASE**

/Trial No	1		2		3		4		5	
Cone penetration initial reading (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cone penetration	39.8	40.10	105.0	104.50	104.50	119.50	149.20	149.00	178.00	177.70
final reading (mm)			0							
Container	D	H	K	E	J	G	1	C	L	F
Mass of wet soil + mass of container (g)	81.92	77.91	78.02	72.95	93.19	77.05	75.95	77.00	75.04	81.18
Mass of dry soil + mass of container (g)	31.00	77.01	75.57	71.51	71.01	7S.OO	73.00	74.00	71.89	77.67
Mass of moisture	0.92	0.90	1.45	1.44	2.18	2.05	2.95	3.00	3.15	3.50
Mass of container (g)	70.00	SS.OO	64.00	61.00	61.00	65.00	63.00	64.00	62.00	68.00
Mass of dry soil	11-00	11.01	10.57	10.51	10.01	10.00	10.00	10.00	9.89	9.67
Moisture content	8.36	8.17	13.7	13.7	21.58	20.51	29.50	30.00	31.85	36.19
Average	8.27	13.70	21.04	29.75	34.02					

DEPTH: 300MM **BASE COURSE**

Trial No	**1**		**2**		**3**		**4**		**5**	
Cone penetration initial reading (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cone penetration final reading (mm)	42.40	43.00	81.20	80.90	139.20	138.80	204.10	204.50	231.50	231.30
Container	C	D	K	H	E	A	1	J	B	F
Mass of wet soil + mass of container (g)	74.30	79.20	75.00	75.91	75.22	72.24	72.75	86.64	74.07	78.12
Mass of dry soil + mass of container(K)	73.40	78.20	73.50	74.4	73.21	70.20	70.25	79.07	71.00	74.90
Mass of moisture	0.90	1.00	1.5	1.51	2.01	2.04	2.50	2.55	3.07	3.22
Mass of container (g)	63.00	68.00	64.00	65.00	64.00	61.00	61.0	70.00	62.00	66.00
Mass of dry soil	11.40	10.20	9.50	9.40	9.21	9.20	9.25	9.090	9.00	8.90
Moisture content	8.65	9.80	15.79	16.06	21.82	22.17	27.03	28.05	34.11	36.18
Average	9.23	15.93	21.99	27.54	35.15					

Methodology

Highway pavement is a structure consisting of superimposed layers of selected and processed materials whose primary foundation is to distribute the applied vehicle loads to subgrade. Therefore the ultimate aim is to ensure that the transmitted stresses are sufficiently reduced, so that they are not exceeded the supporting capacity of the subgrade, O'flaharty 1983.

In highway pavement construction, there are three main physical properties of soil which must be put into consideration before any execution, are mechanical analysis, liquid limit, plastic index, and in addition Group Index used in subdividing the fine grained soil. The soil materials include in the various group of Highway Research Board system are divided into two major classes. These are, the granular material containing 35% less material passing the 75µm B.S sieve, and silt-clay materials containing more than 75µm sieve, Ogbaru is placed under silt-clay material of plastic clay soil with high liquid limit characteristic in relation to moderate plasticity indies subject to high volume of change, especially during and after flooding event Vazirani and Chandola (1989).

In course of construction, the surface of a flexible pavement is cleared down to the designed depth compacted of the intended road, which consist of surface, binder course, base course, sub-base course ,capping and subgrade, BICE (2013).

The stress transmits through the road structure from vehicles above spreads and lessens with depth stronger and more expensive material needed in the upper levels. The nearer the surface, the flatter the profile, because of uneven surface discomfort vehicle occupant and wear more quickly. In the course of construction compaction takes place on each layer of the road structure to avoid gab (void). The sub-base is laid as soon as possible after final stripping to formation level to prevent damage from rain or sun baking which could cause surface cracks.

The base consists of good quality soil of ≥ 85% CBR, Ralign (2012). The surfacing is laid a single course and helps to distribute the load of traffic above on to the base course, which is a weaker material, which provides a flat thinner surface course of 19mmΦ stone size.
Surfacing is done in wide range of bituminous material, ranging in thickness from 20mm to 40mm.

Concrete pavement is constructed with highly specialized mechanical equipment operated by skilled workmen, Lister (1972).

The entire operation is carefully organized, with each workman assigned definite task and responsibilities and thorough inspection on execution.Thereafter comes the result of these effects as finished pavement of uniformly high quality and excellent smoothness, with paver and batch (plant) truck as the most prominent equipment for concrete laying in paving, H.R.B (1987).

At the central plant, cement aggregates except water are batch into compartmentalized dump truck to be conveyed and discharge one at a time into a mixer that travels along the road way to be placed between steel side forms that are fastened to the subgrade immediately the paver follows suite in spreading the concrete and finishes its surface rolled, on these side forms Gillete (1975).

Analysis and Result

Flexible pavement has been in the past the preferred choice in road construction because of its low initial cost as compared to rigid pavement for rural road construction plan. In view of the availability of cement in large quantity within Nigeria, courtesy of Dangote cement industry limited and rising price of important bituminous materials, Okonji Iweala (2014).

Rigid pavement has been prudently considered as far better as an alternative to flexible pavement considering the cost of exporting crude oil, important refined oil and bituminous materials with huge amount of subsidy. Consequent to that, the superiority of rigid pavement over flexible pavement is well recognized, the world over, in the recent time and many developing nation have invested huge amount of money on rigid pavement, in expectation of long durability and cost effective projects Spellman and Spickemire (1997). A good road network of rigid pavement results in meeting the increasing passenger and freight traffic on high traffic corridors for the rapid rural development.
The initial cost or investment on rigid pavement on rural link roads is 25% more than the flexible pavement but to lifecycle cost of concrete pavement is proved to be economical over flexible pavement as is compared in the performance and durability of both pavement by Clarke and Johnson (1979) in their comparative design of performance and cost for a road on peat.

The life cycle cost analysis is precisely defined by Clarke and Johnsons (1979) as the procedure by which a pavement design alternative is selected, which provides a satisfaction level of service at the lowest cost over designed life Clarke and Johnson (1979) in the comparative design performance and cost for rapid, conducted a study that consider the advantage of yearly maintenance cost of rigid pavement at about N25M per km for single lane rural road to cover filling of sealing compound in the joints and repairs and inflation rate of 7% inclusive.

Besides life cycles cost, nearness to cement factories, George (1977 in Stringkage Cracking of soil-cement base suggested the consideration for quick and rapid delivery concrete pavement to prevent climate and environmental hazard.

Moreover, Lister (1981) in Design and Performance of current bond base emphasized on the need to consider, in the “tables” below, that Atterberg limit showed that the correlation within highway engineering properties of soil in Ogbaru local government area are found to be influenced by factors like clay material which retains much water especially in the rainy season, Oglesby (1975).

Khanna (2006) provide an overview in his highway engineering, that a soil becomes brittle in shrinkage limit considering the stress and strain shearing rate in the dry season causing expansion and contraction, leaving base and subgrade in a deteriorating state and the pavement failure because of lower soil shear which is the case of Ogbarua Swampy area, considering the result of soil experiment in the tables below

Consequently, the liquid limit experiment with different samples in different depth of 1200mm, 900mm and 600mm in both subgrade and base courses showed that the soil contains and retain much water being clayey soil of moisture contents between 25-30.

Obviously, the results confirmed the sh9rinkage nature of clayey soil within low shear strength, causes failure of most flexible pavement base courses and subgrade.

Conclusion

The comparison of both flexible and rigid pavement, considering shear strength of alluvial soil subgrade of Ogbaru Swampy area, rigid pavement is a preferable choice because is composed of Portland cement concrete surface course which substantially stiffer than flexible pavement due to high modulus of plasticity.
Furthermore the selection criteria of the type of pavement, flexible or rigid is based not on the initial cost of

construction but life cycle cost, which includes, the discounted maintenance and pavement strengthening cost that are incurred during the design life of the pavement Clarke and Johnsons (1979).

A careful evaluation of rigid pavement as a necessary alternative to flexible pavement initial low cost does not rival the rigid pavement for rural road construction plan.

In view of availability of cement and its low cost in recent time, Courtesy Dangote cement factories, compare to scarcity and increase in price of imported bitumen and fuel subsidy, making the product very exhibiting to procure, Okonji-Iwealor (2014).

Rigid pavement is very much an alternative to flexible pavement considering freight traffic and increase in passenger. The correlation between soil type and the grannular contents. The higher the grannular content and the lower the plasticity of the of the soil the better the pavement performance, Ogbaru local government deserves a good road pavement design that would be cost effectively, produce a durable road pavement that has a significant life before any attention is required to the matrix of construction.

Recommendation

In view of the fact that rigid pavement spreads loads over a considerable area of subgrade by beam action, the construction and execution of rigid pavement must avoid direct laying of pavement over expensive soils because of water from fresh concrete being drawn into the subgrade which may well and disrupt the newly placed pavement.

In the post construction, the joints and Cracks of the completed pavement should be devoid of water percolation which could lead to differential expansion of the subgrade and the pavement could be curled upward at the joint and becomes exceedingly rough.

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