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Federal University of Technology, Minna, Nigeria.

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FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA
Technology for Empowerment

Nigerian Journal of Technological Research.

Vol. 8, 2013 Special Edition

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- ENGINEERING SCIENCES
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General Information

Background Brief: The Nigerian Journal of Technological Research (NJTR) is the official journal of the Federal University of Technology, Minna, Niger State, Nigeria. It was first published in June 1989. It has since made giant strides in its effort to provide an avenue for the dissemination of relevant modern up-to-date research information in the core areas of discipline available in The University at inception; namely, Pure and Applied Sciences, Engineering Technology, Environmental Technology and Agricultural Technology.

Philosophy: As a strictly scientific and technological journal, it tends to provide information on problem solving technology to its immediate environment and the international community.

Development: The journal being responsive to the dynamic nature of research and development in the Federal University of Technology, Minna and its environs, has widen its scope of information dissemination to include but not limited to Information Communication Technology (ICT), Management Technology, Educational Technology and Entrepreneurship. It has developed electronic communication procedures to ensure that, it has the capacity to reach a larger community at a faster rate. It is the anticipation of the journal that scientific data which will provide very current information to problem solving in the identified areas of The University program will be found in it.

Management: The Nigerian Journal of Technological Research has a unique management structure which enables it to carry out its functions promptly. This include; The Management Board, Editorial Board, Editorial advisory Board, Regional editors, Associate editors and a Business Manager. These groups bring to beer their vast knowledge which ensures the quality and reputable academic output from the journal.

Finally, The Management Board and The Editorial Board of The Nigerian Journal of Technological Research believe firmly in quality of information that will benefit mankind, hence their commitment to ensuring productivity and quality of information dissemination.

Editorial Comments.

The engineering discipline becomes very important in structural development of any nation. It sets the pace for core industrial development and it is necessary that the national development is brought into focus at all times. The 2013 engineering conference in The Federal University of Technology Minna has been designed to ensure that a forum which can quickly address some immediate national challenges are discussed.

The papers that have met the standard of publication of The Nigerian Journal of Technological Research and have immediate relevance in providing some thought for national development have been packaged in this special edition, The integrated approach on energy drive in the keynote paper is very central to the energy industry in Nigeria. Critical points on various use of natural raw materials available in the country are issues which must be identified and reasonable solution provided for national discuss.

Noting the theme of the 2013 engineering conference as focusing on "Challenges in Energy supply and infrastructural development in developing Countries" it is imperative in the life of the Nigerian society that any scientific tool which will positively harness existing resources for the betterment of the citizens is necessary. Energy forms the crucial part of any economy and it will require all inputs available to get the right energy requirement for any nation. Developed economy has always depended on improving daily on the energy needs of their nation. Investing in the required research also has helped these economies.

The continued variation in climate change worldwide must bring to scientific desk all hands to meet the challenges which come with it as it relates to the energy needs of the world. Those technologies involving automobile engineering concepts of vehicles using biofuels are part of the challenges that must be visited and addressed by engineering science worldwide..

The Nigerian Journal of Technological Research will constantly highlight challenging,- well researched studies for the consumption and utilization of it's readers. This special edition on the 2013 engineering conference in The Federal University of Technology Minna, Nigeria, is highly recommended to all aspects of the economy and industries for their use and networking. The Editorial Board as always believes in ensuring quality standard is maintained in all it's publications. All professional bodies are welcome on board with their quality submissions.

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Forensic Investigation of Premature Failure of a Roadway Pavement in Minna, Niger state, Nigeria

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Abstract:

Field and laboratory studies were conducted to investigate the premature failure of a township roadway pavement in Minna, Niger state, Nigeria. Tests conducted on the pavement layers of the failed road included moisture content, particle size distribution of soil samples, Atterberg limit tests, in-situ density and dynamic cone penetrometer (DCP) tests. An empirical equation from published literature was used to compute the California bearing ratio (CBR) of various pavement layers from DCP data. Data from the tests indicate that the field moisture content of the pavement layers (i.e., subgrade, sub-base and base) were high, recording values above the optimum moisture content (OMC). Some soil materials from the pavement layers at the various failed sections had fines content above specification requirements for such layers. Atterberg limits tests revealed high liquid limits as well as plasticity index values. Generally, the field density values of the subgrade layers were found to be low equivalent to 82 - 98 percent degree of compaction, while the density of the sub-base and base layers at some failed locations were equally low achieving a degree of compaction of about 85 - 99 per cent, against specification requirement of 100 per cent. CBR values were mostly lower than recommended values by local codes. Overall, high proportion of fines and plasticity index values together with inadequate compaction of pavement layers as well as low CBR were identified as key factors responsible for the failure.

Keywords: California bearing ratio, degree of compaction, minna, pavement, pre-mature failure
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Introduction

Despite advancements in pavement technology in past decades, premature failures continue to occur that cost governments lots of money in repairs. Such failures of highway pavements is a common experience on Nigerian roads (Madedor,1983; Madedor, 1992; Akintorinwa, 2011; Osuolale *et. al.*, 2012) and constitute serious problems that threaten public safety, cause unnecessary delay in traffic flow, breakdown of vehicle and most significantly, causes road traffic accidents that had resulted in loss of lives and properties.

Failure of road pavements involve pavement deterioration to a point where it no longer satisfies the criteria under which it was designed, either in terms of reduced structural capacity, increased roughness, reduced surface friction, or other circumstances, and would therefore require major rehabilitation (Paterson, 1987). Pavement failures can either be functional (surface pavement failure) which manifest on the road in the form of waviness/corrugation, rutting and potholes caused by environmental factors like poor drainage, lack of maintenance and misuse of the highway pavement or structural (deep-seated pavement failure) manifesting as rutting, cracking, ravelling and/or shear failure in the pavement and are attributed to factors, such as properties of construction materials, subgrade conditions, traffic loading and poor workmanship (AASHTO, 1986; Ogundipe and Olumide, 2012). Failure process is often self perpetuating in that the development of distress cracks allows the ingress of water into the pavement exacerbating the conditions that may have initially led to the cracking.

The present study is an investigation of the premature failure of Yakubu Lame Road, a two-lane, relatively low-traffic volume section of Minna township road network constructed with an asphalt surface over two different layers of unstabilized lateritic soil. Signs of distress manifested on the road within months after opening to traffic. The major type of pavement distress identified along the road is extensive deformation in the form of fatty depressions and mounds, displacements, corrugations and undulations, all manifested as deviations of the road surface from a uniform flat condition which have a detrimental effect on the riding quality. These early failures progressively increased in both extent and magnitude and necessitated the rehabilitation of the road. For this reason, a forensic evaluation was initiated and conducted on this road.

Background

This section of the road network was originally constructed about 30 years ago. The road lies within latitude 9°37′ N and longitude 6°33′ E, Nigeria. The alignment is relatively straight, with a nominal length of 2.50km while the grade can be described as gentle. A typical profile of the pavement structure consisted averagely of 150 mm lateritic base over a 150 mm lateritic sub base installed on a compacted sub-grade (Table 1).

Table 1: Composition of the Road Pavement

Layer	Average Thickness(CM)	Description
Surface layer	100	Hot mixed, hot laid asphalt
Base	150	lateritic
Sub-base	150	lateritic
Subgrade	-	Native soil

Materials and Methods

In conducting the forensic evaluation, field tests such as Dynamic Cone Penetration (DCP) and in-situ density using the sand replacement method at different designated locations as well as laboratory testing of materials collected from different locations were adopted.

Sampling

Disturbed soil samples of subgrade, subbase and base materials were collected from seven designated failed locations of the road, from depth of 150 - 250mm for base, 250 - 400mm for subbase and 400 - 600mm for subgrade below the asphaltic surface. They were packed into sacks, labeled and transported to the soil mechanics laboratory of Department Civil Engineering, Federal University of Technology, Minna where laboratory analysis of the materials, such as moisture content, sieve analysis and Atterberg limit (i.e., liquid limit, LL, plastic limit, PL and plasticity index, PI) were carried out following standard procedures outlined in BS 1377 (1990).

Field Tests

Base, sub-base and subgrade conditions were measured for their field strength through the use of the dynamic cone penetrometer (DCP) which was used to determine their CBR values and the in-situ density test was used to evaluate the degree of compaction a construction (Abu-Farsakh, 2

Dynamic Cone Penetration (

The DCP is an instrument (F for the rapid *in-situ* mea structural properties of th pavements constructed with u (Livneh, 1989; Chen et al., 200 from DCP test are in turn use the *in-situ* CBR value of comp and Pratt, 1983; Harisson, 198 A DCP consists of an 8 kg through a height of 575 mm having a base diameter of 20 Ishai, 1987). The penetration mm) was measured using a ca each blow that is applied. I measure up to 800 mm de extension rod and up to 1200 fitted with an extension rod. conducted at 7 test locations, hand side (R) and three on the l along the roadway and specif cover the various degrees c deterioration.

Fig. 1: The Dynamic cone penetrome

In-situ density test (Sand method)

The verification of the degree of c site was determined by a sim consisting essentially in re weighing a part of compact replacing it in the hole with san apparatus recording the volume then calculating the density of the following procedures outlined in Nig

Standard Specifications (NGS, 1997) as well as BS 1377 (1990).

California Bearing Ratio (CBR)

To assess the structural properties of the pavement subgrade, the DCP values were correlated with the CBR value. Different empirical relationships between the DCP-PR in (mm/blow) and CBR values are available in literature. In this study, the empirical correlation by The U.S. Army Corps of Engineers (USACE) (Webster *et. al.,* 1992) was used and is expressed as follows:

$$\text{Log CBR} = 2.465 - 1.12(\log \text{PR}) \quad (1a)$$

or

$$\text{CBR} = 292/\text{PR}^{1.12} \quad (1b)$$

Results and discussion

Moisture content

The moisture content test results are summarized in the Table 2. The moisture content was sampled for each pavement layer at different locations. The results showed higher-than-normal level of moisture present. For example, the moisture content ranged from 12.55 - 32.48, 9.51 – 24.45 and 7.66 – 13.5 respectively for the subgrade, sub base and base layers. Subjective observations at test pits gave indication that moisture entered the sub base and base layers through the poorly-compacted subgrade. High moisture content in the base, sub base and subgrade layers is indicative of an impending problem in the pavement. It is often associated with (1) water infiltration through a porous asphalt layer or longitudinal joints; or (2) a moisture susceptible base that wicks moisture up from the subgrade.

Table 2: Field moisture content test results of soil samples from the various pavement layers

Location	Subgrade	Sub base	Base
CH 0+200R	32.48	24.4	9.69
CH 1+050L	30.00	18.24	13.50
CH 1+050R	22.36	10.25	8.78
CH 1+550L	28.20	10.00	12.55
CH 1+550R	30.72	11.10	10.00
CH 2+050L	18.82	10.91	7.66
CH 2+050R	12.55	9.51	8.22

Particle size analysis

Soil samples from the designated locations analyzed for grading characteristics have percentage finer than 0.075mm ranging from 33.9 - 67% for subgrade, 31-46% for sub base and 8 - 36% for base layer respectively.

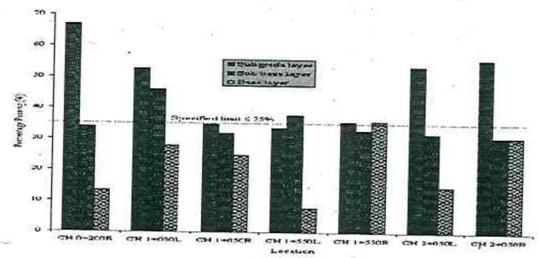

Fig. 2: Grading test results showing percent passing sieve No. 200 for materials sampled from the pavement layers at the selected locations compared to specification limit

When appraised for compliance with the relevant specification of the local code (NGS, 1997) in terms of percent passing sieve No. 200, (Fig. 2) only samples from CH 1+050R and CH 1+550L are within the acceptable requirement for subgrade, while for sub base, only sample from CH 1+550L failed to meet the specified limit. Lastly, judging from particle size distribution test results and data from construction records, it appears that some breakdown of the gravel component in the base was occurring, although most of the materials still met the specifications except for samples from CH 1+550R. However, as no testing have been conducted to assess whether the material was prone to breakdown, it is difficult to conclude whether this was a contributing cause to the failure.

The increased percentage of fines in the sub base layers possibly prevented efficient drainage. With higher percentage of fines content in the layer, lower permeability will ensue. In addition, the swelling of these clayey materials upon wetting could develop internal forces that can initiate or accelerate deterioration (Amadi, 2011).

Atterberg limits

The results of the liquid limit (LL) and plasticity index (PI) along with the required specification limits for the various pavement layers are presented in Figs. 3 and 4 respectively. The LL of subgrade samples are all below the 50% threshold value with exception of sample from CH 0+200R while all sub base and base samples were well within the limit. For the PI requirement, the data in Fig. 4 shows that subgrade samples from CH 0+200R and CH 1+050L had PI slightly above the specification requirement.

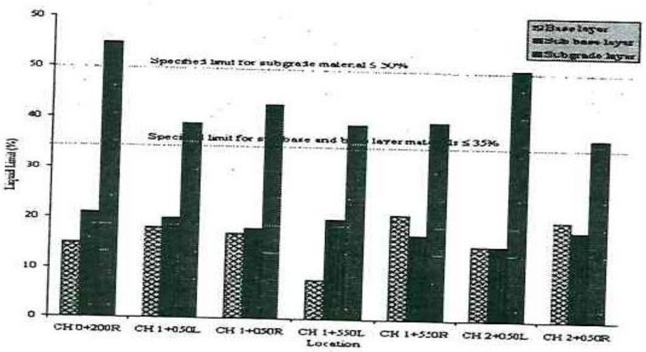

Fig. 3: Liquid limit of soil samples collected from the pavement layers at the selected locations

On the other hand, only samples from locations CH 0+200R and CH 1+550R met the requisite PI requirement for sub base layers while samples from the base layer at CH 1+050L, CH 1+550R and CH 2+050R recorded PI values above the requisite limit.

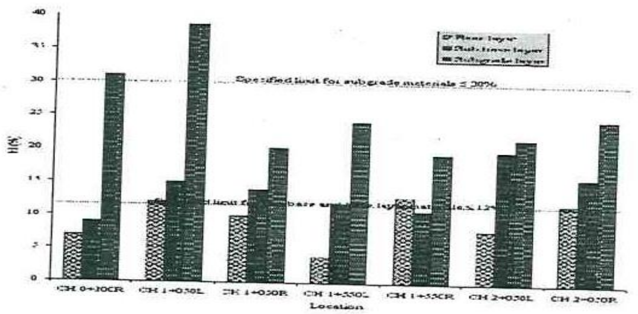

Fig. 4: Plasticity index test results of pavement material collected at the selected locations

In-situ density test result

The summary of field density test results is reported in Table 3. The field density values at the various designated locations of the road ranged from 1590 to 1906 kg/m^3, 1620 to 1880 kg/m^3 and 1859 to 2008 kg/m^3 representing 82 to 98%, 85 to 98% and 92 to 99% compaction for the subgrade, base and sub base layers respectively. This indicates that adequate compaction of the pavement materials was not achieved at all tested locations during construction. This resulted in deformation and consequent damages of pavement layers as moisture easily infiltrates or wicks into the pavement.

Table 3: Result of field density te layers at the various designated corresponding percent compaction

Location	Sub grade		Sub ba
	ρ(Kg/m^3)	%	ρ(Kg/m^3)
CH0+200R	1590	82	1620
CH 1+050L	1700	88	1688
CH 1+050R	1750	90	1826
CH 1+550L	1880	97	1880
CH 1+550R	1695	87	1856
CH 2+050L	1906	98	1868
CH 2+050R	1900	98	1849

California Bearing Ratio (CB

The correlated CBR values fc layers at various locations wh measure of stability and strengt in Fig. 5. These results were c required specifications to ide where requisite CBR values were during construction. It was c comparison that requisite CBR achieved in some locations such CH 1+050R and CH 1+050L f well as sub base layers and C 1+050R, CH 1+050L and CH base layer during construction w assisted the pavement to its distre

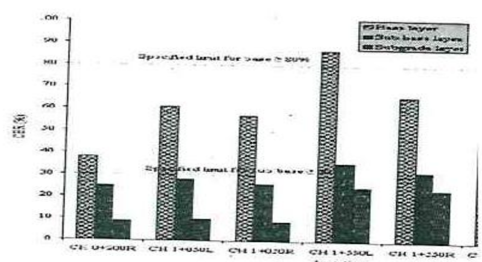

Fig. 5: Derived CBR of paver designated locations

Conclusion

From the findings and analyses laboratory test results, the investig following:

- There was higher-than-normal the pavement. This may have breakdown and degradation under traffic.
- High percentage of fines and p materials from the designated pavement layers which is a materials with questionable quali
- Inadequate compaction coupled strength of soil in the fill (sub ba subgrade layers at most of the loc

From the foregoing, it was concluded that the premature failure of the road pavement was largely due to insufficient compliance or adherence to the relevant specification requirement for pavement construction. This may have resulted from construction inconsistencies in the company's procedural style, staff (contractor and supervising agency) inexperience with quality assurance and control or deliberate acts by the construction company to cut costs.

The consequence of pavement construction that deviates from the specified requirements when subjected to field conditions is failure. This was exactly what happened in the case under study. Based on the outcome of the investigation, it was recommended that extensive pavement repairs be carried out.

Acknowledgements
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