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Evaluating the Significance of Poor Road Design as a Factor of Road Failure: A Study of Onitsha-Enugu Expressway, Southeastern Nigeria

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ABSTRACT

Evaluating the significance of poor road design as a factor of the road failure of Onitsha-Enugu expressway, Southeastern Nigeria using a survey design method which employed the use of individual interviews and a well structured questionnaire to collate data. To determine the significant causes of road failure among causes listed, One-way Analysis of Variance was used. The ANOVA shows that the variation among the causes is not significantly different, a Post HOC test was applied to classify the listed factors. The mean values was used to rank the factors as follows; 1. Inadequate maintenance, 2. Mismanagement by the government, 3. Old age of the road pavement, 4. Incompetence of the contractor, 5. Bad nature of the soil, 6. Stress of heavy vehicles, 7. Poor road design; meaning that the least of the factors of the roadway under study is poor road design. The work concluded that poor road design is not a significant factor of the road failure although there is need for redesigning and reconstruction of the roadway. Sequel to these findings and conclusion, the work recommends that efforts be made by the stake holders in road construction to ensure accurate design of any road way before its construction proper which will consider all the characteristics of the area to be cut across by the roadway, the service burden to be borne by the road way and the expected life span. Relevant geologists, climatologists and engineers to be enlisted at the design and planning stages of any roadway before its construction proper. There should be routine and periodic maintenance as this is necessary not minding how good or bad the road was designed for it to stand the test of time. There should be monitoring and properly supervising of the construction engineers to see that they accurately implement what was preplanned by the designing engineers not trying to cut costs that may be detrimental.

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

For over six years the Onitsha-Enugu expressway has failed and the reconstruction has lingered for so long. Several thousands of lives and properties worth several million naira are lost as a result of frequent motor accidents, caused by this failed highway pavement. Several factors are responsible for road failures, which include geological, geomorphological, geotechnical, road usage, design and construction inadequecies, and maintenance factors (Adegoke–Anthony and Agada, 1980; Ajayi, 1987). Field observations and laboratory experiments carried out by Adegoke–Anthony and Agada (1980), Mesida (1981), and Ajayi (1987) showed that road failures are not primarily due to usage or design construction problems alone, but can equally arise from inadequate knowledge of the characteristics and behavior of residual soils on which the road are built and non-recognition of the influence of geology and geomorphology during the design and construction phases thus the design of the roadway should be able to accommodate these factors, mainly climate and geology as they determine the actual behavior of the roadway.

1.2 STATEMENT OF PROBLEM

Travelling by road in many parts of Nigeria especially in the Southeast and particularly in Anambra State is a nightmare as the roads are in terrible condition despite the huge expenditure on their reconstruction and maintenance. A typical example of road whose failure bugs the mind of regular users is Enugu-Onitsha Express Road. The failure of the road has resulted to the following:

i. Loss of lives and properties and human injuries through accidents. It will actually amount to a waste of time trying to enumerate the number of lives and human injuries incurred on the road almost on daily basis because of road failure. Among these is a particular one that formed both state and national news headlines, and also left an unforgettable sight and experience, especially as one comes to the spot. On that fateful day over seventy human beings lost their lives in the multiple auto accident that occurred on the 9th day of October, 2009 at the Umunya section of the road.

a. According to the former sector Commander, Federal Road Safety Commision Mr. Ayobami Omiyale, in 2008: 168 cars, 168 buses, 110 lorries and 218 motorcycles were involved in 431 crashes. From these accidents, he said, 409 people were injured while 138 persons were killed in Anambra State roads with a reasonable no of crashes and death recorded along Onitsha-Enugu Expressway. In the first half of 2009, he said, 87 cars, 88 buses, 122 motorcycles and 58 lorries were involved in 217 crashes in which 169 persons were injured and 104 people killed, with the Onitsha-Enugu flank having close to 50% of the death toll and total crashes even when the Umunya incident which took several tens of lives yet to be included in the statistics.

b. Also a report from the present Sector Commander of the Federal Road Safety Corps (FRSC) Anambra State, Mr Hyginus Omeje, has it that a total of 91 deaths from 313 road crashes were recorded in Anambra in 2012. He said that 183 motorists and travellers were injured in 66 fatal accidents during the period under review. The commander said that in December alone, 12 people died from 32 crashes while 84 persons were injured as against 64 deaths and 467 injuries were recorded in 141 accidents in 2011, showing a significant increase and one of the major roads in which these accidents occur is the Onitsha-Enugu Expressway.

c. Other sections of the road, where not less than one life was lost and many others left at least in terrible condition are Nkwelle-Ezunaka Junction, Nteje section in front of FRSC office, around Enugu-Agidi Junction, around Ninth Mile Corner, Ugwu-Onyeama area, and most recently, the accident at Unizik Temporary Site Junction on Tuesday, 7 August 2012 where four little kids were crushed by a trailer which lost control in a traffic jam caused by the failed road drainage under construction between Unizik Junction and Kwata Junction Awka, along the expressway to mention but a few. Cases of miscarriages and other health disorders suffered by people cannot be measured. This is mainly experienced when travelling with commercial vehicles with most drivers bouncing in and out of potholes, cracks and raveling while on speed just to meet up with there daily account, while the helpless passengers could do noting but go home and suffer the bruises.

ii. Environmental pollution and degradation. Vehicles staying longer time than necessary at such failed sections due to bad roads consume more energy and thus emit more carbon dioxide into the atmosphere while a lot of species are destroyed; and biodiversity is sometimes altered through petrol tanker fires caused by crashes at bad road points etc. For instance, the Umunya incident of 2009 and many other car crashes, petrol tanker fires and trailers/lorries/trucks overturn which results to pollution. The movement of large amount of particulates of dust into the air is a constant experience on dry days around Nkpor, Ogbunike and Umunya areas where the road still wears the red mud or laterites. Both the residence and those passing are affected. This in turn causes Air Borne Diseases and longer accumulation of such particulates enhance global warming.

iii. Encourages armed robbery along affected areas. In a public opinion pool organized by the Newswatch magazine, a bus driver plying the Enugu/Onitsha expressway complained that there is a place around 9th Mile Corner along the expressway, that has a lot of potholes and armed robbers take advantage of it to rob passengers. (Ajaero, 2009). Also the bad road spots at the Umumba area is been noted for robbery attacks especially at nights.

iv. Impedance of human movement and the flow of economic activities. Presently movement by road from Enugu to Onitsha is a very ugly experience and takes more time almost three times what it should be for a normal good road of same distance.

It is to this effect that a need to investigate on the place of poor road design in the road failure arises, having established the gap that no such study has been conducted on the road under study.

1.3 AIM OF STUDY

This study is aimed at establishing the level of significance of poor road design as a factor of the failure of Onitsha-Enugu expressway Southeastern Nigeria.

1.4 STUDY AREA

The Onitsha/Enugu Expressway is a dual carriage way which extends from Onitsha head bridge to Abakpa Junction in Enugu. Passing through Onitsha, Nkpor, Ogbunike, Umunya, Awkuzu, Abba, Enugu-Agidi, Awka, Amansea in Anambra State and Ugwuoba, Oji River, Umumba-Ndiuno, Imezi Owa, Nsude, 9^{th} Mile Corner and Ngwo in Enugu State, with a length of about 120km. It is situated within longitude $6^{o}45^{l}$E to $7^{o}30^{l}$E and latitude $6^{o}00^{l}$N to $6^{o}30^{l}$N. For clarity of the location, see Figure 1 (the Map of Nigeria showing the study area).

Fig. 1: Map of Nigeria Showing the Study Area.
(Source: http://www.ngex.com/nigeria/places/states/enugu.htm).

1.5 THEORETICAL FRAMEWORK

This work is based on Failure Theory which simply is the science of predicting the conditions under which solid materials fail under the action of external loads. The failure of a material is usually classified into brittle failure (fracture) or ductile failure (yield). Depending on the conditions (such as temperature, state of stress, loading rate) most materials can fail in a brittle or ductile manner or both. However, for most practical situations, a material may be classified as either brittle or ductile. `In mathematical terms, failure theory is expressed in the form of various failure criteria which are valid for specific materials. Failure criteria are functions in stress or strain space which separate "failed" states from "un-failed" states. A precise physical definition of a "failed" state is not easily quantified and several working definitions are in use in the engineering community. Quite often, phenomenological failure criteria of the same form are used to predict brittle failure and ductile yield (Besson and Steglich, 2003).

The Failure Theories are indispensable in understanding the processes of pavement failures for both ductile and brittle Sub-grades and Sub-base courses (the layers under the pavement surface). For the purpose of this study, we will lay hands on four important failure theories, namely (1) maximum shear stress theory, (2) maximum normal stress theory, (3) maximum strain energy theory, and (4) maximum distortion energy theory.

Maximum shear stress theory: This theory was postulated by Tresca in the year 1868. It states that failure will occur in the part of any material if the magnitude of the maximum shear stress (tmax) in the part exceeds the shear strength (typ) of the material determined from uniaxial testing.

Maximum normal stress theory: This theory was postulated by Rankine in the year 1850. It states that failure will occur in the part of any material if the maximum normal stress in the part exceeds the normal strength of the material as determined from uniaxial testing. This theory caters for brittle materials and we have learnt that brittle materials behave differently in compression and tension tests. In compression test it fails when the compressive stress reaches Suc, the ultimate compressive strength of the material, and in tensile test it fails when the tensile stress reaches Sut, the ultimate tensile strength of the material. Also generally the magnitude of Suc is larger than Sut for brittle materials.

Maximum strain energy theory: This theory postulates that failure will occur when the strain energy per unit volume due to the applied stresses in a part equals the strain energy per unit volume at the yield point in uniaxial testing. Strain energy is the energy stored in a material due to elastic deformation, which is, work done during elastic deformation. Work done per unit volume = strain x average stress.

Maximum distortion energy theory: This theory was postulated by Von Mises in the year 1913. It is also known as shear energy theory or von Mises-Hencky theory. This theory postulates that failure will occur when the distortion energy per unit volume due to the applied stresses in a part equals the distortion energy per unit volume at the yield point in uniaxial testing. The total elastic energy due to strain can be divided into two parts. One part causes change in volume, and the other part causes change in shape. Distortion energy is the amount of energy that is needed to change the shape. (Li, 2001).

Out of the four theories, only the maximum normal stress theory predicts failure for brittle materials. The rest three theories are applicable for ductile materials.

Highway pavements are constantly under stress of vehicular load and the Sub-grades which are soils and or rock materials are either ductile (for plastic materials like clay) or brittle (for non-plastic materials like sandstones and igneous rocks). Thus the understanding of the above theories becomes very essential in the analysis and evaluation of highway pavement failures which is the problem at hand.

2.0 LITERATURE REVIEW

2.2.1 Causes of Road Failure

It should be noted that the failure of road pavements is a product of both natural and anthropogenic factors. Abynayaka (1977) established that major factors responsible for road failures to include: poor road construction, poor road design, wrong clinic of construction material, collapse of drainage substructure. The Transport Road Research Laboratory (1991), argued that climatic factors can also affect the strength of road structure. Temperature fluctuations and acid rain attack on the base material of the road in water-logged area can weaken the sub-base of the road material capillary action, thereby reducing the supporting power of the read pavement. The various causes / causative factors identified in this review are as follows;

2.2.1.1 Poor Geotechnical Characteristics of the Soil (Sub-grades), Subbases and Construction Materials.

Oglesby, Clarkson and Gary (1982) in their description of the characteristics of soils for highway pavements, denoted that it is very important to understand the basement soil (or sub-grade) and other materials used in construction of pavement structures for highways and other transportation facilities as the sub-grade is the supporting structure upon which the pavement surface and its special under courses rests and both the sub-grade and these special under courses (Base course, sub-base and wearing course) are of rock origin. According to them, the moisture content and moisture irrigation in soils is a function of the Geologic makeup (the sedimentology: texture and structure, porosity & permeability etc) of the sub-grade soil and the moisture water content and migration characteristics of the soil mass and it's reaction to water affects it's strength and this is a function of its grain size and mineralogy.

Gidigasu (1983), in his review suggested that inadequate width of the shoulders which provide lateral support to the pavement would also lead to road failure especially when the shoulders are made of cohesive soils and worst still, when such soil are not properly compacted. Penetration of rain water during the wet season and higher water table weakens the material in the road pavement and during the dry season evaporation of soil water from the clayey shoulder material causes soil moisture suction under the road, both conditions tends to increase the deterioration of the pavement. Graham and Shields (1984) investigated the complex properties of postglacial clay at Winnipeg in Canada. After sampling and laboratory analysis, the geotechnical properties of this clay was confirmed to be troublesome causing major negative impacts on civil engineering structures and construction in the city. The identified problems include; house foundation movements, low stability of riverbanks, poor highway pavement performance, difficult excavation, and a high incidence of watermain breaks.

According to Akpokodje (1986), in his laboratory analysis of the soils within the entire length of the Port Harcourt—Enugu expressway classified them to consist of (1) concretionary laterite gravels, (2) non-lateritic tropical sandy/clayey soils which are gravelly in some places and (3) silty to fat clays formed from shales. The particle size distribution and the plasticity of the majority of the soils indicate that by standard acceptance specifications they are unsuitable for base materials. He stressed that although the pavement materials used for the expressway are inferior under conventional standards, mostly isolated rather than widespread pavement failures have so far occurred. Such failures are presumed to be more related to poor field compaction rather than the inferior quality of the construction materials. Also he noted that where the troublesome weathered shale forms the Sub-grade, severe pavement failure usually occurs. Arumala and Akpokodje (1987) in their investigation of the pavement conditions of roads in the Niger Delta and the geotechnical properties of the soil materials used in constructing them, an attempt to find permanent solutions to the recurrent widespread pavement failures in the region, most severe surface deformations, pavement cracking and failures occur in the seasonally flooded fresh/salt water swamps because of the high water table, poor drainage and the very fine-grained silty clays/clays used.

Okagbue and Uma (1988) in their geological and hydrogeological survey of a problematic section of the Port-Harcourt- Enugu expressway, covering Lokpaukwu, Lokpanta and Leru areas, were able to prove that the road problem is linked to the geological and hydrogeological conditions of the area. As it was evident that the problematic section of the road is built on a considerably jointed, fractured and weathered shale formation as a sub grade, at the foot of an escarpment having a high concentration of natural groundwater discharge resulting in increased groundwater storage, high water table, constant wetting of pavement Sub-grade and subsequent deterioration. Alexander and Maxwell (1996) worked on controlling shrinkages cracking from expansive clay sub-grades. They pointed out that pavements built on sub-grades of expansive clay soils are affected by volume changes through seasoned wetting and drying cycles. These clays are highly reactive to moisture which results in clays showing significant volume change as a direct result of moisture content variation.

Jegede (1997) investigated A case of long-term and frequent highway pavement failure induced by poor soil properties, at a locality along the F209 highway at Ado-Ekiti. After the laboratory soil mechanics tests carried out on the disturbed soil samples collected from the failed sections of the road identified poor soil bearing capacity, poor Sub-grade quality of materials like kaolinite and montemorrilonite (clays) as the root of the problem.

The results of the investigations of geotechnical properties of the Sub-grade soils in some sections of the Ibadan end of the Lagos–Ibadan expressway through laboratory analysis of collected samples by Adeyemi and Oyeyemi (1998) showed that the Sub-grade soils below the stable sections have a higher maximum dry density, unsoaked California bearing ratio (CBR) and uncured, unconfined compressive strength than those below unstable sections. In addition, the soils below stable sections have both a lower proportion of fines and clay-sized fraction and a lower optimum moisture content and linear shrinkage than the material below the unstable sections. Surprisingly, the soils below the unstable pavements not only have a lower plasticity index and higher soaked CBRs than those below the stable pavements but also are more mechanically stable. Thus they concluded that significant differences need not exist between the geotechnical properties of soils below stable zones and unstable sections before such parameters can serve as bases for predicting the stability of flexible highway pavements in the tropics.

Abam, Ofoegbu, Osadebe, and Gobo (2000) explored the impact of hydrology on the Port-Harcourt–Patani-Warri Road, by reviewing the hydro-meteorological, drainage and terrain peculiarities of the area against the backdrop of the design, alignment and performance of the road. In their findings, they ascribed the poor performance of the road to:

i. The southeast-northwest orientation of the road in a region with predominately northeast-southwest surface and subsurface flow, in which the road acts like a dam;

ii. The inferior construction aggregate composition;

iii. Changes in pavement condition due to interaction of local road aggregates with water.

Gupta and Gupta (2003) in their work on Highway Failure and Maintenance, made it clear that the Sub-grade soil is an integral part of a road pavement structure as it provides the support to the pavement from beneath; therefore should posses sufficient strength and stability under adverse climatic and loading conditions to avoid failure. Roy (2003) through theoretical considerations and empirical observations have demonstrated the occurrence of gravity ground-water flow systems in valleys where precipitation is high in adjacent mountains. In such systems the valley floor is often a ground-water sink and adjacent mountains contain ground-water sources. He was of the opinion that optimum conditions for growth of ice lenses beneath highway pavement consist of a frost-susceptible soil, a source of water, and the absence of high negative pore-water pressures. He thus suggested that proper selection of a highway route with respect to ground-water flow systems in mountain valleys may minimize pavement failure caused by frost heaving.

The Central Roads Research Institute (CRRI, 2004) in their report on the field survey investigation of the failed Rao Pitampur Toll Road near Indore, Madhya Pradesh, India, spotted that the road was constructed over a black cotton Sub-grade. The existing bituminous surface was observed to have extensive undulations. The other type of distress was in the form of settlement of the road pavement which might be attributed to the intrusion of sub base material into the soft black cotton Sub-grade soil, thereby adversely affecting the riding quality of the pavement. A general condition survey of the pavement surface was conducted to assess the type of distress. Special emphasis was laid on the drainage aspect and other relevant data were collected during the course of detailed investigation. The study indicated the failure of the surfacing, ravelling, extensive potholes, depressions, map cracks, edge failure and settlement of the surfacing accompanied by shoving of the surface layer. Considering the extent and severity of distress, the road was not expected to perform its intended function unless suitable remedial measures were suggested. The details of the suggestions are as below:

(i) Geofabrics were recommended at only those portions, which required full depth reconstruction because of extensive failures caused by poor drainage and absence of a sand cushion layer over the existing Sub-grade.

(ii) The drainage system is inadequate and should be improved by constructing side drains using geofabrics on either side of the road wherever required.

Akpan (2005) in his study carried out to relate the frequency of pavement failures, the engineering indices of the Sub-grade materials and the underlying geology. The results show a high variability in the indices such as the liquid limit, LL, the plasticity index, PI, the maximum dry density, MDD, the optimum moisture content, OMC, compressibility and the California Bearing Ratio, CBR, between the different geologic units. Engineering indices having significant correlation with CBR (the major criteria for assessing the quality of Sub-grade materials), are used to develop a scheme for evaluating the materials at different failure points along the Calabar-Itu Highway in Nigeria. The evaluation shows that locations exhibiting high failure rates are underlain by shaly or marly Sub-grade whereas locations characterised by low failure rates are underlain by weathered basement or sandy unit as Sub-grade. It is recommended that maintenance and provision of drainage facilities will go a long way to reducing the rate of failure.

Ajani (2006) in his review, commented that from available records, premature highway failures occur both in the northern and southern regions of Nigeria. However, it seems to be more prevalent and more extensive in the southern region. In the north, premature failure occurs mainly as washout on identifiable sections while in the south, it is usually extensive sometimes covering the entire highway pavement due to the geography and geological formation of the area.

Momoh, Akintorinwa and Olorunfemi (2008) used geophysical survey involving Schlumberger Vertical Electrical Sounding (VES) and dipole-dipole electrical resistivity, magnetic and Very Low Frequency Electromagnetic (VLF-EM) methods to investigate the significance of the geological factors in terms of the nature of the subsoil, the near surface structures and the bed rock structural disposition as possible causes of failures along the Ilesha-Owena highway located within the Lagos-Ibadan- Akure highway in the northern part of Osun State, Southwestern Nigeria. Detailing the subsurface geoelectric sequence, mapping the subsurface structural features within the sub-grade soil and delineating the bedrock relief as a means of establishing the cause(s) of the highway pavement failure. The magnetic profile, inverted VLF-EM model, dipole-dipole and geoelectric sections along the stable segment are diagnostic of generally resistive and homogeneous subsurface devoid of any geological feature. Along the failed segments low resistivity clay enriched, water absorbing substratum and linear features suspected to be faults, fracture zones, joints and buried stream channels were delineated. The clayey sub-grade soil below the highway pavement and identified suspected geological features are the major geologic factors responsible for the highway failure. Other factors include poor drainage and excessive cut into near-surface low resistivity water absorbing clay enriched substratum.

Adiat, Adelusi and Ayuk (2009), used integrated geophysical methods to investigate the courses of incessant road failure along some parts of Igbara-oke – Ibuji road – southwestern Nigeria. Results from the geophysical survey identified the causes of the road failure to include: Clayey nature of the topsoil / Sub-grade soil on which the road pavement is founded. Clay, though highly porous but less permeable owing to poor connectivity of its pores, retains water without releasing it thus makes it swell up and collapse at the exertion of pressure and this subsequently lead to road failure. Also reported by this group was the presence of near surface linear features such as faults, fractured zones, fissures and joints etc. in the subsoil beneath the road pavement as this creates structurally weak zones that enhance groundwater accumulation and hence pavement failure.

2.2.1.2 **Faulty Design and Poor Road Construction**

For any road pavement to be sound and stand the taste of time, it must be well designed and properly constructed. Many other factors of road failure can be taken care of at the design and construction stages.

Paul and Radnor (1976) in their work titled "Highway Engineering" stated that road design involves more than substituting data or taking values from a design chart, they also argued that many design methods in use are either entirely or partially empirical and may not give the desired result unless prior knowledge of the environment is known and rooms for adjustment in design created during construction. They disclosed that this has been discovered from many experimental roads. In addition they pointed out that all over the world, despite the level of technology, the number of design methods available have no hard and fast rule attached to them in designing flexible pavement.

Abynayaka (1977) who worked on the prediction of road construction failure in developing countries, reasoned the same way with Paul and Radnor (1976) by attributing faulty design to the fact that tests under which the specification for materials and equipment to be used are based and performed are in different environments. Again, he stated that there is a tendency of under-forecasting of the of traffic volume due to the developing nature of towns and cities in developing countries. Consequently this may result to under design and hence possible over stressing of the road pavement structure and eventually failure. They further disclosed that in Nigeria, award of contracts is most of the times based on no special ethics but on compassionate grounds. Thus constructions of roads, they said, is put in the hands of people with little or not technical know-how and hence early failure of roads. He further disclosed that majority of the specifications for a particular road contract is ignored during construction. This is for the contractor to maximize profit as against producing good quality road with longer life span. He particularly described how the dimension for roadways, pavement thickness and requirements for asphalt mixes are reduced in order to make profit ad save time in some Nigerian roads.

However, according to the World Bank (1981), even when road designers overcome the problems of design, the next problem that normally comes up is whether the constructor has the competence to execute the work according to specifications. They made it clear that the problem of poor road construction ranges from the selection of contractors (i.e award of contracts) to the procedure of acceptance of the completed job through regular inspection of the job while work is in progress.

The United Nation Educational Scientific and Cultural Organization (UNESCO) (1991) described road design as the translation of field location, survey and other data into specific plan to guide construction. It further discussed that a faulty design leads to failure, and good road design must ensure flexibility to minimize erosion hazards under varying site conditions. In another development, the World Bank (1991) stated that choice of construction materials for a particular road should be a function of topography, climate, and edaphic factors. They established a standard, which said that an ideal road must be built on three layers, namely:

a) The structural bed layer

b) The sub-base layer

c) The pavement layer

Roads are bound to fail where any of the three layers is absent.

Again, the FMWH (1992) stated that in Nigerian road designs (flexible pavement) are based on Concrete Pavement Restoration (CPR) methods, using pavement design specification of the FMWH. They further disclosed that in the specification handbook, the quantitative values and qualities of materials to be used are given, buttressing further the need for proper road design.

The federal Ministry of Works and Housing (FMWH) (1995) in a seminar on the importance of drainage system in all Nigerian roads, disclosed that faulty design is one of the causes of road failure. It again maintained that in the design of drainage structure, such data as soil conditions, rainfall intensity, and subsurface conditions are not collected prior to the design. Even if this rule is strictly followed, in some places, some are still neglected. It was also made clear that surface drainage is designed to remove storm waters from the travel roadway as rapidly as possible so that traffic may move safely and effectively. This means that drainage structure is a serious factor in road failure.

Jain and Kumar (1998) in their report on the causes of cracks occurrence in Ramghat-Aligarh Road near Aligarh, commented that a team from IIT Roorkee visited the site and found that the density of the different layers was in conformity to the average value given by the records of construction time and the workmanship was of good quality. However, the cracks have appeared due to the following reason:

(i) The top surface layer Mix Seal Surfacing (MSS) was constructed on existing BM layer. The layer of BM was exposed to unexpected rain and water percolated into lower portion through BM layer. The longitudinal drainage was not proper along the road and cross drainage works were also missing at various locations and the entire pavement was in saturated condition. That is why the water which had percolated into the lower layers could not escape through the sides. At one or two locations water was observed in BM layer while taking the density of BM and MSS layers by sand replacement method.

(ii) The road was widened on one side so there was differential settlement. It disturbed the camber position and the total thickness of the pavement crust was not uniform along the pavement width. This also caused variation in strength as well as load distribution of the pavement along the road width and results in cracks.

(iii) MSS itself is semi dense coat and during heavy rains, water was stagnated on the pavement surface. Due to continued stagnation of water, MSS layer also allowed percolation of water into lower layers.

According to Jain and Kumar (1998) IIT Roorkee was also requested to estimate the overlay requirements of Meerut Bypass and the cause of its failure. It was found that there is a wide variation in overlay thickness requirement of this 18.2 km road section. It varies from 25 mm (in terms of BM) at 15-16 km to 185 mm at 0-1 and 8-9 km. Here it was seen that water was stagnating along the road at some sections and side slopes were eroded. This resulted in the entry of water into the embankments and cracks had appeared in the pavement. These cracked sections required more strengthening in terms of layer thickness

Kumar (2002) commented on the study assigned to IIT Roorkee to investigate the corrugations over the newly laid Semi Dense Bituminous Concrete (SDBC) in Army Area of Roorkee sometime in the year 2001. The investigating team observed that although the quantity of bitumen, aggregate quality and proportioning were good but the compaction was done after the temperature of the mix had cooled down. As a remedy, the contractor was asked to provide a sand bitumen layer. Comments on Erosion and Road Failures (http://www.krisweb.com/watershd/roads.htm) has it that Road failures can be triggered by several different mechanisms which may include:

- Side Cast Material: When roads are being constructed, material excavated from the road bed is often side-cast off the edge of the road. This mound of material perched on a steep slope can become saturated and trigger a landslide that may take the road bed with it.
- Fill and Cut-Bank Failures: Forest roads are often built across weakly consolidated soils. If the road bed is not properly compacted and armored with a layer of rock, the road bed itself may fail as it becomes saturated. The exposed soil of a road cut can become saturated during a large storm event and trigger a landslide that takes out the road as well.
- Plugged Culvert: Each time a logging road crosses a stream, culverts are used to funnel the water under the road. The culvert is buried with fill material so that the logging road remains fairly level at the stream crossing. When culverts get plugged in large storm events, water backs up behind them and can take out the road. This type road failure is a human-induced debris torrent which contributes large amounts of sediment to the stream. If there are road crossings downstream from a culvert failure, they too will fail as the debris torrent extends down stream.
- Headwall or Mid-Slope Failure: When roads are constructed across steep headwater areas or across mid-slope areas with emergent ground water, they often fail. The compaction associated with road construction and use can block the flow of shallow ground water. This ground water pushes up near the surface and can

saturate the road prism that in turn increases its likelihood of failure. Roads in headwater or mid-slope locations are often constructed on steep slopes and failures initiate debris torrents that can cause significant destruction.

2.2.1.3 Poor Maintenance Operations/Functions

According to Paul, and Radnor (1976), road maintenance includes both physical maintenance, activities such as patching, filling of joints, moving, and also traffic services like painting, pavement markings, erecting signs and litter control. However, the Asphalt Institute (1976) in her manual series disclosed that road maintenance is limited and the maintenance man is does is just to make one dollar out of two dollar worth of job; this is not good and safe for our roads.

John and Gordon (1976) in their engineering manual captioned "A practical Guide to Earth Road Construction and Maintenance", noted that each road in which the natural soil is used as a running surface is not easy to maintain, particularly during the rainy season due to slippery surfaces, tendency to form corrugations that transverse the road or longitudinal rutting. They were also of the opinion that the need for road maintenance arises when the road develops cracks, raveling or twisting pavement surface.

Paul and Radnor (1976) on the other hand argued that though traffic and climatic conditions and the soil characteristics of different regions vary, there are maintenance operations, which can be used equally well in all regions. They disclosed that this operation was launched as cost effective approach, otherwise what they called "six-step approach" to prevent maintenance. They emphasized further that the Department of Transport (DOT) of the state of Georgia in the United States of America calls it Concrete Pavement Restoration (CPR). They established and disclosed the "six-step approach" adopted by Georgia, DOT as:

a) Slab stabilization

b) Slab replacement (where necessary)

c) Repair of spalls

d) Resealing transverse and longitudinal joints

e) Shoulder restoration

f) Diamond grinding.

On the other hand, Oglesby and Garry (1978) were of the opinion that road maintenance starts immediately after construction and commissioning for public use in order for it to give maximum service. They argued that the basic requirement of a road is that it should provide a uniform skid resistance running surface that has longer life span and needs little maintenance.

The TRRL (1991) said that the sustainability of a road facility depends on how well the roads is constructed and maintained. It stated that constant maintenance of a road facility ensures a lasting road and shows good management of a road facility. In order to have constant road maintenance, crew organization is needed in the form of direct labour to ensure efficient and regular road maintenance.

2.2.1.4 Traffic Effects and Human Impacts on the Roads

According to Paul and Radnor (1976) Traffic causes stress on road pavement as well as accelerating the distress caused by other factors. They are of the view that increased traffic flow repeatedly leads the road surface and the amount of pavement deformation increases as the number of load application increases.

The American Association of State Highway and Transportation Officials (AASHTO) (1976) in the manual they produced Bridge Maintenance, established some traffic characteristics responsible for the adverse effects of the road pavements. These characteristics include:

a) The traffic composition

b) The abrasive nature of loading

c) The speed of the vehicles

d) The vehicle wheel configuration

e) The tyre pressure

f) The Axle load and

g) The number and nature of repetition of the loading suffice to say that all these factors are rampant along the Onitsha/Enugu expressway because of its position as the major road through which goods move from north to the southeast and from the south to the north. The commercial value of Onitsha also enhanced this.

Similarly, the Anambra state Ministry of Works and Housing (ANSMWH), (1998) attributed road failure to human impacts on the roads. It was disclosed that corporate bodies like power Holding Company of Nigeria (PHCN), Nigerian Telecommunication (NITEL), Water Corporation, etc impact the roads without proper repair. It was stated that for example water corporation, in an attempt to lay down water pipes for water supply to the consumers cut across the road and when the road is reinstalled the job will not be well done, thus leading to road pavement distress and causing discomfort to road users. It was clear that this indiscriminate cutting across the roads results to complete road failures in the long run.

Also FMWH (1995) remarked that some individuals construct big bumps or excavation across some roads in Nigeria in order to check over-speeding without knowing the effects of such constructions on the road pavements.

Again the former Commissioner for works and Housing in Anambra state, in a media chart delivered on December 12, 2004 disclosed that during social unrests like riot, rampage or celebrations, youths normally burn tyres on the asphalted roads. The asphalt used in paving the roads is made of petro-chemical material (Bitumen), which is inflammable and can burn when heated. The resultant effect is that the burnt portion s will become weak and limp when in contact with water. This later develops to cracks and eventually potholes and small ditches on the road pavement, resulting in failures.

Ibrahim (2011), a Nigerian Daily Times Online reporter, reported an interaction with the head of the Federal Road Maintenance Agency(FERMA), in Jos on the 30th day of May 2011, Mr. Ifeanyi Nweke, who commented that "One other challenge is knowing the causes of the failure of our roads, considering the quantum of loads that ply the roads on a daily basis". "Our roads are constructed not to carry loads above 42 tones but the failure of our rail system has made it imperative for the transporters to carry goods above what is expected," he said. He thus called for the re-introduction of weigh-bridges on the roads to put a check on road users who carry goods beyond the limit. "Besides, many of these roads were constructed a long time ago and cannot stand the kind of weight being carried on them on daily basis". "If the Federal Government re-introduces the system, more revenue will be generated from law-breakers who will be taxed for the extra loads they carry," he said.

2.2.1.5 Environmental and Climatic Factors

Paul and Radnor (1976) pointed out that most of the defects credited to traffic are actually initiated by environmental and climatic factors, and are later developed by traffic. According to the shrinkage cracks which sometimes occur initially at the underside of a road pavement due to temperature and moisture changes are often found to increase in size on the last load applied to it by traffic. They concluded that temperature change, moisture differences and soil characteristic, which vary in different regions, contribute to the problems of road failure.

The TRRL (1991) in a report on road research disclosed that climatic factors can also affect the strength of road structure. It was stated that temperature fluctuation and acid rain attack on the base material of the road in water-logged areas can weaken the sub-base of the road materials through capillary action, thereby reducing the supporting power of the road pavement.

The World Bank (1991) in a paper titled "Nigeria Highway Sector Study" supported the view of TRRL (1991). Here it was stated that in some parts of Nigeria, temperature could rise as high as 35^0c in the day time and as low as 25^0c at Night. This fluctuation in temperature, according to it, induces stress on the road pavement. This results in cracking of poorly mixed asphalted road pavements. It was further stated that this high temperature could reduce the bond stiffness of the surface of the flexible road pavement leading to rutting under traffic. This means road failure.

Again, Abynayaka (1977) stated that when roads are poorly drained, such factors like erosion can take place leading to ejection of materials out of the road pavement.

2.1 GAPS IN LITERATURE

i. None of the works reviewed tried to establish the implications of poor road design, but the standard of road constructed starts from good design where all other factors that will make the road to

3.0 METHODOLOGY

The study adopted a survey design which employed the use of individual interviews and a well structured questionnaire to gather information on the causes of the road failure and impacts of the road failure on the road users. This in turn was collated into data which was analyzed using some statistical tools. To determine the sample size for the questionnaire distributed, the findings of Onuoha et al 2014 was adopted and 270 questionnaires were distributed to people to source for information on the subject matter at locations where the proper respondents could be found considering the fact that they cannot fill it while the vehicle are moving. For the purpose of increasing the reliability of the respondents and authenticity of data, due to the inability of the researcher to reach out to the road users or access them while the vehicle is moving, the opinion pool was conducted at the Enugu-Awka motor parks at Onitsha, Enugu-Onitsha motor parks at Awka, and Awka-Onitsha motor parks at Enugu, the purpose being to capture the actual road users for respondents.

4.0 DATA PRESENTATION / ANALYSES

Presentation, Analyses and Discussion of Questionnaire Data

Before the questionnaire was adopted as an authentic and reliable tool for data generation, a reliability test was done. The Reliability Test and Item Analysis Using Likert Scale Analysis by Coding shows that from the number of respondents used for the field survey which is 270 persons/respondents, none of the respondents was excluded in the analysis. The reliability of the research tool which could be interpreted thus, a value less than 0.6 implies weak tool and value more than 0.6 is an indication of strong and reliable research tool. In this research, the value of Cronbach's Alpha is 0.993 which implies the tool is reliable and can be used for research purpose.

The table1 below shows the responses of respondents on causes of the road failure as listed in the questionnaire.

Table 1: Grouping of Responses of Respondents on Causes of the Road Failure

Cause	Number of respondents agree and the %	Number of respondents disagree and the %	Decision
Bad nature of the soil	149 (70%)	63 (30%)	Agree
Poor road design	104 (50%)	104 (50%)	Agree or Disagree
Stress of heavy vehicles	127 (62%)	79 (38%)	Agree
Old age of the road pavement	191 (75%)	64 (25%)	Agree
Incompetence of the contractor	175 (70%)	75 (30%)	Agree
Mismanagement by the government	165 (65%)	87 (35%)	Agree
Inadequate maintenance	193 (73%)	71 (27%)	Agree

Source: Authors Field work (2014).

The decision was based on the number of respondents that agreed to the problem as one of the causes of road failure. The values in brackets are percentages computed for each question without the number of respondents who were neutral to the questions. Higher percentage implies higher number of respondents in support of the question. From the Table 1, only about 50% agreed that poor road design is a factor of the road failure thus the decision to fairly agree or disagree that it is not a factor.

To determine the significant causes of road failure among causes listed, One-way Analysis of Variance was used. The result is as shown below;

Hypothesis:

H_0: there is no significant difference in the classification/grading of causes of road failure by respondents.

H_1: there is significant difference in the classification/grading of causes of road failure by respondents.

Table 2: Descriptive Observation of Responses of Respondents on Causes of the Road Failure

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	2	106.0000	60.81118	43.00000	-440.3668	652.3668	63.00	149.00
2.00	2	104.0000	5.65685	4.00000	53.1752	154.8248	100.00	108.00
3.00	2	103.0000	33.94113	24.00000	-201.9489	407.9489	79.00	127.00
4.00	2	127.5000	89.80256	63.50000	-679.3440	934.3440	64.00	191.00
5.00	2	125.0000	70.71068	50.00000	-510.3102	760.3102	75.00	175.00
6.00	2	126.0000	55.15433	39.00000	-369.5420	621.5420	87.00	165.00
7.00	2	132.0000	86.26703	61.00000	-643.0785	907.0785	71.00	193.00
Total	14	117.6429	48.32360	12.91503	89.7416	145.5441	63.00	193.00

Source: Statistical Analysis Result

ANOVA

Table 3: Observation From Analysis Of Variance

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1926.714	6	321.119	.079	.997
Within Groups	28430.500	7	4061.500		
Total	30357.214	13			

Source: Statistical Analysis Result

The ANOVA shows the variation among the causes is not significantly different but the classification is as follows;

Multiple Comparisons

Table 4: Observation LSD for Causes of the Road Failure

(I) factor	(J) factor	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	2.00000	63.72990	.976	-148.6973	152.6973
	3.00	3.00000	63.72990	.964	-147.6973	153.6973
	4.00	-21.50000	63.72990	.746	-172.1973	129.1973
	5.00	-19.00000	63.72990	.774	-169.6973	131.6973
	6.00	-20.00000	63.72990	.763	-170.6973	130.6973
	7.00	-26.00000	63.72990	.695	-176.6973	124.6973
2.00	1.00	-2.00000	63.72990	.976	-152.6973	148.6973
	3.00	1.00000	63.72990	.988	-149.6973	151.6973
	4.00	-23.50000	63.72990	.723	-174.1973	127.1973
	5.00	-21.00000	63.72990	.751	-171.6973	129.6973
	6.00	-22.00000	63.72990	.740	-172.6973	128.6973
	7.00	-28.00000	63.72990	.674	-178.6973	122.6973
3.00	1.00	-3.00000	63.72990	.964	-153.6973	147.6973
	2.00	-1.00000	63.72990	.988	-151.6973	149.6973
	4.00	-24.50000	63.72990	.712	-175.1973	126.1973
	5.00	-22.00000	63.72990	.740	-172.6973	128.6973
	6.00	-23.00000	63.72990	.729	-173.6973	127.6973
	7.00	-29.00000	63.72990	.663	-179.6973	121.6973
4.00	1.00	21.50000	63.72990	.746	-129.1973	172.1973
	2.00	23.50000	63.72990	.723	-127.1973	174.1973
	3.00	24.50000	63.72990	.712	-126.1973	175.1973
	5.00	2.50000	63.72990	.970	-148.1973	153.1973
	6.00	1.50000	63.72990	.982	-149.1973	152.1973
	7.00	-4.50000	63.72990	.946	-155.1973	146.1973
5.00	1.00	19.00000	63.72990	.774	-131.6973	169.6973
	2.00	21.00000	63.72990	.751	-129.6973	171.6973
	3.00	22.00000	63.72990	.740	-128.6973	172.6973
	4.00	-2.50000	63.72990	.970	-153.1973	148.1973
	6.00	-1.00000	63.72990	.988	-151.6973	149.6973
	7.00	-7.00000	63.72990	.916	-157.6973	143.6973
6.00	1.00	20.00000	63.72990	.763	-130.6973	170.6973
	2.00	22.00000	63.72990	.740	-128.6973	172.6973
	3.00	23.00000	63.72990	.729	-127.6973	173.6973
	4.00	-1.50000	63.72990	.982	-152.1973	149.1973
	5.00	1.00000	63.72990	.988	-149.6973	151.6973
	7.00	-6.00000	63.72990	.928	-156.6973	144.6973
7.00	1.00	26.00000	63.72990	.695	-124.6973	176.6973
	2.00	28.00000	63.72990	.674	-122.6973	178.6973
	3.00	29.00000	63.72990	.663	-121.6973	179.6973
	4.00	4.50000	63.72990	.946	-146.1973	155.1973
	5.00	7.00000	63.72990	.916	-143.6973	157.6973
	6.00	6.00000	63.72990	.928	-144.6973	156.6973

Source: Statistical Analysis Result

Using the Post HOC test which is used in statistical hypothesis for classification, two treatments/items are said to have almost the same characteristic if the significance value is greater than 0.05 and the higher the value the closer the items in classification. Based on this fact, problems listed in the research tool can be grouped as 1, 2, and 3 having almost the same number of respondents and 4, 5, 6, and 7 having almost the same number of respondents. The mean values can be used in ranking the problems as;

i. **Inadequate maintenance**

ii. **Mismanagement by the government**

iii. **Old age of the road pavement**

iv. **Incompetence of the contractor**

v. **Bad nature of the soil**

vi. **Stress of heavy vehicles**

vii. **Poor road design**

The problems were arranged in ascending order which implies the least of the least of the factors of the road failure of Onitsha-Enugu expressway under study is poor road design.

4.1 DISCUSSION / SUMMARY OF FINDINGS

It is crystal clear that for any engineering structure to be sound it starts from the design and finally to the actual implementation of the design and plan. From the literature reviewed, it is obvious that poor road design is one of the major factors of road failure, but considering the percentage of the respondents supporting this factor and the result of the statistical analyses, it became glaring that road design is not likely one of the main factors of the road failure. The response of some of the engineers working on the road suggest that the road design cannot be a factor of the road failure as the road has lasted for a very long time and within this span of time the design was what it supposed to be except for recent changes due to growth and development leading to the redesign and reconstruction of the road. Come to think of it, the road was designed by the same company and the construction executed by the same contractor, thus the reason for the failure of some sections of the road while others remain un-failed suggests that the designing of the road will not be a likely factor of the road failure as contained in the work of Onuoha et al 2014. The disparity in the findings of this work and that of a recent work by Onuoha et al 2014 was mainly because they based their findings only on the responses from the questionnaire while this work also adopted personal interviews with some stake holders of the recent reconstruction going on along the road.

4.2 CONCLUSION AND RECOMMENDATION

The work concluded that poor road design is not a significant factor of the road failure although there is need for redesigning and reconstruction of the roadway. In line with these findings and conclusion of this work the following recommendations were made in order to mitigate the problem road failure.

1. Ensure an accurate design of any road way before its construction proper which will consider all the characteristics of the area to be cut across by the roadway, the service burden to be borne by the road way and the expected life span.
2. Enlisting of relevant geologists, climatologists and engineers at the design and planning stages of any roadway before its construction proper.
3. Ensuring that a road gets its routine and periodic maintenance as this is necessary not minding how good or bad the road was designed for it to stand the test of time.
4. Monitoring and properly supervising the construction engineers to see that they accurately implement what was preplanned by the designing engineers not trying to cut costs that may be detrimental.

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