Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 2 Issue 11, November - 2016

Investigative Study Of Possible Causes Of Failure Of A Section Of Road In Jos- Plateau, North - Central Nigeria

Wazoh, H. N., Daku, S. S and Samuel, F.G.
Department of Geology, University of Jos, Nigeria
Email address of corresponding author: hannatuwazoh@gmail.com

***Abstract*—The durability of transportation infrastructure is critically dependent on their design and construction. Some roads have experienced early distress after construction while others long after construction. Several design methods have been developed to determine the thickness and composition of road surfaces required to carry predicted traffic for a given period of time. However, maintenance is expected to take place every 2-5 years to keep the asphalt from hardening leading to extensive cracking. Similarly, failed areas should be patched to keep the damaged area from getting bigger. It is in this regard that a study of a section of a road in Jos-Plateau Nigeria was carried out with the aim of examining the defects in relation to geotechnical properties that could probably be responsible for failure of the road. The engineering tests carried out include sieve analysis, specific gravity, natural moisture content, Atterberg limits, compaction and California bearing ratio show that the materials used in constructing the road possess good geotechnical properties. Increase in traffic and loading of the road by heavy duty vehicles beyond the design and carrying capacity of the road is possibly one of factors responsible for the rapid deterioration of the road. Recommendations of changes in construction practice that could minimize or eliminate the likelihood of reoccurrence of the defects have been suggested.**

Keywords—Defects; Pavement; Roads; Road failure; Traffic

1. INTRODUCTION

In Nigeria, road is one of the infrastructural facilities that is in total collapse [1]. Road failure has not only caused set back to Nigerian economy but it has claimed lives resulting from road crashes and loss of properties worth millions of naira annually. Many roads in Nigeria today are old and suffer high incidents of instability. Although, several factors might contribute to road failure, most materials on which Nigerian roads are built may not be in harmony with highway sub-grade specifications [2]. Consequently, studies of pavement failure in some parts of southeastern Nigeria have been attributed to interaction of local road aggregate with water causing swelling, stripping and potholing [3]. Poor construction, problematic soils, poor drainage and poor geotechnical properties of construction materials is said to be responsible for road failures in some roads in the southwestern parts of Nigeria [4]; [5], [6]; [7]; [1] [etc). Most road failures in the tropics (of which Nigeria is one) can be attributed to geotechnical factors [9].

Roads are built to provide safe passage of vehicles and must be properly designed and constructed. After construction, defects could occur for so many reasons and may manifest on roads as potholes, cracks, depression, ruts etc. Usually there is more than one reason for each type of defect but in most cases the accumulation of minute strains appears first as cracks and later as potholes and other surface defects.

A pavement section may be generally defined as the structural material placed above a sub-grade layer. In asphaltic pavement, it is typically a multi-layer system comprising the sub-grade, sub-base, base course and surfacing. Its principal function is to receive load from the traffic and transmits it through its layers to the sub-grade. A pavement is said to be defective, when it can no longer perform this function during its design life. When a road remains functional during its design life then it can be termed a success. Needless to say, as soon as a road is commissioned, it begins to deteriorate. Hence to serve its functional design years, the need for proper maintenance cannot be overemphasized. That means defects however little must be identified and tackled immediately.

In this study, the recently commissioned Goodluck Ebele Jonathan road is considered. The road can be described as a success, yet, very conspicuous defects are identified ranging from potholes, alligator cracks and longitudinal cracks have been observed.

Reasons for such defects are highlighted. Visual observation of the affected areas was made and laboratory test results are reviewed and discussed and recommendations suggested. The 24.50km dualized road is located in the tin city of Jos, plateau state. It is an urban road that is well tarred and posses' good traffic facilities like street lights, drainage on both sides of the road, pavement markings, pedestrian walkways, appropriate road shoulder (Fig.1) This road link travelers to Kaduna and Bauchi states; markets like Farin Gada, Katako and Gada Biyu satellite markets; communities such as Utan, Rock Haven, Alheri, Laranto, Kabong, Rukuba Barrack, Miango, Bassa, Mister Ali, City center, etc; institutions like Jos ECWA Theological Seminary

(JETS), Police Children school, Command Secondary School, Federal Government College, University of Jos, ECWA Staff School and many more. Other agencies and parastatals of government include National Metallurgical Development Centre (NMDC), Transmission Company of Nigeria (TCN) substation etc; the Jos Ultramodern stadium and many hotels, churches, mosques to mention but a few. This road meanders on crystalline rocks; it is underlain mostly by the Younger Granites and in few places by the basement rocks. These rocks are characterized by different rates of weathering at different locations. The general geology of the area can be described as stable.

2. Materials and Methods

Samples of laterite, rock aggregates and asphalt were collected and subjected to engineering tests at the Plateau state Ministry of Works laboratory. The engineering tests carried out include sieve analysis, specific gravity, natural moisture content, Atterberg limits, compaction test and California bearing ratio (CBR).

3. Results and Discussions

3.1 The summary of results of the tests carried out is presented in Tables 1 and 2.

Table 1: Summary of results of specific test on pavement materials

	Tests and value ranges			
Material	OMC (%)	MDD (Kg/m^3)	CBR (%)	P I (%)
Fill	11.5-18.3	1635-1873	7.5-25.2	6.2-23.8
Sub-base	12.2-12.4	2061-2062	20.5-23.2	5.8-6.6
Base course	12.1-14.3	1876-2056	17.8-81.7	6.2-9.3

Table 2: Summary of some geotechnical tests

Trial Pit No	Depth (m)	Natural moisture content (%)	Dry Density Kg/m^3	Sieve analysis (%)		
				Gravel 7	Sand 36	Silt/ clay 200
1	1.50	6.80	1559	10.0	57.0	33.0
2	1.50	19.1	1491	39.0	50.0	11.0
3	1.50	12.2	1604	17.0	61.0	22.0
4	1.50	14.1	1519	34.0	42.0	24.0

3.2 Pavement Materials

The road is made of a flexible pavement and other layers of various thicknesses as described in (fig.2).

The surface layer is made up of wearing and binder courses of 50mm and 60mm thickness respectively. These layers are in contact with traffic loads and they contain the materials that ensure the stability and durability of the road and also provide resistance to the rubbing and grinding action under the wheel of traffic due to mutual attrition. They also serve to prevent the infiltration of surface water into the underlying base, sub-base and sub-grade materials.

The base course of 200mm thick is made up of high quality granular material which is able to withstand high stresses was laid on the sub-base course.

The sub-base of 150mm thick was laid on the sub-grade or fill material.

The sub-grade materials of 150mm thick were imported and used to create an embankment on which the road pavement is constructed.

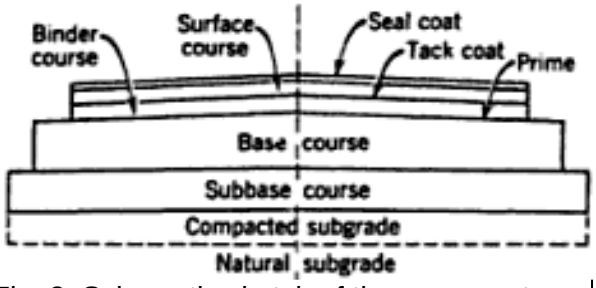

Fig. 2: Schematic sketch of the pavement

3.3 Swelling Potential

The swelling potential of the soil indicated by the plasticity (PI) value is low for the sub-base and base course material while the fill material has a medium swelling potential. Hence the soil can be said to exhibit low to medium swelling potential [10].

3.4 Specific Gravity

The Specific Gravity value of the materials is 2.63 indicating the level of laterisation of the soil. [11] states that the higher the specific gravity, the higher the degree of laterisation. [12] also suggested the use of specific gravity in investigating the maturity of lateritic soils. The higher the specific gravity of a soil, the higher the degree of laterisation and the stronger the soil. The soil material under investigation is adequate for sub-grade, sub-base, base course as component of surface course material considering its relatively high value of specific gravity.

3.5 Compaction Characteristics

The optimum moisture content of the fills, sub-base, and base courses ranges from 11.5% to 14.3% and maximum dry density (MDD) from 1635kg/m^3 to 2056kg/m^3 respectively indicating a good density value of compaction for flexible pavement condition for low volume vehicle [13] However increasing axial load of heavy vehicles plying this road with several tones of materials would affect the level of compaction rate which was originally designed to meet low volume vehicles.

3.6 California Bearing Ratio (CBR)

The California Bearing Ratio of the samples for fills, sub-bases and base courses meet the requirements of the 1997 Nigerian General specification for roads and bridges [14] which states that the CBR should not be less than 30% and 80% for sub base and base layers respectively, even though the sub-base is slightly less than the 30% requirement but the quality of the overlying base course overrides any effect on the sub base. Also, this meets the 1962 Asphalt Institute [15] standard making the soils fair to good for road construction.

Generally, it can be said that the geotechnical or mechanical properties of the materials used for construction are of a good quality and the wearing course material mixture and design is appropriate for the road.

3.5 Water Table Level

The water table level estimated from a hand-dug well at the edge of the road embankment is estimated to be about 11.5m high. The road adjacent this hand-dug well has a major pothole. The level of water suggests that the ground water in far below to permeate into and even weaken the sub-grade material and cause any problem to the pavement unit. This ruled out the possibility of groundwater interference.

3.6 Failures observed on Pavement

Failures observed are potholes, alligator cracks, transverse cracks, longitudinal cracks and potholes (Fig. 3a, 3b, 3c, 3d).

Fig. 3a: A typical pothole

Fig.3b: Potholes surrounded by alligator cracks

Fig.3c: Low severity longitudinal cracks

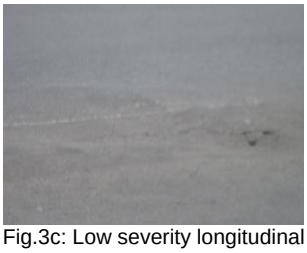

Fig.3c: Low severity longitudinal cracks

Fig. 3d: A patch next to a pothole

A field review of the project was performed to evaluate the condition of the pavements that are a part of this study.The

defects observed on the road pavement appeared not to be from the pavement materials.

Pipes and well for municipal water supply (Fig. 4a & 4b) were left untouched during the road construction. Over time, the effects of dynamic loading of the road resulted to these pipes quickly deteriorating and leaking water into and through the pavement. Water has been observed to pour to the surface on many occasions. Pavements are not meant to hold moisture; it is a major cause of pavement deterioration [16]. Moisture tends to affect a number of pavement material properties including load bearing capacity, shrinkage and swelling. This has resulted to the deformation of the pavement under load.

Fig. 4a: A well at the edge of road embankment

Fig. 4b: A buried pipe

Roads are designed for a specific amount of traffic. However, all road surfaces wear under the action of traffic. Increase in traffic and overloading beyond the design and carrying capacity of the road might be responsible for the rapid deterioration of the road particularly by heavy duty vehicles. The security challenges in the town's central area and rehabilitation of other roads have added to the traffic on this road. Generally, the roads in Jos are overloaded with traffic that would have been conveyed through other transport modes other than the roads.

3.6.1 Failure Hypothesis

From visual observation and consultation, a brief failure hypothesis can be speculated. Water from the leaking pipes under the pavement moved into the pavement material in a radial pattern, that is, in vertical and lateral directions resulting to vertical erosion similar to what is referred to as piping in foundation or embankment of materials. These materials are composed of different grain sizes. First the fine materials eroded and then coarse in that order. The creation of void or openings under the asphaltic-concrete layer plus the action of traffic load might have resulted to the subsidence of the asphaltic-concrete layer that is seen on the surface as pothole.

3.6.2 Effects of Road Failures

1. Accidents
   A number of accidents have been counted at points with major potholes. In most cases tricycles maneuvering potholes to the speed lanes end up being hit by vehicles behind. First timers on the road make up a large part of the victims.
2. Adverse economic development
   This interferes with commercial activities in the state. Breakdown of vehicles affects movement of goods and personnel within the economy. Gada biu, Farin gada and Zaria road are known to be some of the business areas of Jos.
3. State's reputation
   Opinion of visitors to the State is very important. Plateau is known for tourism, this definitely is one way that will score the state low.

RECOMMENDATIONS

1. The construction of a road starts from conception, planning and design. Agencies in charge of road work should be more proactive in the activities leading to the success of design and construction of roads.
2. There should be collaboration by government Ministries, department and agencies such as water board, ministries of works, lands and survey and town planning, etc in execution of such projects.
3. Where necessary, tunnels should be constructed for water pipes, electrical cables and any other installations across road pavements.
4. Other modes of transportation like rail lines and tramps should be developed to reduce the pressure on road transportation.

5. Regulatory agencies should wake up to their statutory responsibilities by encouraging and enforcing contractors to construct good quality roads and adherence to standards.
6. Curing is critical to good performance and durability. Renewed emphasis on good curing practices needs to be given attention and priority. Poor curing leads to plastic surface cracks, which opens the pavement up to water infiltration. That water is the mechanism that feeds many of the deterioration mechanisms identified in this study.
7. For a sustainable road development there is need for adequate maintenance of the roads. Therefore, agencies of government like Federal Road Maintenance Agency (FERMA) and the Plateau State road maintenance agency should be empowered to adequately maintain these roads.

CONCLUSION

A large part of any road network undergoes instability due to poor construction, lack of adequate maintenance or the underlying geology. Although the underlying geology is good and the materials used in the construction of the road possess' good geotechnical properties, there are still avoidable defects such as potholes, alligator cracks and longitudinal cracks. These defects are possibly caused by deterioration of water pipes passing through the pavement gushing water on the road, indiscriminate breaking of the road by telecommunication companies thereby providing leeway for water to further deteriorate the road. Increase in traffic and overloading beyond the carrying capacity of the road by heavy duty vehicles is another possible factor responsible for the failure of the road. The effects of these defects include accidents, time wastage and rapid wear and tear of vehicles and its attendant loss of financial resources maintaining these cars. It is hoped that in any future construction, however little, special consideration will be given to the future expansion of the city.

ACKNOWLEDGMENT

The authors wish to express their profound gratitude to Works Yard Department of Ministry of Works Plateau state for their assistance during the course of this study.

REFERENCES

[1] Kekere, A. A., Lawal, L.O. & Awotayo, G.P. (2012). Relationship between geotechnical properties and Road failures along Ilorin – Ajase Ipo Road Kwara State, Nigeria. Journal of Mechanical and Civil Engineering (IOSR-JMCE) www.iosrjournals.org, vol. 4(4), pp.1- 4.

[2] Owoyemi, O.O and Adeyemi, G.O (2012). Highway geotechnical properties of some lateritic soils from the Sedimentary Terrain of the Lagos – Ibadan highway, IJSER http://www.ijser.org, vol. 3 (12). pp.1-14.

[3] Abam, T. K. S., Ofoegbu, C. O., Osadebe, C. C.,and Gobo, A. E. (2000). Impact of hydrology on the Port-Harcourt-Patani-Warri Road. Environ. Geol., vol.40, pp.153–162.

[4] Adeyemi, G.O. (1992). Highway geotechnical properties of lateritised residual soils in the Ijebu-Ishara geological transiton zone of Southwestern Nigeria. Unpublished Ph.D Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria, vol. 1. pp. 115-118.

[5] Jegede, G. (2000). Effect of soil properties on pavement failures along the F 209 highway at Ado-Ekiti, Southwestern Nigeria. Construction and Building Materials Elservier, Oxford 14, pp. 311 – 315.

[6] Jegede, G. (2004). Highway pavement failure induced by poor geotechnical properties at a section along the F209 Okitipupa-Igbokoda high way, South-Western Nigeria. Ife Journal of Science, vol. 6(1), pp. 42.

[7] Ogundipe O. M (2008). Road pavement failure caused by poor soil properties along Aramoko-Ilesha Highway, Nigeria. Journal of Engineering & Applied Sciences.

[8] Ndefo Okigbo (2012). Causes of Highway failures in Nigeria. International Journal of Engineering Science & Technology (IJEST) Vol. (11).

[9] Gidigasu M.D., (1976). Laterite soil engineering, Elsevier, Amsterdam, 554pp.

[10] Ola , S.A. (1981). Mineralogical properties of some Nigerian residual soils in relation with building problems. Eng. Geol., vol. 15, pp.1 – 13.

[12] Gidigasu, M. D. (1980). Geotechnical evaluation of residual gravels in pavement construction. Engineering Geology, Vol.15, pp.173-194.

[13] O'flaherty C.A (2001.) soils for Road work: In O'flaherty, C.A. (ed). Highways the location, Design, Construction and maintenance of pavements.133.www.amazon.com.

[14] Federal Ministry of Works and Housing (FMW) (1997). *Nigerian General Specification for Roads and Bridges (Revised Editio*n), vol. 2, pp. 137-275.

[15] Asphalt Institute (1962). The Asphalt hand book. Maryland USA, Pp. 176.

[16] Distress identification manual for the long term pavement performance program (2014). Prepared by Federal Highway Administration, Department of Transportation, United States of America, pp. 129.