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Causes of failure of Nigerian roads: A review

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Abstract

Many cases of road failures have been reported by experts in Nigeria from North to South, East to West. Most of these roads are in a deplorable condition and professionals have attributed it to a number of causes. This study reviewed causes of failure of roads in Nigeria and categorized them into lack of careful and diligent geotechnical studies, inadequate knowledge of geology of the area, and other conditions. Roads that have failed due to lack of proper geotechnical studies include; Awotan-Akufo, Sagamu-Papalanto highway, Onitsha-Enugu Expressway and Akoko highway. Geotechnical studies provide information on the physical and mechanical properties of soil or rock around or brought to the construction site. Some roads have failed as a result of improper consideration of geology for instance the Shagamu -Benin expressway, Lagos- Ibadan expressway, Ibadan -Ife, Osogbo -Iwo expressway, Abakaliki area and Port Harcourt -Enugu expressway. Roads are founded on geologic earth materials and are greatly controlled by geology; hence, geology is very important in road construction. Other conditions such as old age, inadequate maintenance, poor design and construction, lack of drainage, use of poor and substandard materials, and heavy traffic have also led to road failures. Despite the absence of definite statistics, most experts agree that the rate of roads failure have increased in recent years in Nigeria. There is strong evidence to suggest that while geotechnical processes are becoming better controlled and more reliable, failures of small, medium and big scale geotechnical works such as roads continue to arise with embarrassing frequency in the country.

Key words: Geology; Geotechnical; Roads; Failures; Nigeria

1. Introduction

Roads have proved worldwide to be the most effective and preferred mode of transportation for goods and persons (Alo and Oni, 2018). Road transport has gained popularity due to its ability to provide better accessibility through door-to-door services and its suitability for short haulage of passengers and freight. In Nigeria, road transport is the most affordable and efficient means of transport for the majority of people as other modes of transport are either too expensive or not fully developed. Consequently, there is excessive axle loads on majority of Nigerian roads. According to Onuoha and Onwuka (2014), road failure could be defined as a discontinuity in a road pavement resulting in cracks, potholes, bulges and depressions. A road pavement is supposed to be a continuous stretch of asphalt lay for a smooth ride or drive, however visible cracks, potholes, bulges and depressions may occur to disrupt such smooth ride. The disruption in smooth ride is generally regarded as road failure.

It is important to highlight that Nigerian roads have often been characterized with long cracks, potholes and other pavement defects. These have posed a serious challenge and disaster such that Nigerians can hardly travel a kilometer without coming across long cracks and potholes. These have resulted to a spike in the number of road accidents and a plunge on the nation's economic development. Every single road built is often known to have a stipulated design life; but roads often times fail long before the planned expected date; some fail after construction, some after flooding while

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others last to its entire life expectancy with appropriate maintenance (Emmanuel et al., 2021). Nigeria has the largest road network in West Africa. According to the Government Infrastructure Concession Regulatory Commission, Nigeria has about 195, 000 km of road network of which about 60,000 km are paved. Most of the major road networks were constructed in the 80s and early 90s (Styles 2013).

As a result of poor maintenance and low-quality materials used for repairs, the condition of roads is deteriorating. Travelling is very difficult and sometimes almost impossible in many areas on secondary roads during the raining season due to potholes and eroded surfaces. Nigeria's most important highways run from South to North and were designed to bring farm produce from the hinterlands to the coast for export and to link the economies of Northern and Southern Nigeria (Vanguard, 2020). When the foundation materials upon which buildings or roads are constructed are not put into consideration or thought not to be important, then one prepares to suffer the effect of eventual collapse of structures if the "conditions become right for the collapse" to occur (Teme et al., 2008). In view of the importance of roads to the economy of any nation and the rapid rate at which Nigerian roads are deteriorating, it is important to take a cursory look at the causes of such failures and then proffer solutions to ameliorate such causes thereby curtailing the huge budgetary expenses spent yearly on roads rebuilding and maintenance by government.

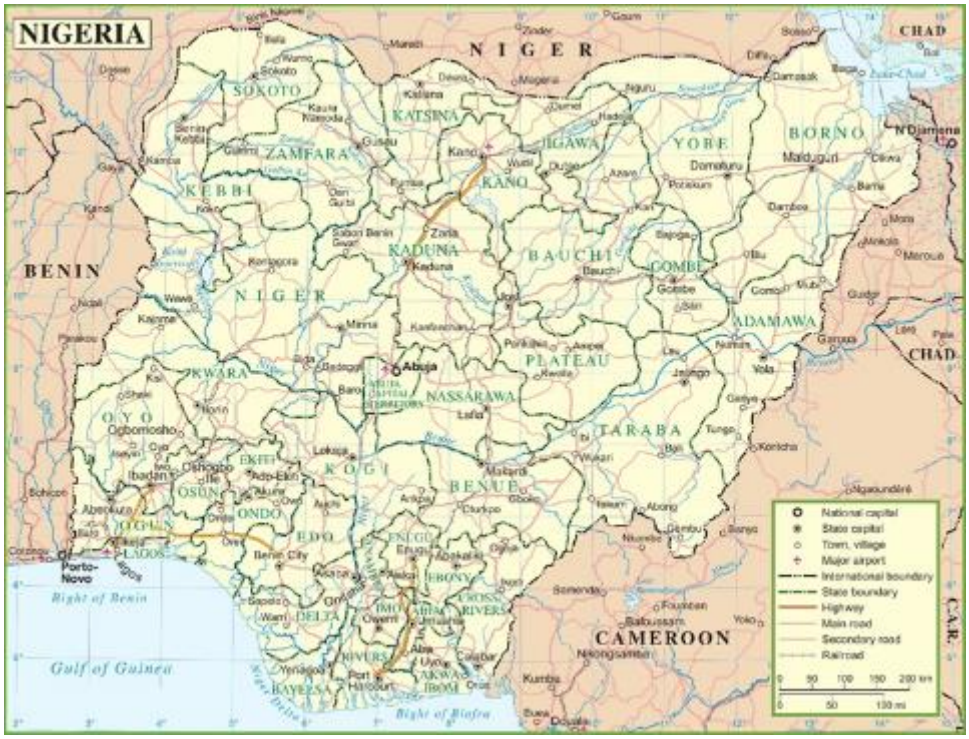

Figure 1 Map of Nigeria showing major roads and highways in the country (Ayo and Ikechukwu, 2013)

2. Causes of Roads Failure in Nigeria

Geotechnical, geological, road usage, construction inadequacies, design and maintenance are among the factors that may be responsible for road failures in Nigeria (Emmanuel et al, 2021). Furthermore, Adegoke et al (1980) and Nwankwoala et al (2014) identified geological, geomorphological and geotechnical factors, design and construction inadequacies and maintenance as causative factors of road failure in Nigeria.

2.1. Geotechnical Causes

Roads are actually constructed on or with geological materials (rocks or soils), and these materials' properties influence their performance as transport medium. Poor geotechnical properties of residual soils used in the construction of roads in Nigeria may result in road pavement deterioration (Olofinyo et al. 2019). Most countries have stipulated standards for the geotechnical properties of soils to be use for road construction and Nigeria is no exception. It is in realization of the importance of geotechnical properties of soils that the Federal government of Nigeria stipulated the Nigerian specifications for roads and bridges (1997) for the various geotechnical properties of any soil to be use as sub-base, and base course material as can be seen in Table 1 below. Most of the roads constructed in Nigeria mostly does meet all or some the specifications stated herein.

Table 1 General Specifications for Road and Bridges. Source: FMW & H (1997)

Property	Subgrade	Subbase
% passing sieve, No 200 (75μm) (%)	≥35	≥35
Liquid Limit (%)	≤50	≤35
Plastic Index (%)	≤30	≤12
O.M.C (%)	-7	6-7
M.D.D (Mg/m3)	≥1.8	≥1.6
CBR Soaked (%)	≥7	≥30
CBR Unsoaked (%)	≥15	≥80

The Lagos- Ibadan expressway is one of the important and busiest roads in southwestern Nigerian that has continually failed. In finding the root cause of the incessant failure, Layade, et al (2017) identified fractured bedrock, clay and sandy clay soil with high permeability and porosity as the causes of the incessant failure experienced on the road. However, Simeon et al (2018) identified high natural moisture content of the soil along the failed section of the road, high percentage of fines, and high (> 8%) linear shrinkage value which made the soil susceptible to shrinkage and swelling. Oyem et al (2020), identified poor drainage condition, high percentage fines as some of the causative factors responsible for the deterioration and failure of the Sagamu – Papalanto highway in Southwestern Nigeria. In the same vein, in assessing the failure of Ipele – Isua highway, Daramola et al (2018), attributed it to poor drainage, high linear shrinkage, low CBR and poor compaction characteristics. The Isua – Idoani in Southwestern Nigeria failed due to poor drainage, high linear shrinkage of 5 -11.4%, high percentage fines of >35%, low maximum dry density and high liquid limit values (Daramola et al, 2015) .

The widespread deterioration and failure of Nigerian roads have been attributed to the indiscriminate use of lateritic soils without full knowledge of their geotechnical limitations (Oyelami and Alimi, 2015). Studies have shown that some lateritic soils due to their mode of formation, geotechnical properties and field behavior could differ considerably from soils of similar particle size distribution and plasticity characteristics developed from the same parent rocks. Poor geotechnical characteristics of soils are typically responsible for infrastructure failures (Akpan 2005; Ademilua 2018)

2.2. Influence of Geology and mineralogy to road failure

An accurate knowledge of geology is very important in road construction (Bell, 2008), since road construction takes place either at the surface or below the surface. Geology provides a systematic knowledge of construction materials and their occurrence, formation, durability, strength, hardness and uses. Hence, geology has an important influence on most construction operations since it helps determine the nature, form, and cost. For example, Bell, (2008) observed that road design and tunnel constructions are largely dependent on geological considerations. Some of the geological factors that are really important includes adequate knowledge of surface and subsurface conditions (nature of soils and rocks) below the proposed highway route, the presence of undetected linear features and geologic structures such as joints, fractures, faults and geologic contacts or other weak zones of rock boundaries (Momoh et al., 2008; Adiat et al., 2009)). For example, studies conducted by Gidigasu (1983), Graham and Shields (1984), Jegede (1997), Gupta and Gupta (2003), Momoh et al (2008) and Adiat et al (2009) of failed highway pavements using geophysical methods showed that geological factors such as the near surface geologic sequence, existence of geological structures like fractures, faults, ancient stream channels, and shear zones influences road failure.

In addition, the presence of expansive clays such as montmorillonite, chlorite, halloysite and others (1987), and heterogeneity of the sub-grade materials (Mesida, 1987), as well as poor drainage contribute immensely to the collapse of highway pavements. The type of clay minerals present in the soil always affects the behavior of the soil (Sani, et al. 2020). Montmorillonite is another type of clay mineral with an expanding lattice (Mermut and Cano, A.F. 2001), it expands considerably when wet and contracts substantially when dry. This characteristic has always been a problem for engineers when constructing on soils that have this clay minerals present in them. Soil investigation helps to determine varying physical and engineering properties of soil, which can vary from place to place and from layer to layer. Therefore, the non-recognition or consideration of these factors has led to the failure of many highway routes and other engineering structures across the country as observed by Adegoke–Anthony and Agada (1980), Mesida (1981), Ajayi (1987).

Many studies of failed sections of roads in Nigeria have suggested the link between underlying geology and road failures. This calls for proper and adequate knowledge of residual soils used in road construction, because the lithology of the underlying parent rocks plays significant role in the geotechnical performance of the lateritic soil ((Oyelami and Alimi, 2015). Geotechnical assessment of subsoils helps in comprehending the behavior of the soils that can cause remarkable impairment to road construction and also propose solutions in problems connected with both expansive and unexpansive soils (Daramola et al. 2015; Amadi et al. 2015) notwithstanding failed road sections, which in most cases are caused by use of poor construction materials or being founded on an incompetent subgrade and subbase materials (Adebiyi et al. 2018, Babadiya and Igwe, 2021) such as shale. Shales naturally do not make a good road base material, hence pose serious threat to life span of roads. Roads are literally constructed on geologic materials and these materials' properties impact their functioning as transport medium (Gupta and Gupta 2003; Olofinyo et al. 2019).

Layade et al, 2017 carried out an integrated geophysical study in a segment of Ibadan-Lagos dual-carriage road in south western Nigeria to examine the geological factors responsible for highway failure and they found out the presence of near surface linear geologic structures from the surface to a depth of 15 m which suggests probable conductive zones that have devastating effects to the foundation of the road pavement. Momoh et al (2008) examined the geological factors responsible for the failure of the Ilesha – Owena highway and found the causative factors of the failed sections include low resistivity clay, water absorbing sub-stratum and linear structures suspected to be faults, fractures zone, joints and buried stream channels. The Ilesha – Akure highway in in southwestern Nigeria failed along the four segments examined due to the presence of near surface linear structures which were inferred to be faults/ fractures and lithological contacts beneath the highway pavement (Akintorinwa et al, 2011)

2.3. Poor ground condition and use of substandard construction materials

Factors that affect low quality of materials are poor grading of aggregates and low bearing strength of soil. These factors hasten pavement worsening such as cracking. Pavement performance depends on when and how maintenance is performed. The Nigerian Specification for Road and Bridges specified standard ranges for the geotechnical and mineralogical properties of soils before they can be used for road construction. For a soil to be used as a sub-base material, percentage of soil particles passing sieve No. 200 should not be greater than 35 %. But not all soils meet these stipulated standards because they have varied behaviors depending on their geotechnical properties. Soils formed in situ by chemical and mechanical weathering of parent rocks are termed residual soils and they have chemical similarity to their parent formation material. In Nigeria, some soils used for road construction were observed to have originated from parent formation materials with poor geotechnical properties of residual soils used in the construction which have resulted in road pavement deterioration

Montmorillonite is the predominant clay mineral found in Abakiliki shale, making it a problem soil for road construction. Tse and Efobo (2016) listed the possible reasons for the recurring failure of the Port Harcourt – Enugu expressway to include poor quality of soil used as sub-grade, presence of shales of low permeability and the presence of montmorillonite. Aghamelu and Okagbare (2011) observed that most road contractors in Abakaliki and environs because of the high cost of haulage of suitable materials, utilizes the Abakaliki shales for road construction which often fails due to its expansive nature.

3. Ways to minimize road failures in Nigeria

Care should be taken to ensure ways to minimize road failures in Nigeria; the foundations, walls, and top slab are rigidly tied together by high-tensile reinforced steel to ensure the structure's firmness, so that floodwater does not penetrate the structure and carry it away. The materials for making concrete should meet all requirements in accordance with the recommended standard specifications for road and bridges.

Lack of provision of the drainage system on the highway leads to the reduction in the strength character of the soil as a result of ingress of water. The values of natural moisture contents of most failed roads indicates that the load bearing capacity of the soils increase rapidly as the moisture content values are lower than the plastic limit values. The higher liquid limit values obtained for most of the soils may have contributed to the failure of those sections as liquid limit correlates to the compressibility of soils (Olubanjo et al., 2018). In order to avoid this, it is advisable to install drains to help keep soil dry. Resurfacing is not recommended as it is only a short-term solution. This is because once road deteriorates the subsurface follows and affects the new surface as well.

Government to establish an anti-corruption team made up of men and women of integrity who will not request the contractors to "grease their palms" in order to become lenient in enforcing specification. Also, it is necessary to establish a Contractor's Accountability Program where genuine complaints are lodged against contractors. For non-performance,

poor performance, dereliction or repudiation, it is recorded against the said contractors. For continuous record of such offences, the contractor is banned from bidding future contracts for a period of time thus weeding out non performers and creating a contractor pool of proven performers (Onuoha and Onwuka, 2014).

The drift should be firmly anchored to the bedrock of the river across its full span in rocky riverbeds. Anchoring ensures that no water flows under the foundation, which would undermine the drift. Excess storm-water passes over the drift. For drifts constructed in a sandy riverbed, seepage underneath is allowed through the sand to infiltrate water to the downstream side of the river. The structure's foundation should be protected from being undermined by the river's flood flows. Undermining of the structure washes away the rock fill, which results in the structure collapsing under the traffic load and the drift being washed away (Teme et al., 2008).

Small and localized fatigues in the failed sections of any road should be repaired by removing the cracked pavement areas as a short-term measure and to be reconstructed in the long run due to the pronounced failures on the pavement. Geotechnical properties of the constituent layers should also be given adequate attention to enable effective transmission of the load on the pavement to the subgrade without much deformation. Further investigation should be carried out on the pavement, especially on the asphaltic concrete in order to assist future designs (Akanbi et al., 2021).

Other possible solutions to the incessant causes of road failure in Nigeria could include but not limited to the following; strict adherence to geotechnical standards and design details, geotechnical stabilization/ replacement of poor soils, geological/ mineralogical stabilization e.g. grouting of fault/ fractured subsurface and the use of lime and other stabilizers to correct expansive soils.

4. Conclusion

The possible causes of the failure of Nigerian roads are variables ranging from the lack of adherence to geotechnical standards and design, influence of sub-surface geologic structures and mineralogy of the subgrade or the borrowed materials used for the construction of the road, poor ground condition and the use of substandard construction material. The enormous budgetary expenses spent annually on road rehabilitation and maintenance can be minimize if adequate attention is given to geotechnical and design details, the geology of the propose area in which a road is to be constructed is carefully looked at. Other possible solutions to ameliorate road failure in Nigeria include; geotechnical stabilization/ replacement of poor soils, geological/ mineralogical stabilization e.g. grouting of fault/ fractured subsurface and the use of lime and other stabilizers to correct expansive soils; use of anti-corruption watch dogs in the award of road contracts; installation of drains along flood prone areas to minimize the effect of poor drainage on roads which has negative effect on the roads.

Compliance with ethical standards

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Disclosure of conflict of interest

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