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Geotechnical Investigations of Road Failures Along Benin Technical School Road, Benin City, Edo State

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Abstract

The study evaluated the possible causes of pavement failures in Benin Technical School Road, Benin City, Edo State. Disturbed soil samples were collected from three (3) Sampling points in the study area at a depth of 1m each. Soil samples were kept inside a polyethene bag and taken to the laboratory and their geotechnical characteristics was analysed according to ASTM. Sieve analysis, natural moisture content, specific gravity, Atterberg limits, Compaction and California Bearing Ratio (CBR). The results of the test showed that the soil samples were mainly silty /clay with little amount of fine sand. The percentage of soil passing the 75 mm sieve size ranges from 20% - 33.1% for sampling points 1, 2 and 3. The liquid limits was determined to be 31.94%, 23.38% and 21.03%, while the plasticity index ranges from 11.95% - 17.67% for the three sampling points. The specific gravity ranges from 2.48-2.51. The maximum dry density values (MDD) are 1.83g/cm^3, 1.84g/^{3}and 1.81g/cm^3, while the optimum moisture content values were 12.87%, 12.0% and 11.19% respectively for the three sampling points. The California Bearing Ratio, (CBR) ranged from 3.46% to 21.70% for soaked and 16.10 –37.59 for unsoaked samples in the three sampling points. From the CBR result it can deduced that none of the soil samples met the criteria for road sub-grade as CBR values for all the soil samples were above the required 10%.Findings indicates that failure along the study area were due to the unsuitability of the soils as sub grade material and effect of ground water intrusion.As a consequence may be responsible for the road instability; ultimately leading to failed portions.The soil was classified as A-2-4 soil based on AASHTO soil classification system. Also, the results of this research will add to existing literatures in the in design and construction of roads that can stand the test time.

1. Introduction

The availability of good road networks is the pivot upon which major economies of the world and industrialized cities oscillate. The unavailability of good roads across Nigeria have not only negatively impacted on the free flow of goods and services but also significantly impacted food supply chain due to difficulties experienced by farmers in conveying their agric produce across Nigeria [1]. Road network plays a vital role in socio-economic development of many nations. Nigeria is among the countries with one of the highest records of road accidents. As a consequence, there is incessant loss of lives and properties attributable to inefficient and incompetent road design experts. A road is a system with various components which are interrelated in order to achieve desired results. A road is a multi-layered system comprising of sub grade, sub base and base course. Its principal function is to receive load from the traffic and transmit it through its layers to the sub grade [2]. Roads are defective when they no longer have the capacity to perform its statutory function of receiving and transmitting loads to various layers during its design life. Road construction should begin with conceptualization, planning and design [3].

The design and construction of most roads in Nigeria are finalized without assessing and evaluating the geology and geotechnical behavior of the underlying soils. This has led to multiple failures encountered in roads or highways. The relationship between highway pavements and their foundation soils cannot be overemphasized, in any nation that desires to develop. In all cases, the geological history of any locality has very strong influence on the derived engineering soils [3]. Despite subsequent reconstruction and rehabilitation of the failed sections along Kajola-Oda Road, pavement distress continues to reoccur shortly after repairs.

Preliminary studies have shown that environmental and geotechnical properties play significant role in design and construction decisions. A major cause of road accidents has been attributed to bad/ defective roads which are exacerbated by wrongful application of constructional materials especially laterite as base and sub base materials by constructional companies. The continual practice of stereotyping engineering designs also contributes to road failures [1].

[5] studied the geotechnical properties of some failed sections along Osogbo -Awo road. They concluded that the presence of clay in the road sub grade elicited poor engineering properties which were below Federal ministry of works and housing specifications and as fallout contributed to the dilapidated conditions of the road were largely responsible for the persistent road failures in the area.

[6] Observed that the flexible highway failures along the Oyo-Ogbomoso road, which manifested as waviness/corrugation rutting and potholes were due to environmental factors such as poor drainage, lack of maintenance and misuse of the highway pavement. They also observed that runoff from precipitation, largely found its way into the pavement structure damaging them in the process.

[7] Has also stated that soils classified as A-3, A-2-4 and A-2-6 is considered suitable for sub-grade, sub base and base materials. They also posited that the binding or cohesive characteristics of most of the soil samples analyzed in the study area with their accompanying large granular sizes and low moisture content makes them suitable materials for road construction.

[1] Revealed that the Abakaliki shale does not meet the requirement as road construction material due to its high plasticity. This implies its susceptibility to expansion on moisture influx and establishing a direct relationship between soil plasticity and roads failures.

This study was aimed at investigating the possible causes of failed sections in Benin Technical School Road, Ugbowo, Benin City, which have experienced several degradations even after repairs and reconstruction. Geotechnical analysis was conducted on soil samples obtained at specific points and their suitability criterion as constructional materials was also determined.

2. Methodology

2.1 Description of study area

The study area Benin technical school road, Egor, Benin city lies between Latitude N 06° 25’ 53.9” and Longitude E005°35’20.9”. The elevation of the study area ranges from 106m to 107.6m. Boring techniques were deployed for the collection of soil samples by a means of a hollow auger. The drilled depth was 1m each at the various sampling points. The geotechnical analysis carried out on the samples include sieve analysis, Atterberg limits, natural moisture content, compaction and California bearing ratio CBR tests. The particle sizes were determined through the use of mechanical sieve shaker, Consistency Limits includes Liquid limit, plastic limit are also known as Atterberg limits gave). The difference between the liquid and plastic limits is the plasticity index, which is the range of moisture content over which the soil remains plastic. All soil tests were done in accordance with American Association of State Highway and Transportation Official AASHTO) [8].

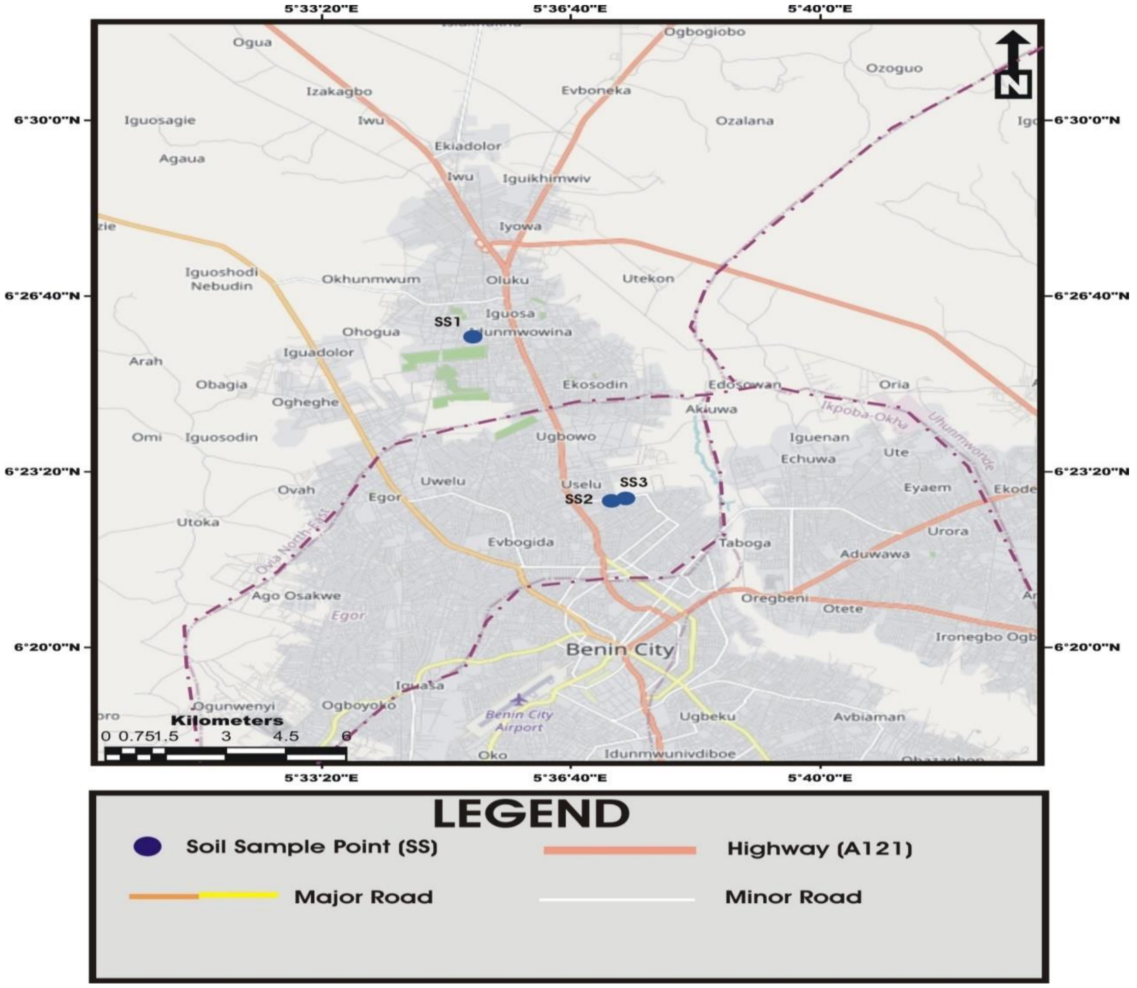

Figure 1: Map of the study area

2.2. Compass survey and GPS Reading

The direction of drainage and a map of the study were determined by carrying out a compass survey of the area using Global positioning system (GPS). Field coordinates and elevations were placed in decimal format and digitized with software. A powerful contouring and mapping package was used to produce a contour and drainage maps.

2.3. Collection of samples

The continuous flight auger was used for drilling to a depth of 1m each and three disturbed soil samples were collected from a distance of 100 m apart.
The samples collected were kept in a polythene bag and taken to the laboratory for geotechnical index properties analysis. The geotechnical tests carried out were Particle size analysis, Consistency tests (Liquid Limit, Plastic Limit), Standard compaction tests, California bearing ratio, Moisture content and Specific gravity. All laboratory tests were performed in compliance with British standard specification BS 1377: Part 1-9, 1990 [9]. The geotechnical tests carried out to determine the suitability criteria of the soil samples as sub grade, sub base, and base material were done using the AASHTO standard methods as it relates to specification for roads and bridges.

3. Results and Discussion

3.1 Particle size distribution

The result of the particle size distribution contained in Table 1 revealed that the soil clay content ranged from 20% to 33.1%. With the highest value of 33.1% recorded in sampling point 1. This indicates that the soil samples were mainly silty/ clay with little amount of fine sand. The high amount of fines could be attributed to intense weathering of the underlying geology of the area. According to the American Association of State Highway and Transportation Officials (AASHTO), these soils can be classified as A-2-7. [7] Have posited that only A-3, A-2-4 and A-2-6 are considered suitable for sub-grade, sub base and base materials. Thus, the instability of the road pavement in the study area is due the impervious nature of the soil materials.

Table 1: Summary of laboratory tests results for Sieve Analysis Test

Sampling points	Location	Depth (m)	PERCENTAGE PASSING SIEVE NO		
			1.18mm	**0.425mm**	**0.075mm**
1	Technical School Road	1.0m	98.8	74.0	33.1
2		1.0m	93.0	68.7	16.0
3		1.0m	98.1	70.3	20

3.2 Atterberg Limits

Table 2 indicates that the Liquid limit of the soils ranged from 21.03% to 31.94% while the plastic limits ranged from 8.58% to 14.27%. The Atterberg limits tests were conducted to ascertain and evaluate the nature of soil characteristics in the study area. [10 11] have specified Liquid limit of ≤ 30% and Plasticity index of ≤ 13% for base course materials and Liquid limit of < 35% and Plasticity index of <16% for sub base materials. Therefore, soils from sampling locations 1, 2 and 3 were suitable as Sub base materials. The failure of the road may necessarily not be as a result of weak base and sub base materials but also due to poor design [12]. The low plasticity index is indicative that the soils were friable and non-cohesive. Therefore, could lead to ingress of water into the subgrade and consequently, affects the stability of the road.

Table2: Atterberg Limits

Sampling points	Location	Depth (m)	LL (%)	PL (%)	PI (%)
1	Technical School Road	1.0	31.94	14.27	17.67
2		1.0	23.38	8.58	14.80
3		1.0	21.03	9.08	11.95

3.3. Specific Gravity

The specific gravity results as shown in Table3 ranged from 2.48% to 2.52% with the highest value recorded at sampling location 2. [11] Have asserted that the specific gravity of laterites should be within the range of 2.60 to 3.40 and the specific gravity of clay should range from 2.2 to 2.6. The result however depicts that the road was established on non-lateritic horizon in all the sampling locations. It further signifies that the soil were within the clay group. Such soils would exhibit swelling tendencies due to its inability to ease out water, therefore creating and unstable condition that hinders the performance of the road [13]. The high water retention could be responsible for the deformation of Benin Technical School road.

Table3: Specific Gravity Results

Sampling points	Location	Depth (m)	Specific Gravity
1	Technical	1.0	2.48
2	School	1.0	2.52
3	Road	1.0	2.51

3.4. Compaction Test

The maximum dry density of the soils ranged between 1.81 and 1.83 mg/m^3 whiles the optimum moisture content ranged from 12.0 and 12.87%. Soil samples with high amount of maximum dry density and low optimum moisture content have been considered more suitable as sub base and sub grade materials [6]. [14] Placed MDD values of 1.85 to 2.13mg/m^3 as most suitable for sub grade. The optimum moisture content of soil samples in the area met the Federal ministry of Works and Housing specification of ≤ 18% for sub-base and base materials.

Table 4: Summary of laboratory tests results for Compaction Tests

Sampling points	Location	Depth (m)	Maximum Dry Density (g/ cm^3)	Optimum Moisture Content (%)
1	Technical	1.0m	1.83	12.87
2	School	1.5m	1.84	12.0
3	Road	2.0m	1.81	11.19

3.5. California Bearing Ratio

Table 5 present the result of Unsoaked California Bearing (CBR %). CBR ratio ranged from 15.69% to 43.19% while values of soaked ranged from 2.63% to 35.45%. A significant decreased in value of CBR values was observed. The reduction could be attributed to the absorption of water into the compacted (sub-grade) soil, hence leading to a decrease in soil strength due to penetration of water. Federal ministry of works and housing 1997 has specified values of CBR for road sub grade, sub base, and base as 10%, 30% and 80% respectively under unsoaked condition. From the result it can deduced that none of the samples met the criteria for road sub-grade as CBR values for all the soil samples were above the required 10%. As a consequence may be responsible for the instability of failure of the road. However, samples from location 1 and location 2 with exception of location 3 were suitable as road sub-base materials.

Table 5: Summary of Laboratory Tests results for California Bearing Ratio.

Sampling points	**Location**	**Tested Layer**	**UNSOAKED**		**SOAKED**	
			2.5mm	5.0mm	2.5mm	5.0mm
1	Technical school road	BOTTOM	16.10	16.33	3.46	2.90
		TOP	15.69	15.78	3.30	2.63
2	Technical school road	BOTTOM	33.03	42.47	33.93	35.45
		TOP	26.75	37.37	27.66	28.49
3	Technical school road	BOTTOM	43.19	39.62	31.62	33.04
		TOP	42.77	37.59	19.15	21.70

3.6. Average Moisture content

The result of average moisture content of the soil samples ranged from 11.19 % to 18.45% across sampling locations. The highest value was recorded at sampling 3 with 18.45%. The moisture content in the study area was relatively high due to the geology of the area. [4] Has posited that high moisture content reduces the shear strength of soils. Weak shear strength will cause soils to become friable which could lead failure.

The Average Moisture Contents (AMC) of the samples was determined in the laboratory and the results are presented. The test was carried out to determine the soils moisture content as during the site investigation.

Table 6 Summary of Laboratory Tests results for Average moisture content

Sampling Points	Location	Depth (M)	Average Moisture Content %
1	Technical School Road	1.0	11.19
2		1.0	16.56
3		1.0	18.45

4.0. Conclusion

The results of the geotechnical analysis have shown that the soil samples were mainly sands with obvious amount of silts and clay present. Using the AASHTO soil classification system, the soil was categorized as A-2-4 soil which is not suitable as sub grade material. Hence the soil was non plastic. The result of CBR indicates that none of the materials met the FMWH specifications as sub grade materials. The specific gravity result also revealed that the soils were not laterites but underlain by clay. In conclusion, the cause of incessant road failures in the study area could be linked to unstable geotechnical properties of soils in the study area, wrong drainage designs and improper application and usage of constructional materials.

Recommendation

It is recommended that since the soil has been classified as A-2-4 soil, for it to be properly used as sub grade material, proper survey and design of the area should be conducted. The deformation of sub grade under traffic is most likely to occur where the CBR value falls below 2% and in such scenarios, it is usually recommended that the underlying materials be replaced with more suitable material probably with CBR value of not less than 2% and thickness between 0.5mm and 1.0mm. Subgrades with CBR values of 15% and above should have standard thickness of 150mm. Meanwhile, the value of this test ranges from 2.63% to 35.45% respectively indicating that they were not suitable as fill materials.

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