Investigation Of Highway Pavement Failure Along Ibadan - Iseyin Road, Oyo State, Nigeria

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ABSTRACT

The rate of highway failure in Nigeria is alarming and it calls for urgent and decisive action. The causes of the failures had been examined in some States in Nigeria but there are less records of such study around the study area. This research is therefore aimed at investigating the possible causes of the highway failure along the study area.

Twenty samples of subgrade and subbase materials were collected at failed and unfailed sections of Ibadan to Iseyin road. The samples were subjected to the following laboratory tests grain size analysis, Atterberg limit (liquid limit and plastic limit), British standard compaction, West African standard compaction and California bearing ratio tests.

The study revealed that the percentage passing sieve No. 200 for the grain size analyses range 17.30 - 32.00% for subgrade and range 19.00 - 39.10% for subbase. The liquid limit and plastic index values range 26 - 35% and 9 – 15% respectively for subgrade, while the liquid limit and plastic index values for subbase range 26 - 35% and 8 - 15% respectively. The values of maximum dry density and optimum moisture content range 1.88 - 2.12 g/cm^3 and 10.15 – 13.2% for subgrade and 1.90 - 2.24 g/cm^3 and 9.2 – 14.4% for subbase. The California bearings ratio (CBR) values for the sample of subgrade range 10 - 29% for 48 hours soaking. The CBR values of subbase range 9% - 35% for 24 hours soaking.

The results therefore show that all the samples of subgrade and subbase materials conform to Federal ministry of works specifications for road works except subbase samples SBF1, SBF3, SBF4 SBF7 and SBF9 and this may be responsible the failures.

1. Introduction

Generally, every work of construction in civil engineering is built on soil or rock and in many instances they are also used as raw materials for construction of infrastructures, such as buildings, earth dams, liners and covers for landfills and highway pavement. Therefore, a good understanding of the properties of the soil and its behaviour under load before usage is highly essential in civil engineering and highway pavement construction [1].

Failure of highway pavement is a major experience which occurs on Nigeria roads. The failure of highway pavements is dated back to the colonial period [11, 4, 8]. The failures had been attributed to some factors, such as properties of construction materials, subgrade conditions, environmental conditions, traffic loading, lack of drainage and poor workmanship [2, 8, 9, 10]. The highway failures are usually defined in terms of the extent of cracking, patching and potholes, surface deformation and surface defects [5].

In recent times, highway pavement failure has been a very serious problem that cause unnecessary delay in traffic flow, distorts pavement aesthetics, breakdown of vehicle and most significantly, causes road traffic accident that had resulted into loss of lives and properties amount to millions of dollars [7, 10]. Hence there is a lot of concern about the state of disrepair of all categories of roads and the need to reappraise the construction materials and method used on roads within the country in order to check and overcome all the end result of highway pavement failures already mentioned.

Some studies had been conducted on possible causes of highway failures in Nigeria,especially in Ekiti, Ondo, and some parts of Osun State [7, 8, 10] but there is paucity of research on the geotechnical investigation of the causes of highway failure in oyo State and especially the Ibadan – Oke Ogun axis. Therefore, this research investigated the possible causes of highway pavement failure along Ibadan – Iseyin road, south western Nigeria.

2. Description of study area

The study area is a 65km road spanning between Ibadan and Iseyin town. It lies within Moniya in Akinyele local government area of Oyo state to Iseyin in Iseyin local government area of Oyo State. The map of the study is shown in Figure 1.

Geologically, the study area lies within South western Nigerian basement complex, which forms a part of the Africa crystalline shield. The basement complex is composed predominantly of folder gneiss, migmatite, schist and quartzite of precambian age.

There exist predominantly two seasons, namely; wet and dry season. The wet season starts in Apirl and ends in early October while the dry season starts in late October october and ends in early April. The study area appears to be well drained during the dry season. The drainage patterns are combination of dendrite and radial. The branches of the drainage patterns discharges into streams and rivers [1].

3. Materials and methods

3.1Sampling

The method adopted in this project involves reconnaissance survey of the road to determine the failed and unfailed sections. The samples of subgrade and subbase were collected in August 2010, the sampling locations comprise Moniya, Idiogin, Idiya, Akowe, Itosi, kambi, Sagbo, Bala, Ekeje and Iseyin as shown in Figure 1.

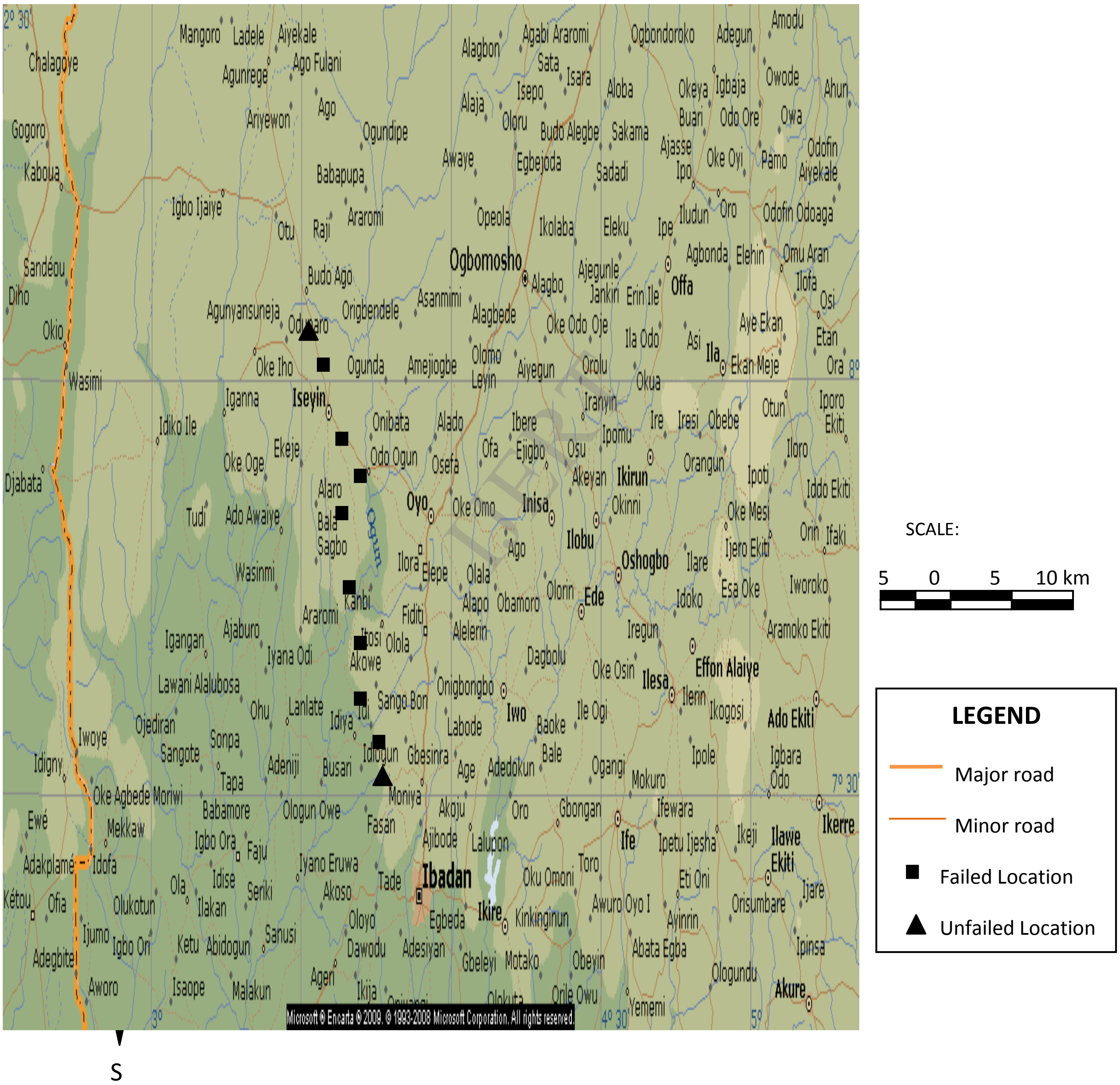

Figure 1: Map of Ibadan - Iseyin road network showing sampling locations

Samples were obtained at the edge of the shoulder of the road, and were dug out using digger and shovel from depth of 300mm for subbase and 1200mm for subgrade below the asphaltic surface. They were suitably packed into sacks and labelled in such a manner that each material can be identified distincly. They were transported to the laboratory for the following tests: Sieve Analysis, Atterberg limit, Compaction and California Bearing Ratio in accordance with BS 1377 [3].

3.2Test Procedures

(a) Particle size distribution. The samples were air dried for about 24 hours and those with cluster particle were pulverised to their natural sizes. 500 gram of each sample was weighed and wet sieve using 425 µm sieve. Residues of the washed samples were oven-dried and pulverised into fine mass. Each sample was placed in sieve stack and shaken using mechanical shaker. The weight retained in each sieve was recorded for further computations and plotting.

(b) Compaction test. The dried soil sample passing the 20mm BS sieve of about 8kg was used. The sample was mixed thoroughly with suitable amount of water of 2.5% intially and later increased to 5%, 7.5% and 10% on subsequent tests. The soil was compacted using British Standard and Western African Standard. The British Standard Method of compaction test make use of a small mould of volume 1000cm^3, small rammer of mass 2.5kg and the sample is divided into three (3) layers, each layer being compacted with 27 blows per layer at a falling height of 300mm while the West Africa compaction method makes use of big mould of volume 2305cm^3, a big rammer 4.5kg in mass. The sample is divided into five layers and each layer is compacted with 27 blows per layer at a falling height of 450mm [3, 6]. A reprehensive sample of the specimen was taken and the moisture content determined. From the graph of the dry density against moisture content, the maximum dry density (MDD) and optimum moisture content (OMC) were determined.

(c) California bearing ratio (CBR) test. Fresh sets of air-dried samples were compacted in a 152mm diameter 173mm height CBR mode following already described procedure but at 27 blows per layer. A piece of filter paper was placed on the compacted sample and the base was replaced by a perforated plate and immersed in water for 48hours. The socked sample was taken to the CBR machine and readings of force were taken at interval of penetration of 0.625mm.

4. Results and Discussion

4.1 Particle size analysis

The results of particle size analyses for the twenty samples are presented in Figures 2 and 3. The percentage passing BS sieve No. 200 is less than 35% except subbase samples SBF7 and SBF9. These results are within the requirement of FMW specification materials that will be used for road construction in terms of particles size. In addition, since the soil samples contain less fine particles, in the event of rise in water table around the area, the samples may not be susceptible to swelling. Also, the smaller particles will fill the space between the large particles, thereby giving a dense mass of interlocking particles with high shear strength and low compressibility.

4.2 Atterberg limits

The results of the liquid limit (LL), plastic limit (PL) and plastic index (PI) are presented in tables 1 and 2. Table 1 shows the liquid limits and plastic indices for the subgrade soils. The liquid limits and plastic indices are all below 50% and 30% respectively. They are within the acceptable requirements for soil sample that can be used as subgrade or fill during construction of highway in Nigeria [6]. These results indicate that the samples contain less fine particles such as clay and they have less affinity for water and low compressibility. Therefore, the failures may not be due to infiltration of water into the subgrade layer. The failure may therefore be due to some other factors. Table 2 shows the liquid limits and plastic indices for the subbase samples. The liquid limits and plastic indices range from 26 to 35% and 8 to 15% respectively. The values of the liquid limits are within the specification of FMW [6]; LL not greater than 35% but the PIs of some of the samples, SBC, SBF2 and SBF4 were slightly above the FMW specification of not more than 12%. The slight higher values of PI could account for the failure of the roads at those sections.

4.3 Compaction

The results of the maximum dry densities (MDD) and optimum moisture content (OMC) for the subgrade samples are presented in Table 1. The MDD and OMC range from 1.88g/cm^3 to 2.12g/cm^3 and 10,15 to 13.2% respectively. These results are similar to the earlier findings of [7, 8, 10]. The MDD and OMC for the subbase are presented in Table 2. They range from 1.90g/cm^3 to 2.24g/cm^3 and 9.2% to 14.4%.

4.4 California bearing ratio

The result of California bearing ratio (CBR) test is presented in Tables 1 and 2 for the subgrade and subbase samples respectively. The CBR for the subgrade range from 10 to 29%, this value shows that the samples are suitable as subgrade because their CBR is greater than 3 to 10%; the specification for materials to be used as subgrade [6]. The CBR values for the subbase range from 9 to 35 after soaking for 24 hours. The following samples SBC, SBF2, SBF5, SBF6 and SBF8 conform to standard having values greater than 30% which is the minimum requirement for soaked CBR for subbase samples. While samples SBF1, SBF3, SBF4, SBF7 and SBF9 are not adequate for subbase having values less than minimum requirement of 30%. This deficiency in terms of strength could be responsible for the failure.

5. Conclusions

It can be concluded that the materials used as subgrade are suitable because the values of their geotechnical properties are with the specifications and the road did not fail because of this layer. However, some of the samples used as subbase have the properties below the specification and this is likely to be responsible for the failure.

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Table 1: Summary of Atterberg Limit, Compaction, California bearing ratio tests and Soil Classification Results for subgrade (British Standard)

Sample no	Liquid limit (%)	Plastic limit (%)	Plastic index (%)	MDD g/cm^3	OMC (%)	Soaked CBR (%)	AASHTO classification
SGC	28	11	15	2.08	13.10	18	A-2-6
SGF1	29	7	13	2.12	10.15	27	A-2-4
SGF2	30	17	13	1.97	13.15	23	A-2-6
SGF3	28	18	9	2.06	11.50	20	A-2-4
SGF4	26	15	11	1.98	10.90	10	A-2-4
SGF5	30	20	10	1.99	11.50	17	A-2-4
SGF6	30	18	13	1.98	11.00	20	A-2-6
SGF7	29	17	13	1.88	14.50	26	A-2-6
SGF8	35	20	15	1.93	11.50	18	A-2-6
SGF9	29	19	10	1.94	13.20	29	A-2-4

Table 2: Summary of Atterberg Limit, Compaction, California bearing ratio tests and Soil Classification Results for subbase (West African Standard)

Sample no	Liquid limit (%)	Plastic limit (%)	Plastic index (%)	MDD g/cm^3	OMC (%)	Soaked CBR %	AASHTO classification
SBC	27	12	15	1.90	9.20	30	A-2-4
SBF1	35	22	12	2.07	13.60	17	A-2-7
SBF2	34	18	15	2.21	9.60	30	A-2-7
SBF3	30	20	10	2.06	13.10	17	A-2-4
SBF4	34	19	15	2.11	14.40	18	A-2-7
SBF5	30	20	11	2.17	9.50	35	A-2-4
SBF6	27	18	8	2.24	10.00	31	A-2-4
SBF7	26	15	10	2.01	11.90	18	A-2-4
SBF8	30	20	10	2.06	10.50	31	A-2-4
SBF9	26	18	8	2.21	10.13	9	A-2-4

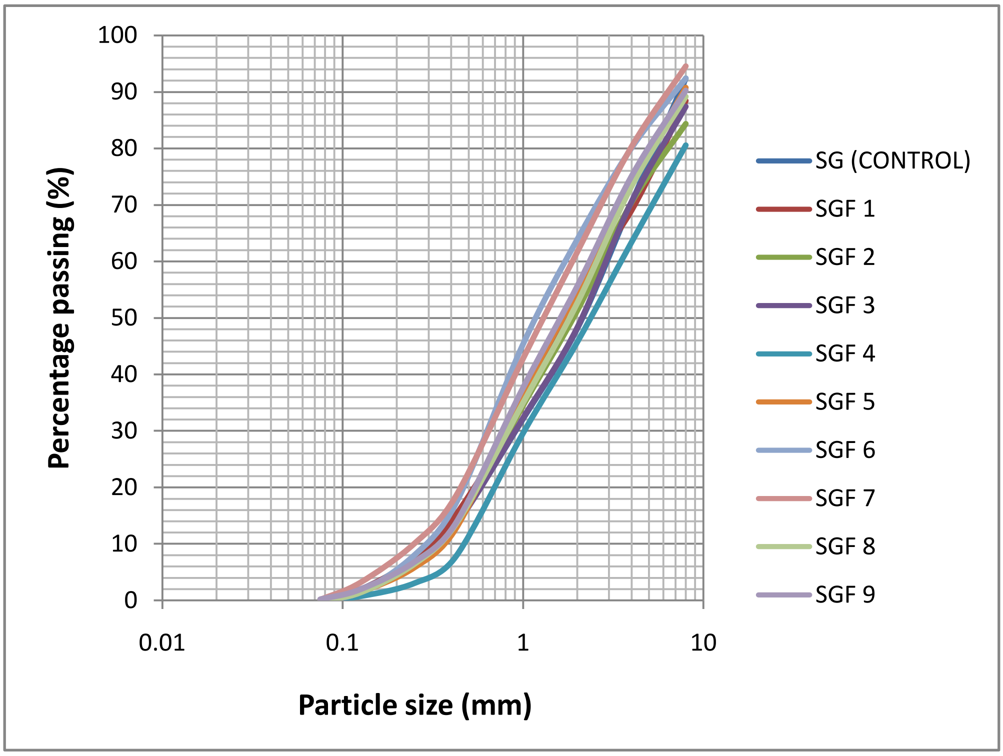

Figure 2: Particle size distribution curve for subgrade samples

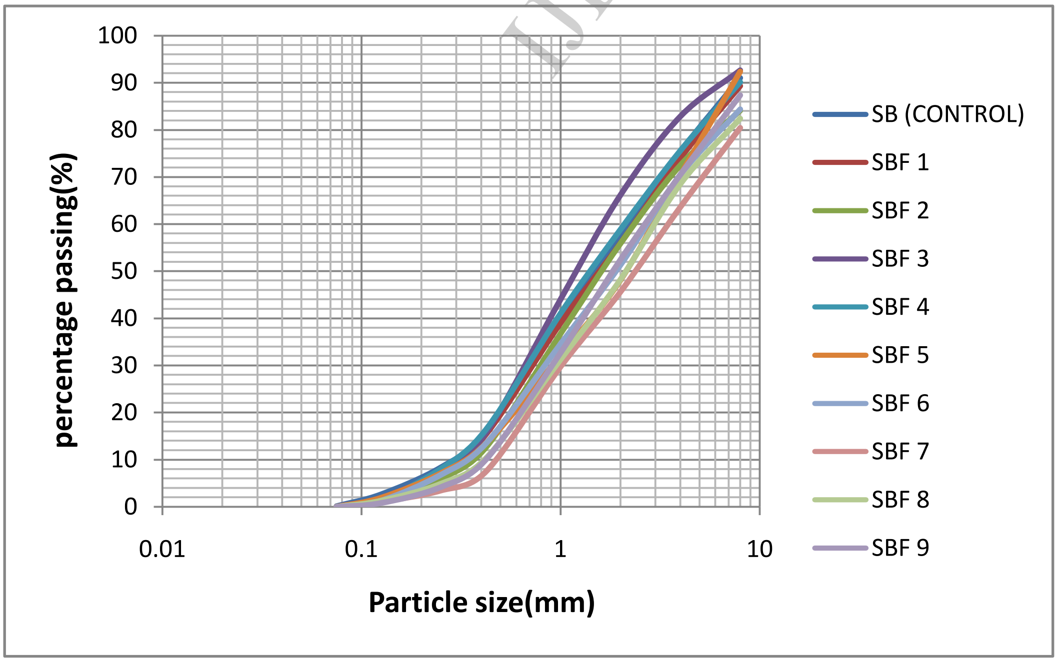

Figure 3: Particle size distribution curve for subbase samples