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Comparative Analysis of the Soil Geotechnical Characteristics of the Failed and Unfailed Sections of the Onitsha-Enugu Expressway, Southeastern Nigeria.

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ABSTRACT
This work compared the soil geotechnical characteristics of the failed sections of the road and that of the un-failed sections of the road to establish whether they are significantly different or related. To achieve this, soil samples from both failed and un-failed sections of the road were analyzed. The data so generated, were tested using Correlation Coefficient for relationship and Students T-test for difference. It was found that there exist insignificant relationship between the failed and the un-failed sections of the road, there is significant difference between the two variables and there is wide discrepancies between the geotechnical characteristics of the failed sections and the standard of soil geotechnical characteristics set by the Federal Ministry of Works for highway sub-grades. It was therefore concluded that the road failure was due to poor geotechnical characteristics of the soil. The work recommended that the variation in the geotechnical characteristics of the soils along the roadway should be accommodated during reconstruction. Sequel to this, knowledge of soil geotechnical characteristics and underlying geology of an area becomes indispensable before any construction, reconstruction or rehabilitation project commences.

INTRODUCTION

1.1 Background of the Study

Aigbedion (2007), defined Road Failure as a discontinuity in a road network 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. Visible cracks, potholes, bulges and depressions may punctuate such smooth ride. The punctuation in smooth ride is generally regarded as road failure. According to the Federal Ministry of Works and Housing (FMW&H 1992), failed roads are characterized by potholes, polishing / pavement surface wash, block and longitudinal cracks, drainage collapse, depressions / sinking of roadway, over flooding of the carriageway, gullies and trenches, rutting and raveling all of which are evident along the Onitsha -Enugu expressway under study confirming it's failure.

Several thousands of lives and properties worth several million dollars are lost as a result of frequent motor accidents, caused by failed highway pavements in Nigeria. Several factors are responsible for road failures, which include geological, geomorphological geotechnical, road usage, construction practices, and maintenance factors. Field observations and laboratory experiments carried out by Adegoke–Anthony and Agada (1980), Mesida (1981), and Ajayi (1987) showed that road failures can arise from inadequate knowledge of the geotechnical characteristics and behavior of residual soils on which the roads are built and non-recognition of the influence of geology and geomorphology during the design and construction phases. Thus the treatment of troublesome materials like clays are not been considered by the construction engineers which may be problematic. This was also supported by the works of Gidigasu (1983), Graham and Shields (1984), Akpokodje (1986), Alexander and Maxwell (1996), Jegede (1997), Gupta and Gupta (2003) and Ajani (2006).

Momoh et al (2008) and Adiat et al (2009) in their study of failed highway pavements using geophysical methods, found that some geological factors influence road failure such as the near surface geologic sequence, existence of geological structures like fractures and faults, presence of laterites, existence of ancient stream channels, and shear zones. The collapse of concealed subsurface geological structures and other zones of weakness controlled by regional fractures and joint systems along with silica leaching which has led to rock deficiency are known to contribute to failures of highways and rail tracks (Nelson and Haigh, 1990). The geomorphological factors are related to topography and surface/subsurface drainage system.

Other factors considered by some researchers and scholars include: Faulty Design and Poor Road Construction as in the works of Paul and Radnor (1976), Abynayaka (1977), World Bank (1991), UNESCO (1991), FMWH (1995), Jain and Kumar (1998)**;** Poor Maintenance according to John and Gordon (1976), Oglesby and Garry (1978), TRRL (1991); and Traffic Effects and Human Impacts on the Roads according to AASHTO (1976), ANSMWH (1998), FMWH (1995) and Ibrahim (2011).

According to the work of Onuoha and Onwuka (2014), the present condition of most of the roads in the Precambrian basement complex of south western Nigeria and the sedimentary terrain of the southeast and the

entire Niger-Delta region has stimulated the interest of various stakeholders in the usage and maintenance of our road ways. Rehabilitating these roadways has become a financial burden on the Federal, State, and Local Governments. The Enugu-Onitsha Expressway is a typical example of Nigerian roads whose failure bugs the mind of regular users. Almost every section of the road has failed, resulting to;

- Loss of lives and properties, human injuries etc. through accidents,
- retardation of the rate of economic growth and development in affected areas,
- environmental pollution and degradation,
- impedance of human movement and the flow of economic activities and
- numerous cases of armed robbery attacks along affected areas.

In the light of the foregoing therefore, some questions constantly come to mind: what exactly is the cause of this problem? Again, since not all sections of the road failed, or at least failed equally, does soil characteristics (geotechnical properties) play any role in the durability of the roads. Considering the cost of constructing and maintaining this road, the answers to these questions have become a necessity particularly now that the impacts are multiplying. It thus becomes necessary to compare the geotechnical characteristics of the soils of the failed sections of the road and that of the un-failed sections of the road in order to determine whether or not the geotechnical characteristics of the soil is a factor of the road failure.

1.2 AIM AND OBJECTIVES

The aim of this work is to establish the relationship between the geotechnical characteristics of the failed sections and that of the unfailed sections of the Onitsha-Enugu Expressway.

To achieve the above aim, the following objectives will be pursued:

1. to determine the geotechnical characteristics of the soils of the failed and the unfailed sections along the highway pavement under study,
2. to compare the geotechnical characteristics of the soils of the failed sections and that of the unfailed sections of the road, and
3. to draw conclusions from the result of the analysis and proffer solutions to handle the situation on the site and in similar situations to help mitigate the problem of road failure.

1.3 RESEARCH HYPOTHESIS

1. H_0: There is no significance relationship between the soil geotechnical characteristics of the failed sections of the road and the un-failed sections.
2. H_0: There is no significant difference between the soil geotechnical characteristics of the failed sections and the un-failed sections of the road.

1.4 DESCRIPTION OF THE STUDY AREA

The Onitsha-Enugu Expressway under study 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 Fig.1 (the Map of Nigeria showing the study area) and Fig. 2 (Extract Modified by Author from Map of Old Anambra State Showing the Road Under Study).

Fig. 1.1: Map of Nigeria Showing the Study Area. (Source: Modified from web extract http://www.ngex.com/nigeria/places/states/enugu.htm).

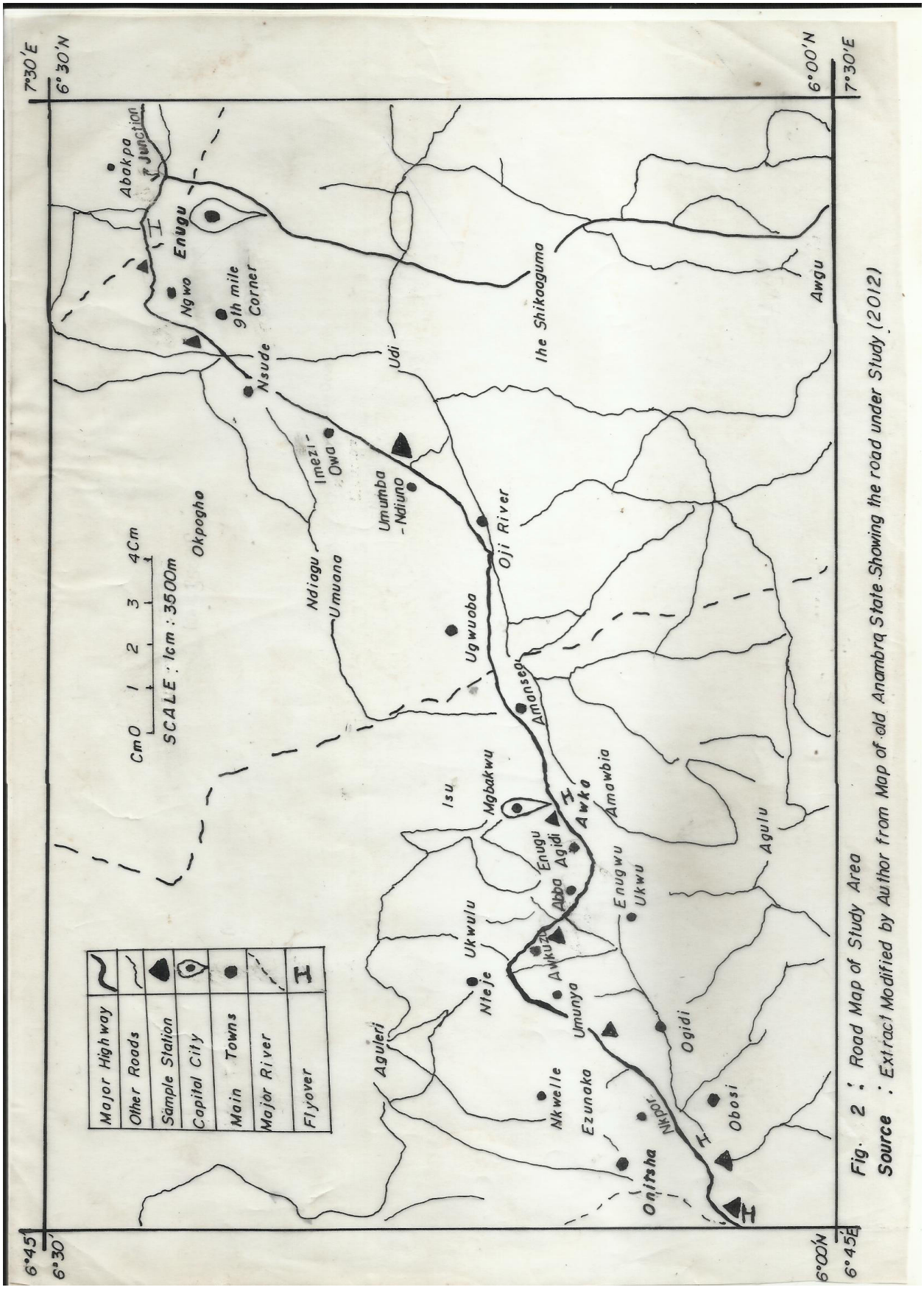

Fig. 2 : Road Map of Study Area
Source : Extract Modified by Author from Map of old Anambra State Showing the road under Study (2012)

Geology

The Onitsha/Enugu Expressway is sitting on Anambra basin of the Southeastern Nigeria it cuts across the following geologic formations:

Ameki Formation (Nanka Sand, Umunya Shale and other units), Imo Shale, Nsukka Formation, Ajalli Sandstone, Mamu Formation and Nkporo/Enugu Shale (which underlies Mamu Formation and is gradationally seen immediately after the New market Flyover in Enugu).

2.0 RESEARCH METHODOLOGY

The study adopted experimental method of research which was mainly concerned with the laboratory analysis of the soil samples collected from various locations in the site. For the purpose of studying both the failed and un-failed sections of the road as well as recognizing the various geologic formations cut across by the roadway under study, eight samples were collected and analyzed, four from the failed sections and four from the un-failed sections of the road. Samples were collected from Bridgehead in Onitsha, Omoba Guest Hall, Umunya near Odumodu Junction, Awkuzu, Awka, Umumba Ndiuno, Ngwo and Enugu after New Market Flyover. These samples were analyzed for the following parameters: Particle Size Distribution, California Bearing Ratio (CBR), Atterberg's Limit (Liquid Limit, Plastic Limit and Plasticity Index) and Compaction.

2.1 RESULTS AND DISCUSSIONS

The results of the laboratory analyses of the eight samples collected from eight stations selected along the roadway under study (four from the failed sections and four from the un-failed sections) are presented in Table 1 and discussed in line with the Standard of the Federal Ministry of Works shown in Table 2.

TABLE 1: Geotechnical Characteristics of Soil Samples Collected Along Onitsha Enugu Expressway

Sample Station	Sampling point/ location	Horizontal Distance of Sampling point from road pavement	Condition of road as at the collection	Depth of sample collection	PARAMETERS ANALYSED								
					Particle size Distribution %		Atterberg Limit			Compaction		CBR %	
					Sand	Silt & Clay (passing Sieve 75 um 200)	LL %	PL %	PI	MDD	OMC	Soaked %	Unsoaked %
STN 1	Bridge Head Onitsha	Centre of the Road	Failed	About 2m	45.9	54.1	85.5	18.3	67.2	1.74	18.2	11.0	5.5
STN 2	Omagba Guest Hall	About 15 meters	Failed	3-4 m	49.9	50.1	50.5	12.0	38.5	1.85	14.2	26.0	24.0
STN 3	Umunya near Odumodu Junction	About 15 meters	Failed	About 1 m	31.7	68.3	88.5	31.4	57.1	1.55	17.4	8.0	6.0
STN 4	Awkuzu	About 10 meters	Un-failed	About 1 m	61.9	38.1	46.0	14.2	31.8	2.03	10.2	30.0	24.0
STN 5	Unizik Junction Awka	Centre of the Road	Failed	About 2m	42.1	57.9	71.5	9.8	61.7	1.50	17.2	16.0	12.5
STN 6	Umumba near market	About 5 meters	Un-failed	About 1 m	68.7	31.3	44.0	21.2	22.8	1.94	12.2	20.0	13.0
STN 7	Ngwo before 9th Mile	About 15 meters	Un-failed	About 1 m	75.1	24.9	30.0	14.1	16.0	2.13	10.1	43.0	36.0
STN 8	Between New market flyover & Trans-Ekulu	About 15 meters	Un-failed	About 1 m	47.7	52.3	78.5	21.1	57.4	1.61	17.2	10.5	7.5

Source: Author's Field Work (2011)

TABLE 2: SPECIFICATION LIMITS FOR SUB-GRADE/FILL MATERIALS FOR ROADS

Material/Layer	Test	Specified Limits	Desired Limits	Requirement of Tests	Specification Clause No
Sub-grade/Fill	**Plasticity Tests**			1 per 1000mm	6181
	(a) Liquid limit	≤ 80 %	≤ 50 %		6122
	(b) Plasticity Index	≤ 55	≤ 30		6122
	Grading Test			1 per 1000mm	6181
	a) Sieve Analysis	≤ 35% Passing 75 um or 200 Sieve			6102
	Density Moisture Content			1 per 500m	6181
	a) Compaction Test	B.S. Compaction			6180
	Insitu Dry Density Test			1 per 100m	6181
	Top 600mm	≥100% of the MDD in BS Compaction			6125
	After 600mm	≥95% of the MDD in BS Compaction			6125
	Next to Structure	≥100% of the MDD in BS compaction			6125
Unsuitable	a) Peat, logs, stumps. Roots, & other perishable or combustible materials				6122
	b) Materials from swamps, marshes & bogs				6122
	c) Top soil and highly organic clay & silt				6122
	d) Clay having a liquid limit exceeding 80% or PI exceeding 55				6122
	e) Highly micaceous materials				6122

Source: Extracted from General Specification for Roads and Bridges F.M.W. (1997)

Particle Size Distribution: The particle/grain size distribution of a soil is an important determinant of its geotechnical characteristics. In construction, clay materials are seen as troublesome. This is because, clay though porous is less permeable and to determine the percentage clay present in the natural soil of an area to know whether it will serve as a good sub-grade or not. This particle size distribution analysis becomes necessary.

From Table 1, it is obtained that samples studied at Station 1 (around Bridgehead Onitsha) has a higher amount of clay with a lower amount of sand-size particles. The clay here is over 54% while the sand is 45.9%. At Station 2 (Omagba Guest Hall near Borromew roundabout) the sand size particles are 49.9% while the clay particles has 50.1%. The result of the analysis of Station 3 (Umunya near Odumodu Junction) has it that sand is 31.7% while clay is 68.3%, but in the case of Station 4 (around Awkuzu/Nteje area) sand is 61.9% while clay is 38.1%. A different was recorded at Station 5 (Unizik Junction, Awka), where sand became lower 42.1% while the clay went up to 57.9%. Another station with a high clay content is Station 7(After Zion Housing Estate near New Market Flyover, Enugu) having clay of 52.3%. Considering the specification limits for Sub-grade material in Table 2, it is obvious that only samples from Stations 6 and 7 fell within the limit of the specification, followed by sample from Station 4. For grading test, good materials are materials having ≤35% passing for sieve 75 um or 200 sieve. Although other parameters are considered before the verdict can be given of which material is good and which is bad. It should be noted that the more the clay, the more troublesome the material is. This is in line with the works of Okagbue and Uma (1988), Jegede (1997), and Akpan (2005) among others.

Atterbergs Limit: From the result of the laboratory analyses, Station 1 has a high liquid limit of 85.5% with a plasticity limit of 18.3% thus a high plasticity index of 67.2 which is greater than the standard limit of plasticity index of 55. At Station 2 the liquid limit is less than the standard limit of liquid limit (which is 80%) and with a moderate plasticity limit. From Table 2, it is clear that a soil with PI >35 is described as highly plastic this is in line with the work of Sowers and Sowers (1970). Such a soil usually has the ability to retain appreciable amount of total moisture in the diffuse double layer, especially by means of absorption. This fact was buttressed by the higher Optimum Moisture Content recorded in samples from stations1,3,5 and 8 (Table 1). High plasticity materials are usually susceptible to high compressibility (Seed and Woodward, 1964; Sowers and Sowers, 1970; Coduto, 1999). An increase in plasticity of material also decreases its permeability and hydraulic conductivity (Sowers and Sowers, 1970) which may be a factor of water logging and flooding both of which results in road failure as evident in the failure around Station 5 (near UNIZIK Junction Awka where flooding led to the failure of the road and the drainage system leading to the loss of lives recorded along that area sometime in August 2012.

It is noted that Stations 1 and 3 have liquid limits greater than that of the set standard by Federal Ministry of Works while station 2,4,5,6, 7 and 8 have liquid limits lower than the set liquid standard. But due to the plastic limit of the samples collected at the various stations, station 1, 3, 5 and 8 exceeded the standard limits of plasticity index set by the Federal Ministry of Works as can be seen in Table 2. It is crystal clear that all the

materials with geotechnical characteristics greater than the set standard are troublesome, seeing that they are all clay materials (weathered shale) showing the different formations t6hat are clay which underlie these stations along the roadway (Ameki formation, Umunya Shale Unit, Imo Shale and Enugu Shale, that is, Stations 1,3,5 and 8 respectively). This` agrees with the woks of Gidigasu (1983), Graham and Shields (1984), Akpokodje (1986), Alexander and Maxwell (1996) and Jegede (1997) which stipulates that clay materials are troublesome materials in construction and must be treated with caution.

Thus one can conclude based on the atterberg limit test that stations 1, 3, 5 and 8 have bad Sub-grade materials while station 2, 4, 6 and 7 are underlain by good Sub-grade materials although other geotechnical parameters must be put into consideration before a final conclusion can be drawn as to the quality of the sub-grade. It can thus be inferred that the failure of the road at stations 1, 3 and 5 is as a result of the soil geotechnical characteristics of these sections of the road.

Compaction: Results of the compaction test showed higher Maximum Dry Density (MDD) for samples from stations 2,4,6 and 7. of 1.85, 2.03, 1.94 and 2.13 mg/m^3 respectively with Optimum Moisture Content (OMC) ranging from 10.1 to 17.2. Stations 1,3,5 and 8 showed lower MDD of 1.74, 1.55, 1.50 and 1.61 mg/m^3 respectively with OMC ranging from 17.2 to 18.2 thus higher (see Table 1). This implies that in construction, the soils of stations 2,4,6 and 7 will be more suitable for Sub-grades and easily compactible than those of stations 1,3,5 and 8. The MDD of Station 3, 5, and 8 (1.55, 1.50 and 1.61 mg/m^3 respectively) which is on the Umunya Shale, Imo Shale and Enugu Shale respectively also agreed with the work of Okogbue and Aghamelu (2010) which states that Shales from Southeastern Nigeria has MDD ranging from 1.50 to 1.68 mg/m^3 the high clay content of these samples must be responsible for their lower MDD and CBR as evident in Table 1. It should be noted that the density of the soil mass affects the strength of the soil. Generally, the strength of a soil increases as its dry density increases. Also the potential for the soil to take on water at later times is decreased by higher densities. This is due to the decreased presence of air space in the soil mass. The in-place moisture content of a soil is often used, along with the soil classification, to determine the suitability of the material as a Sub-grade. Generally, as the moisture content of a soil increases its strength decreases and the potential for deformation and instability increases. There is no doubt then why these sections of the road consistently fail with time unlike other sections. This further implies that the geotechnical factors of these sections of the road might not have been considered during the construction. In addition, this further confirms the assertion by the respondents that part of the reasons for the failure of the road is incompetence of the contractors

CBR: Results of the laboratory CBR tests showed that Stations1,3,5 and 8 showed lower soaked and unsoaked CBR values of 11.0% & 5.5%, 8.0% & 6.0%, 16.0% & 12.5% and 10.5% & 7.5% respectively. While Stations 2,4,6 and 7 showed higher soaked and unsoaked CBR values of 26.0% & 24.0%, 30.0% & 24.0%, 20.0% & 13.0% and 43.0% & 36.0% respectively. The reduction in CBR of Stations 1,3,5 and 8 suggests that moisture influx would be detrimental to the Sub-grades of pavements constructed on them. The higher clay content of the samples might also be responsible for reduction in CBR, which was a geotechnical signal for cautions when used as pavement materials. Thus the materials at Stations 2, 4, 6 and 7 will make better sub-grades all other parameters being equal. This again strengthens the conclusions made earlier from the compaction test.

Therefore, in conclusion of the discussions on Tables 1 and 2, it is evident that the failure of the road at Stations 1, 3 and 5 is from their soil geotechnical characteristics as shown by the results of their PI and grading test, all of which are not in conformity with the standard set by the FMW.

2.2 TEST OF HYPOTHESES

Hypothesis 1

H_0: There is no significant relationship between the soil geotechnical characteristics of the failed sections of the road and the un-failed sections.

H_1: There is significant relationship between the soil geotechnical characteristics of the failed sections of the road and the un-failed sections.

Level of significance: 5% (0.05)

Statistical tool: Correlation Coefficient.

This is a statistical tool that shows strength and nature of relationship between two variables. In this case, it was used to show if there exist significant relationship between failed and un-failed section of the road.

Decision Rule: The test is said to be significant if the value is greater than 0.5, else, insignificant. The result is as follows;

The data of the laboratory analyses of the failed and un-failed sections of the road was feed into the computer with the aid of the SPSS and Minitab as in Table 3 and the correlation determined.

Correlations: failed section, un-failed section

Pearson correlation of failed section and un-failed section = 0.384

P-Value = 0.322 thus we accept H_0 that is there is no significant relationship between the geotechnical characteristics of the failed sections and that of the unfailed sections.

Hypothesis 2

H_0: There is no significant difference between the soil geotechnical characteristics of the failed sections and the un-failed sections of the road.

H_1: There is significant difference between the soil geotechnical characteristics of the failed sections and the un-failed sections of the road.

Level of significance: 5% (0.05)

Statistical tool: Student T- test;

Decision Rule: The test is said to be significant if the value is greater than 0.05, else, insignificant that is reject H_0 if p-value is less than 0.05, otherwise accept H_0. The result is as follows;

Two-Sample T-Test and CI: failed, unfailed

Two-sample T for failed vs unfailed

	N	Mean	StDev	SE Mean
failed	35	33.5	25.4	4.3
unfailed	35	27.4	19.1	3.2

Difference = mu (failed) - mu (unfailed)
Estimate for difference: 6.08
95% CI for difference: (-4.64, 16.81)
T-Test of difference = 0 (vs not =): T-Value = 1.13 P-Value = 0.0262 DF = 68
Both use Pooled StDev = 22.4872

The p-value of the test is less than 0.05 which implies there exist enough evidence to reject the null hypothesis and conclude that there exists significant difference between the variables.

3.0 CONCLUSION AND RECOMMENDATIONS

3.1 CONCLUSION

The correlation between the variables is 0.384 which is less than 0.5. This implies insignificant relationship between the failed and un-failed sections of the road. Also the p-value for the T-test is less than 0.05 which means there is significant difference between the geotechnical characteristics of the failed sections and that of the un-failed sections. It thus becomes crystal clear that the failure of the road is greatly dependent on the geotechnical characteristics of the soil on which the road was built, since the failed sections differ from the set standards by the Federal Ministry of Works for geotechnical characteristics of subgrades as can be confirmed from Table 1..

3.2 RECOMMENDATIONS

Sequel to the above findings and conclusion, the following recommendations were made:

- The geotechnical characteristics of the soils along the roadway vary from point to point and should be treated as such. Zones of high clay content to be treated with caution during reconstruction activities to avoid premature failure.
- All the failed sections with very troublesome clays to be excavated and replaced with good materials before casting the asphalt during reconstruction activities.
- Knowledge of soil geotechnical characteristics and the underlying geology of an area is also very essential and should be ensured before any construction project commence as the stability of the foundation layers particularly depends on this.
- Ready data of the geological and geotechnical status of all major highways should be established to aid proper planning of road reconstruction and rehabilitation projects.

REFERENCES

Abynayaka, S. W. (1977). ***Prediction of Road Construction Failure in Developingt Countries.*** Proc. Institute of Civil Engineering Part I, Pp. 419-446

Adegoke–Anthony,W.C. and Agada, O.A. (1980). "Geotechnical Characteristics of Some Residual Soils and their Implications on Road Design in Nigeria". Technical Lecture. Lagos, Nigeria. pp.1 – 16.

Adiat, K.A.N. Adelusi, A.O. and Ayuk, M.A. (2009). "Relevance of Geophysics in Road Failures Investigation in a Typical Basement Complex of South Western Nigeria". ***Pacific Journal of Science and Technology.*** 5(1): pp.528-539.

*Aigbedion, I. (*2007). "Geophysical Investigation of Road Failure Using Electromagnetic Profiles along Opoji, Uwenlenbo and Illeh in Ekpoma –Nigeria"**.** ***Middle-East Journal of Scientific Research*** 2 (3-4): pp.111-115.

Ajani, A. R. (2006). "Causes Of Premature Failures On Nigeria Highways A Training Course In Tunisia", Unpublished**.**

Ajayi, L.A. (1987). "Thought on Road Failures in Nigeria". ***The Nigerian Engineer.*** 22 (1): pp.10 – 17.

Akpokodje, E. G. (1986). "The geotechnical properties of lateritic and non-lateritic soils of southeastern Nigeria and their evaluation for road construction", ***Bulletin of Engineering Geology and the Environment*** Volume 33, Number 1, pp.115-121. (http://www.springerlink.com/content/a37771860k4n7k96/)

Alexander, W. S. and Maxwell, J. (1996). "Controlling Shrinkage Cracking from Expansive Clay Sub-grade" in Francken, L. B. and Molenaar, A. A. (eds): ***Reflective Cracking in Pavements.*** London: E&FN Spon (2nd edn): pp.64-71.

American Association of State Highway and Transportation Officials (AASHTO), (1976). ***Manual for bridge maintenance.***

Anambra State Ministry of Works and Housing (ANSMWH), (1998). "*Seminar on Cost of Road Maintenance in Anambra State", June, 1998.*

Federal Ministry of Works and Housing (FMWH), (1992). ***Highway Road Maintenance Manual***, part II

Federal Ministry of Works and Housing (FMWH), (1995). " Seminar on the Importance of Drainage System in All Nigerian Roads". Kano March, 1995.

Federal Ministry of Works and Housing (FMWH), (1997). ***General Specification for Roads and Bridges.***

Gidigasu. M.D. (1983). "Development of acceptance specifications for Tropical Gravel paving materials". ***Engineering Geology***.19, pp.213-240

Graham, J. and Shields, D.H. (1984). "Influence of geology and geological processes on the geotechnical properties of a plastic clay". ***Journal of Engineering Geology*** Volume 22, Issue 2, pp109-126. (http://www.sciencedirect.com/science/journal/00137952).

Gupta, B. L. and Gupta, A. (2003). ***Roads, Railways, Bridges, Tunnel and Habour Dock Engineering;*** Standard Publishers Distributors, Nai Sarak, Delhi. 5th Edition.

Ibrahim, K. (2011): "Nigerian Roads Need N70 Billion for Repairs Annually". ***Daily Times.*** Article,| May 30, 2011 - 10:23am . http://dailytimes.com.ng/article/nigerian-roads-need-n70-billion-repairs-annually.

Jain, S. S. and Kumar, P. (1998): "Report on Causes of Cracks Occurrence in Ramghat - Aligarh Road in U.P". Report Submitted to PWD, Aligarh.

Jegede, G. (1997): "Highway pavement failure induced by soil properties along the F209 highway at Omuoke, southwestern Nigeria". ***Nigeria Journal of Science***.

John, H. and Gorden, H. (1976): A practical Guide to Earth Road Construction and Maintenance, ***Engineering Manual*** Vol. 2, No. 1. Pp. 43-45.

Mesida, E.A. (1981): "Laterites on the Highways – Understanding Soil Behaviour". ***West African Technical Review.*** pp.112 – 118.

Momoh, L.O., Akintorinwa, O. and Olorunfemi, M.O. (2008): "Geophysical Investigation of Highway Failure-A Case Study from the Basement Complex Terrain of Southwestern Nigeria". ***Journal of Applied Sciences Research.*** 4(6): 637-648.

Munasingbe, M. and Jeffrey, M. (1995): "Key concept and Terminology of Sustainable Development" in Munasingbe, M. and Shearer, W. (ed) ***Defining and Measuring Sustainability***. Washington D.C. UN University.

Nelson, R.G. and Haigh, J.H. (1990): "Geophysical Investigation of in Lateritic Terrain". ***Geotechnical and Environmental Geophysics.*** Ward, S.H. (Ed), (Geotechnical), SEG, Tulsia. 2: pp.133 – 154.

Oglesby, C. H. and Garry, H. R. (1978):. ***Highway Engineering***, fourth edition, John Willey and sons, New York, p. 691.

Okogbue, C. O. Aghamelu, O. P. (2010): "Comparison of the Geotechnical Properties of Crushed Shales from Southeastern Nigeria". ***Bulletin of Engineering, Geology and Environment.*** Vol.69, No.4, pp587-597.

Onuoha, D. C. and Onwuka, S. U. (2014): "The Place of Soil Geotechnical Characteristics in Road Failure, a Study of the Onitsha-Enugu Expressway, Southeastern Nigeria" ***Journal of Civil and Environmental Research.*** IISTE, USA. Vol. 6, No. 1, pp 55-67.

Paul, H. N. and Radnor, J. P. (1976): ***Highway Engineering***, John Willey and Sons, New York.

Richardson, N.H. (1989): ***Land Use Planning and Sustainable Development in Canada***, Canadian Environmental Advisory Council, Ottawa.

Transport Road Research Laboratory (TRRL), (1991): ***Maintenance Techniques for District Engineers,*** Vol. 2, TRRL. Crow Thorne England.

United Nations Education Scientific and Cultural Organization (UNESCO), (1991): ***Low cost Roads Ossigu Construction and Maintenance Study*** Vol. 1. No.1, Pp. 20-25.

World Bank (1991): ***Nigeria Highway Sector Study Journal***, Vol. II, No.2.

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