Journal of Earth and Atmospheric Research

GEOTECHNICAL CONTROLS ON PAVEMENT FAILURE ALONG IKERE–IGBARA-ODO ROAD, SOUTHWESTERN NIGERIA

[1]Aluko, A.B. and [2]Anifowose, A.Y.B.
[1]Department of Applied Geology, Federal University of Technology, Akure, Nigeria
[2]Department of Remote Sensing and Geoscience Information System, Federal University of Technology, Akure, Nigeria

Paper History
Submitted on 05-06-2026
Accepted on 29-06-2026

Keywords
Pavement failure; geotechnical properties; clay mineralogy; montmorillonite; Basement Complex

ABSTRACT

Premature pavement failure remains a persistent challenge in many tropical developing countries, where geological, geotechnical, and hydrological factors often interact to reduce pavement service life. This study investigates the lithological, geotechnical, and clay mineralogical factors responsible for pavement deterioration along the Ikere–IgbaraOdo Road in southwestern Nigeria. Geological mapping, petrographic investigations, and geotechnical analyses were conducted on sixteen soil samples collected from failed and distressed sections of the road corridor. Laboratory tests included the determination of natural moisture content, specific gravity, grain-size distribution, Atterberg limits, compaction characteristics, and California Bearing Ratio (CBR), while clay mineral assemblages were inferred using activity relationships and geotechnical characteristics. Results indicate that the study area is underlain predominantly by migmatite and granitic rocks. Geotechnical analyses revealed considerable variability in engineering properties, with natural moisture content ranging from 7.64 to 41.18%, liquid limit from 18.4 to 53.5%, plasticity index from 0 to 29.2%, and CBR values from 14 to 63%. Most soils were classified as A-4 to A-7 under the AASHTO system and CL to CH under the Unified Soil Classification System, indicating generally poor to fair subgrade conditions. Clay mineral assessment revealed the occurrence of halloysite, kaolinite, illite, and montmorillonite, with sections exhibiting severe pavement distress commonly associated with soils containing montmorillonite and high plasticity characteristics. The concentration of failures near river channels further highlights the influence of moisture retention and inadequate drainage on pavement performance. The study demonstrates that pavement failure along the Ikere–Igbara-Odo Road is primarily controlled by the interaction of lithology, expansive clay mineralogy, and adverse drainage conditions. These findings underscore the importance of detailed geological and geotechnical investigations during highway planning, design, and rehabilitation projects in tropical basement complex terrains to enhance pavement durability and reduce the incidence of premature failure.

Correspondence: abaluko@futa.edu.ng

1.0 INTRODUCTION

Transportation infrastructure is essential for socioeconomic development, enabling the movement of people, goods, and services, promoting regional integration, and supporting commercial and agricultural activities. In Nigeria, road transport dominates passenger and freight movement, making the durability and functionality of road pavements crucial for economic productivity and sustainable development (FMWH, 2013). Despite significant investments, premature pavement failures remain widespread across Nigeria. Common issues like potholes, rutting, cracking, and pavement collapse often occur before the pavement's intended lifespan, leading to higher maintenance costs, traffic disruptions, and reduced transport efficiency (Daramola et al., 2018; Emmanuel et al., 2021). Pavement deterioration results from multiple factors. While inadequate design, poor construction, excessive loading, maintenance lapses, and drainage problems are traditional causes (Abam et al., 2005), geological and geotechnical conditions also play a critical role, especially in tropical climates where chemical weathering and moisture changes affect subgrade soils (Aghamelu and Okogbue, 2011; Emmanuel et al., 2021). Understanding these factors is key to designing durable pavements.

Studies in southwestern Nigeria link pavement failures to unstable subgrades, clay-rich soils, buried stream channels, fractured bedrock, and poor drainage (Daramola et al., 2018; Emmanuel et al., 2021). Seasonal moisture fluctuations weaken subgrades through water infiltration and drying-induced shrinkage, accelerating pavement damage (Ukor et al., 2023).Similar observations have been reported along the Akure–IkereEkiti highway, where the engineering properties of subgrade soils were identified as major contributors to premature pavement deterioration (Ajiboye et al., 2023).The performance of pavement subgrades depends on soil properties like moisture content, grain size, plasticity, compaction, and bearing capacity (Bowles, 1981; Das, 2018). High plasticity and low California Bearing Ratio (CBR) values indicate soils prone to deformation and poor support. Failed pavements in the region often overlay fine, highly plastic soils with low CBR values (Daramola et al., 2018; Ogunribido and Fadairo, 2020).

Geology influences pavement performance through soil formation, weathering, groundwater, and mineral composition. In tropical Basement Complex terrains, parent rock type affects soil properties—granites weather into clay-rich soils while quartzites produce more stable materials (Mesida, 1987; Adeyemi, 1995). Thick weathered layers, clayey subsoils, and weak zones often underlie failed pavements, trapping moisture and reducing strength (Abam et al., 2005; Daramola et al., 2018). Integrating geological with geotechnical studies offers better insights into pavement failure (Ademila, 2021).

Clay mineralogy also matters. Kaolinite clays have low swelling potential, whereas smectite minerals like montmorillonite cause significant swelling and shrinkage, leading to cracking and instability (Skempton, 1953). Recent studies stress combining mineralogical and geotechnical analyses to understand failures better (Ukor et al., 2023; Obasaju et al., 2025).

The Ikere–IgbaraOdo road is an important route for agricultural and commercial transport in Ekiti State but suffers recurrent pavement failures despite repairs. This indicates that key causes remain unidentified. Most studies focus on geotechnical or geophysical aspects, often neglecting geological observations and mineralogy. Thus, the interaction of lithology, clay minerals, and drainage affecting pavement failures along this road is not well understood. This limits sustainable pavement design and maintenance strategies in Basement Complex areas.

This study aims to investigate the geological and geotechnical factors responsible for pavement failure along the Ikere–IgbaraOdo road by characterizing the underlying geology beneath failed pavement sections, assessing the geotechnical properties of the subgrade soils, analyzing the clay mineralogical characteristics inferred from geotechnical data, evaluating the influence of lithology, clay minerals, and drainage conditions on pavement performance, and recommending appropriate design and maintenance strategies for pavements constructed within tropical Basement Complex terrains. The results will improve understanding of pavement performance in tropical regions and support better engineering and management practices to enhance road durability and sustainability in southwestern Nigeria and similar settings.

2.0 STUDY AREA

2.1 Location and Accessibility

The study area is located along the Ikere–IgbaraOdo road in Ekiti State, southwestern Nigeria (Figure 1). The road serves as an important transportation corridor linking Ikere-Ekiti with IgbaraOdo and adjoining communities. It facilitates the movement of agricultural produce, commercial goods and passengers within the region.

Geographically, the area lies within the Precambrian Basement Complex terrain of southwestern Nigeria and is accessible through a network of federal and state roads. The investigated road segment traverses both elevated and low-lying terrain, including sections crossed by seasonal and perennial drainage channels.

2.2 Climate and Drainage

The study area experiences a tropical humid climate characterized by distinct wet and dry seasons. The rainy season typically extends from April to October, while the dry season occurs between November and March. Annual rainfall is generally high and contributes significantly to weathering processes and groundwater recharge.

The drainage pattern is controlled by local topography and structural features within the Basement Complex terrain. Several streams and river channels such as OdoIgbara, Omi Alade stream, and Awo stream intersect the road alignment. Field observations revealed that some of the severely distressed pavement sections occur near river crossings and low-lying areas where water accumulation and prolonged saturation are common.

2.3 Geology and Geomorphology

The area is underlain predominantly by Precambrian Basement Complex rocks consisting mainly of migmatite, granitic rocks, and charnockite. The migmatite occupies approximately 60% of the area, granitic units include biotite granite and biotite-hornblende granite, while quartzite occurs as prominent ridges within parts of the study area (Figure 3). Petrographic investigations indicate that the granitic rocks are composed principally of quartz, feldspar, biotite, and hornblende, whereas quartzite is composed almost entirely of recrystallized quartz grains. Weathering of these rocks has produced residual soils with varying engineering characteristics. The granitic rocks generally weather into clay-rich soils, while the quartzite yields relatively coarse-grained and less plastic materials (Mesida, 1987).

Topographically, the area consists of gently undulating terrain interrupted by quartzite ridges and localized depressions. These geomorphic characteristics exert significant influence on drainage conditions and groundwater movement, which in turn affect pavement performance.

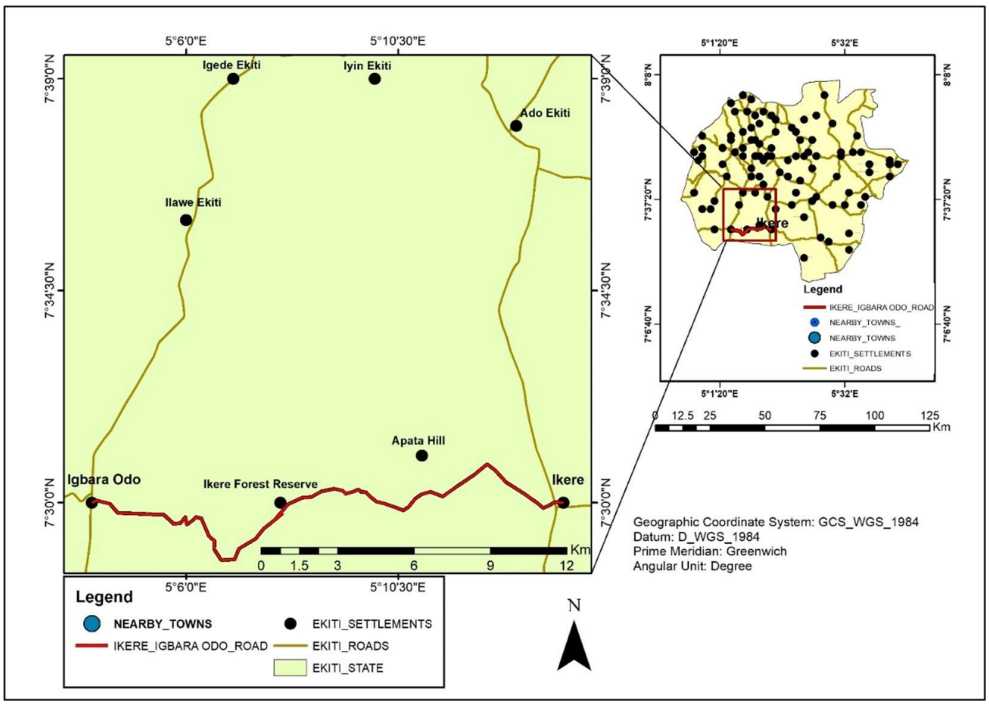


Figure 1: Location map of the study area

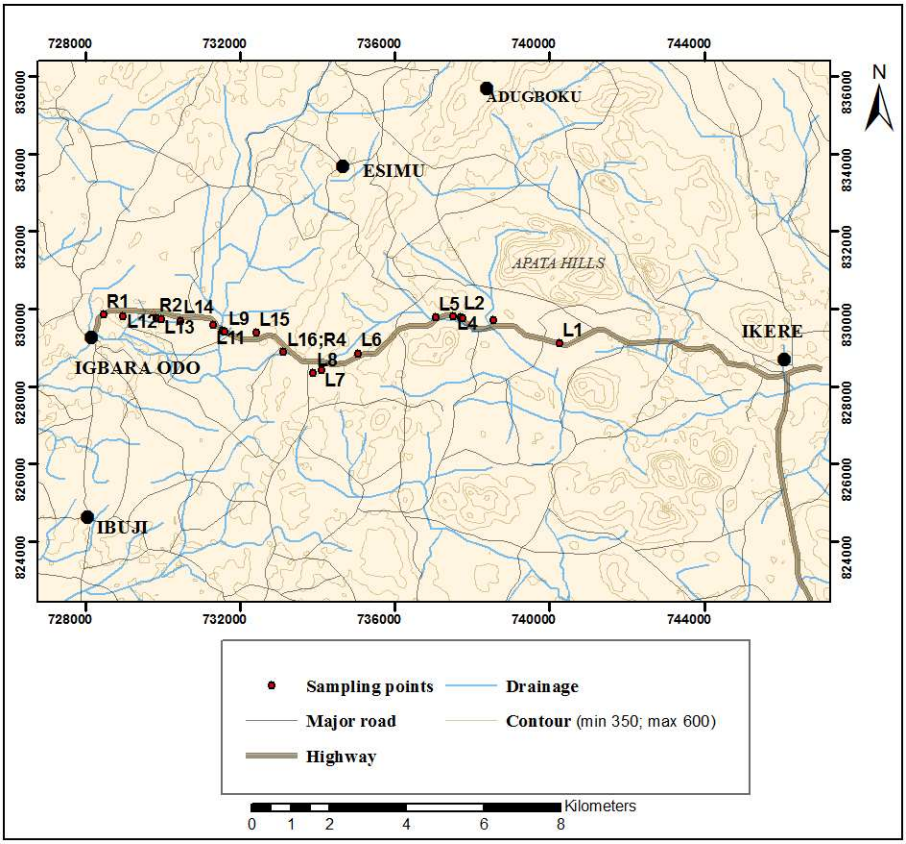


Figure 2: Map showing the sampling points along the road alignment

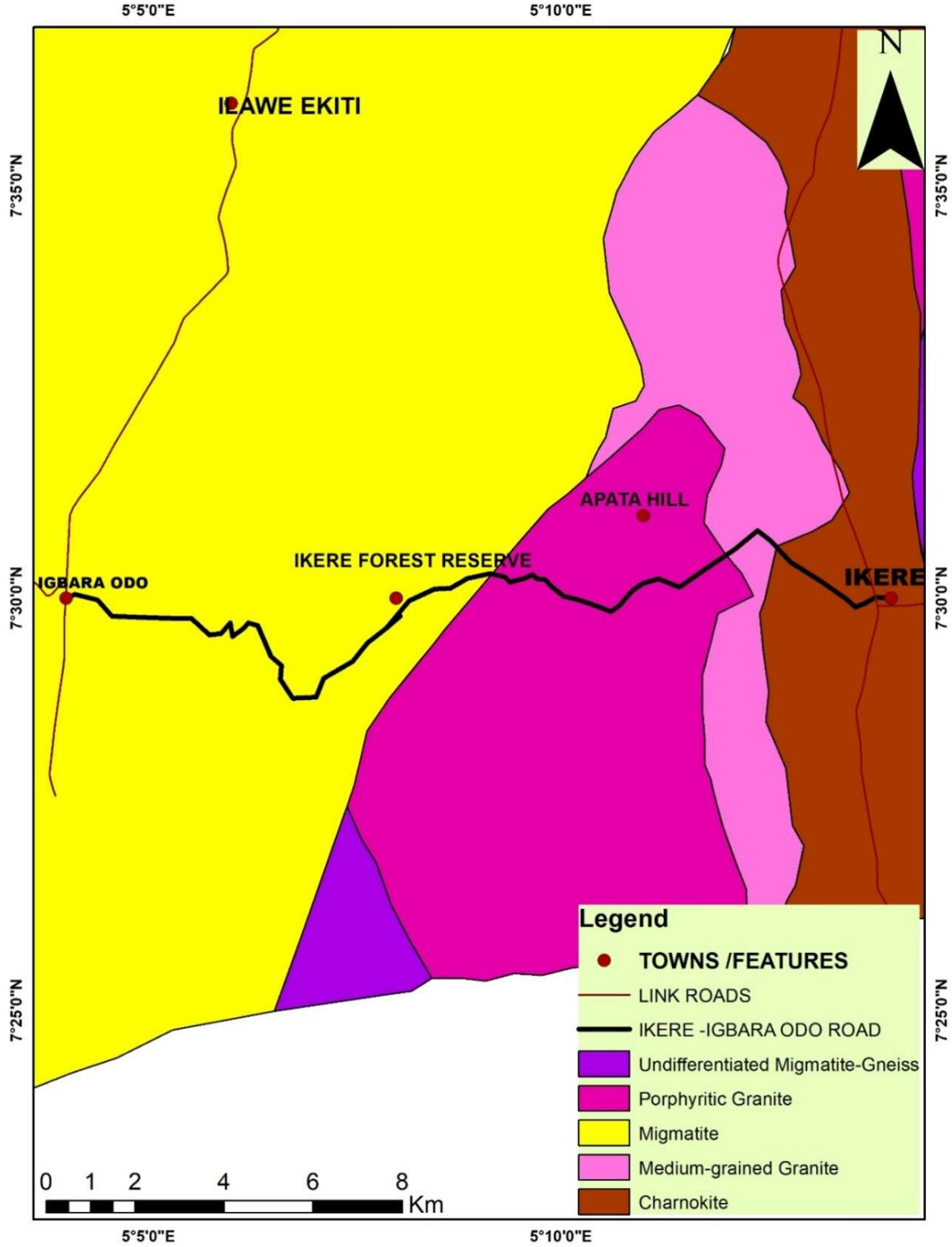


Figure 3: Geological map of the Ikere- Igbara-Odo road in relation to the geology of the area

3.0 MATERIALS AND METHODS

3.1 Field Investigation and Sample Collection

Detailed field investigations were conducted along failed and distressed sections of the Ikere–IgbaraOdo road to identify visible manifestations of pavement failure and to characterize the geological conditions underlying the road corridor. Field observations included the documentation of potholes, rutting, alligator cracking, depressions, edge failures, waterlogged zones and drainage conditions. Geological mapping was undertaken to identify lithological units, structural features and geomorphological characteristics that could influence pavement performance.

A total of sixteen representative soil samples were collected,2 from the stable portion to serve as control, and 14 from failed and distressed portions of the road corridor (Figure 1, Table 1). Sampling locations were selected to ensure adequate representation of the different geological and geomorphological conditions encountered within the study area. Samples were carefully labeled and transported to the laboratory for geotechnical analyses. Rock samples were also collected from exposed outcrops for petrographic examination and characterization.

3.2 Petrographic Analysis

Representative rock samples obtained from granitic and quartzitic outcrops were prepared as thin sections and examined using a polarizing petrographic microscope. Mineralogical composition, textural relationships, and weathering characteristics were evaluated to determine the influence of parent rock lithology on the engineering behaviour of the derived soils. Particular attention was given to the occurrence of feldspar, quartz, biotite, and other minerals capable of influencing weathering processes and clay mineral formation.

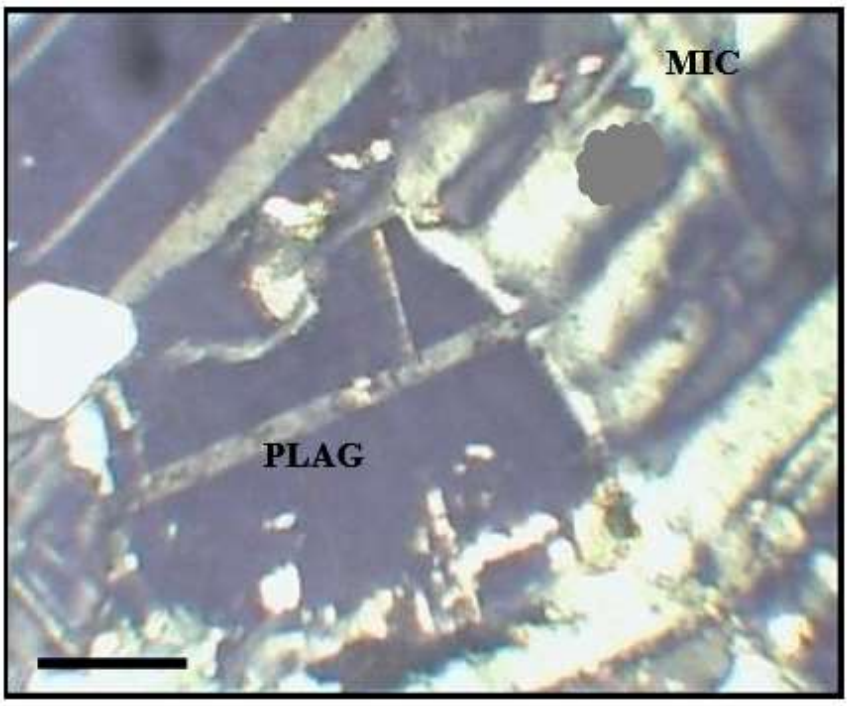


Figure 4: Photomicrograph of biotite granite showing microcline (MIC) and plagioclase (PLAG) minerals (Bar scale: 1 µm)

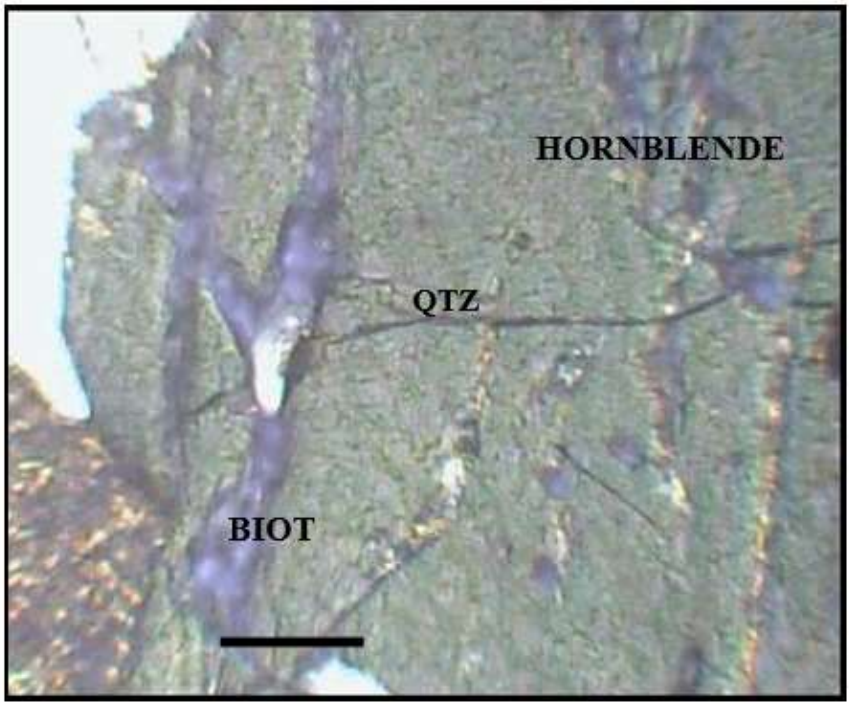


Figure 5: Photomicrograph of biotite-hornblende granite showing biotite (BIOT), Quartz (QTZ) and hornblende (Bar scale: 1 µm)

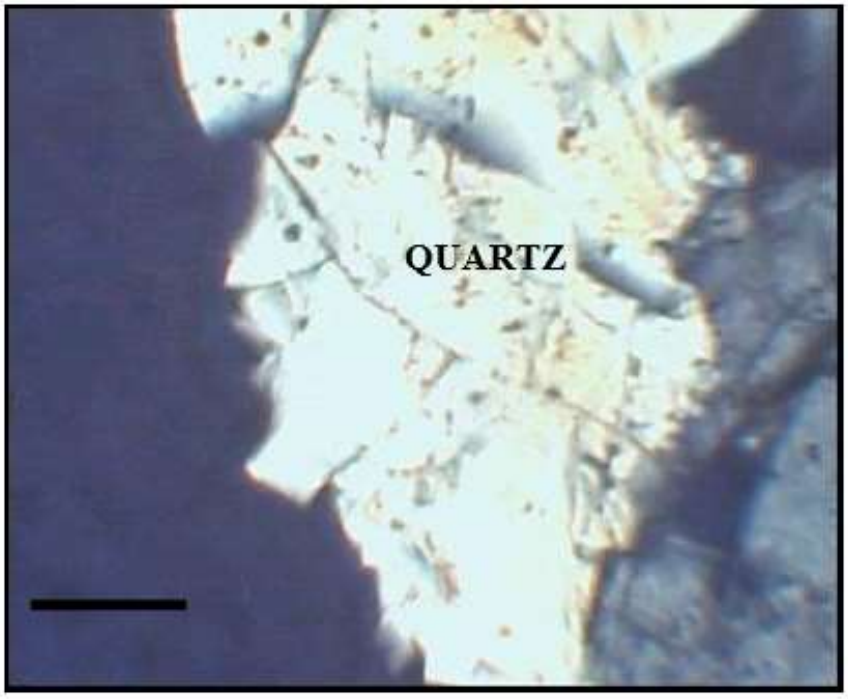


Figure 6: Photomicrograph of quartzite showing quartz mineral (Bar scale: 1 µm)

3.3 Laboratory Geotechnical Investigations

Laboratory tests were performed on representative soil samples taken from the failed pavement sections to determine their engineering properties and assess their suitability as pavement subgrade materials. The tests followed the procedures outlined in BSI 1377 (1990) and the Federal Ministry of Works and Housing specifications for road construction materials (FMWH, 2016). Natural moisture content tests were conducted to evaluate the in-situ water condition of the soils and its potential impact on their behavior. Samples were oven-dried at a controlled temperature until they reached a constant weight, after which moisture content values were calculated. Specific gravity tests were also carried out to determine the relative density of soil particles, providing insights into the mineral makeup and degree of weathering of the parent materials.

Particle size distribution was analyzed using sieve techniques to identify the proportions of gravel, sand, silt, and clay in each sample. These results helped classify the soil and assess the drainage qualities of the subgrade materials. Consistency characteristics were evaluated by determining the Atterberg limits—the liquid limit (LL), plastic limit (PL), and plasticity index (PI). The plasticity index was calculated by subtracting the plastic limit from the liquid limit:
PI = LL – PL, where PI, LL, and PL are expressed as percentages. These parameters helped assess the soil's plasticity, compressibility, swelling potential, and overall suitability for pavement construction.

Linear shrinkage tests measured the soil's tendency to shrink when drying, indicating its shrink-swell behavior and risk of desiccation cracking. Compaction tests determined the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the soils, which are critical for understanding compaction behavior and estimating field compaction requirements during road construction and repair. The load-bearing capacity of the subgrade was assessed using California Bearing Ratio (CBR) tests. The CBR values provided a key measure of subgrade strength and were compared against FMWH standards for pavement materials. Together, these laboratory results formed the basis for evaluating the engineering suitability of the soils and their role in the pavement failures observed along the Ikere–IgbaraOdo road.

3.4 Soil Classification

The investigated soils were classified using both the American Association of State Highway and Transportation Officials (AASHTO) classification system and the Unified Soil Classification System (Casagrande, 1948). These classification systems provide a basis for evaluating engineering suitability and comparing the characteristics of soils from different locations.

3.5 Clay Mineral Assessment

Clay mineral assemblages were evaluated using activity relationships derived from plasticity characteristics and clay fraction data. The method involved the application of the clay activity concept proposed by Skempton (1953), which relates plasticity index to clay content.

Activity values were compared with established ranges for common clay minerals such as kaolinite, illite, halloysite, and montmorillonite. The inferred mineralogical composition was subsequently used to assess the influence of clay mineralogy on pavement performance. Although the approach provides useful information regarding probable clay mineral types, it represents an indirect assessment of mineralogy and should therefore be interpreted in conjunction with geological and geotechnical evidence.

3.6 Data Analysis

The results obtained from the field investigations and laboratory tests were presented in tables and

figures and interpreted based on established geotechnical standards and relevant literature. Relationships among moisture content, plasticity characteristics, clay mineral occurrence, and California Bearing Ratio values were examined to identify the factors controlling pavement deterioration within the study area (Ajiboye et. al 2023).

The geological, petrographic, and geotechnical datasets were subsequently integrated and interpreted to elucidate the mechanisms responsible for pavement failure along the Ikere–IgbaraOdo Road.

4.0 RESULTS AND DISCUSSION

4.1 Geological Characteristics

Geological mapping identified two principal lithological units within the study area, namely granitic rocks and quartzite (Table 1). Petrographic examination of the granites revealed the presence of quartz, plagioclase feldspar, microcline, biotite, hornblende, myrmekite, and sericite. The quartzite was composed predominantly of quartz and exhibited relatively high resistance to weathering.The mineralogical composition of the granitic rocks suggests a strong potential for the development of clay-rich residual soils through prolonged chemical weathering. Feldspars and ferromagnesian minerals present within the granites provide suitable parent materials for the formation of secondary clay minerals that influence engineering behaviour.

4.2 Geotechnical Characteristics of the Subgrade Soils

The soils exhibited considerable variability in their engineering properties. Natural moisture content ranged from 7.64 to 41.18% with a mean value of 33.65%, indicating substantial differences in drainage and water-retention characteristics. Liquid limit values ranged from 18.4 to 53.5% with an average value of 28.3%, while plasticity index values varied between 0 and 29.2%, having a mean value of 13.8%. California Bearing Ratio values ranged from 14% to 63% with an average of 28.25%, indicating significant variation in subgrade strength. The lowest CBR values were recorded in samples associated with severely distressed pavement sections, whereas the highest value occurred in soils derived from quartzitic materials. Maximum dry density values ranged from 1622 to 2098 kg/m³ with a mean value of 1,785.67kg/m^3at optimum moisture contents between 12 and 22%having a mean value of 18% (Table 2).

According to AASHTO classification (Table 3), most soils fall within groups A-4, A-5, A-6, and A-7, indicating materials of fair to poor engineering quality. Similarly, the USCS classification (Table 4) identified most samples as low- to high-plasticity silts and clays. These classifications suggest that many of the soils possess characteristics capable of adversely affecting pavement performance. The predominance of AASHTO A-4 to A-7 soils and the occurrence of moderate to high plasticity materials observed in this study are consistent with findings from similar investigations in southwestern Nigeria, where weak subgrade conditions were implicated in premature pavement failures (Ajiboye et al., 2023; Oyedele et al., 2023).

4.3 Influence of Clay Mineralogy on Pavement Performance

The activity chart analysis (Figure 6) indicates the occurrence of halloysite, kaolinite, illite, and montmorillonite within the study area. Samples associated with stable pavement sections are generally characterized by halloysite, kaolinite, and illite, whereas samples collected from severely failed zones are predominantly associated with montmorillonite or mixed montmorillonite-illite assemblages. Montmorillonitic soils exhibited some of the lowest CBR values and were frequently associated with waterlogged conditions, potholes, rutting, and extensive cracking. The

expansive nature of montmorillonite allows significant absorption of water between crystal layers, resulting in swelling during wet periods and shrinkage during dry periods. Repeated swelling and shrinkage cycles weaken the pavement structure and accelerate deterioration.

In contrast, quartzite-derived soils were generally non-plastic and exhibited superior engineering characteristics. The absence of appreciable clay minerals in these materials contributed to their higher bearing capacities and improved stability.

Table 1: Summary of Field Characteristics of Soil Samples

Sample Name	**Description**		
	Colour	**Natural state of soil**	**Condition of Area**
L1	Reddish brown	Dry	"Unfailed" zone
L2	Reddish brown	Dry	Transported material
L3	Darkish brown	Dry	Cracks, Mud cracks
L4	Brownish	Wet	
L5	Darkish brown	Wet	Stable "unfailed" portion
L6	Greyish	Wet	Fairly stable, close to river
L7	Greyish	Wet	Fairly stable
L8	Yellowish brown	Damp	River close by, failed portion
L9	Dark brown	Damp	Cracks, potholes
L10	Dark greyish	Dry	Mud cracks in rutted area
L11	Dark brown	Water logged	Muddy water in rutted portion
L12	Darkish brown	Damp	Crocodile cracks
L13	Light brown	Dry	
L14	Whitish	Dry	Quartzite
L15	Reddish brown	Damp	
L16	Whitish	Dry	Crocodile cracks, quartzite quarry site, river close by

Table 2: Summary of Geotechnical Properties

SAMPLE NO	SG	NMC (%)	LL (%)	PL (%)	PI (%)	SL (%)	% PASSING SIEVE NO. 200	CBR (%)	MDD (Kg/m^3)	OMC (%)	CLAY MINERAL TYPE
Location 1	2.68	7.64	53.5	43.6	9.9	9.1	47.7	29	1782	18	Halloysite
Location 2	2.45	12.69	45.5	28.7	16.9	8.2	44.9	45	1989	13	Kaolinite
Location 3	2.55	41.18	48.6	24.8	23.9	7.7	59.2	26	1732	19	Illite
Location 4	2.49	17.59	53.5	24.4	29.2	5.3	61.2	27	1755	19	Illite/Montmorillonite
Location 5	2.49	15.19	44.7	25.6	19.2	5.8	59.3	25	1733	19	Illite
Location 6	2.51	24.19	34.6	22.1	12.5	11.0	53.2	44	1976	14	Illite
Location 7	2.53	21.52	41.7	18.0	23.7	10.1	47.5	28	1788	18	Montmorillonite
Location 8	2.61	19.73	41.2	21.8	19.5	8.7	77.2	14	1632	22	Montmorillonite/Illite
Location 9	2.56	9.64	29.3	14.4	14.9	8.2	59.3	28	1789	18	Montmorillonite/Illite
Location 10	2.56	10.30	27.8	12.1	15.7	9.6	58.4	15	1623	22	Montmorillonite
Location 11	2.59	11.77	30.0	18.1	11.1	9.1	53.8	16	1652	21	Illite/Montmorillonite
Location 12	2.62	20.85	49.9	26.2	23.8	6.3	66.4	42	1977	14	Illite
Location 13	2.47	9.07	28.1	24.8	3.4	9.6	50.5	26	1798	18	-
Location 14	2.63	11.29	18.4	N-P	-	14.4	26.2	63	2098	12	-
Location 15	2.63	18.69	43.2	25.6	17.7	9.6	73.2	26	1733	19	Illite
Location 16	2.37	19.62	24.9	N-P	-	13.9	46.6	15	1622	22	-

SG – Specific Gravity
NMC – Natural Moisture Content
LL – Liquid Limit
PL – Plastic Limit
PI – Plasticity Index
LS – Linear Shrinkage
CBR – California Bearing Ratio
MDD – Maximum Dry Density
OMC – Optimum Moisture Content

Table 3: AASHTO Classification of Investigated Soils (AASHTO M 145)

Sample Code	Natural Moisture Content, m	Liquid limit, W_L	Plastic limit, W_P	Plasticity index, PI	% of soil passing No. 200 sieve	Group index, GI	AASHTO Classi-fication
Location 1	7.6	53.5	43.6	9.9	57.4	5.9	A-5
Location 2	12.7	45.5	28.7	16.8	44.9	4.3	A-4
Location 3	41.2	48.6	24.8	23.8	62.7	13.3	A-2
Location 4	17.6	53.5	24.4	29.1	63.4	16.8	A-7-6
Location 5	15.2	44.7	25.6	19.1	58.1	9.1	A-5
Location 6	24.2	34.6	22.1	12.5	53.2	4.1	A-6
Location 7	21.5	41.7	18	23.7	49.5	7.7	A-5
Location 8	19.7	41.2	21.8	19.4	77.2	14.5	A-6
Location 9	9.6	29.3	14.4	14.9	45.8	3.1	A-6
Location 10	10.3	27.8	12.1	15.7	58.4	5.7	A-6
Location 11	11.8	30	18.1	11.9	40.7	1.3	A-6
Location 12	20.9	49.9	26.2	23.7	72.8	17.3	A-7-6
Location 13	9.1	28.1	24.8	3.3	50.5	0	A-4
Location 14	11.3	18.4	N/P	0	26.2	0	A-1-A
Location 15	18.7	43.2	25.6	17.6	56.8	7.9	A-5
Location 16	19.6	24.9	N/P	0	46.6	0	A-4
Mean Value	**16.9375**	**38.43125**	**23.58571429**	**15.0875**	**54.0125**	**6.9375**	

Table 4: Unified Soil Classification System (USCS) Classification after (Casagrande, 1948) (ASTM D2487–17)

Sample Code	Natural Moisture Content, m	Liquid limit, W_L	Plastic limit, W_P	Plasticity index, PI	% of soil passing No. 200 sieve	Group index, GI	USCS Classi-fication Code
Location 1	7.6	53.5	43.6	9.9	57.4	5.9	MH
Location 2	12.7	45.5	28.7	16.8	44.9	4.3	MI
Location 3	41.2	48.6	24.8	23.8	62.7	13.3	CI
Location 4	17.6	53.5	24.4	29.1	63.4	16.8	CH
Location 5	15.2	44.7	25.6	19.1	58.1	9.1	CI
Location 6	24.2	34.6	22.1	12.5	53.2	4.1	CL
Location 7	21.5	41.7	18	23.7	49.5	7.7	CI
Location 8	19.7	41.2	21.8	19.4	77.2	14.5	CI
Location 9	9.6	29.3	14.4	14.9	45.8	3.1	CI
Location 10	10.3	27.8	12.1	15.7	58.4	5.7	CL
Location 11	11.8	30	18.1	11.9	40.7	1.3	CL
Location 12	20.9	49.9	26.2	23.7	72.8	17.3	CL
Location 13	9.1	28.1	24.8	3.3	50.5	0	CL
Location 14	11.3	18.4	N/P	0	26.2	0	CL
Location 15	18.7	43.2	25.6	17.6	56.8	7.9	CI
Location 16	19.6	24.9	N/P	0	46.6	0	CL
Mean Value	**16.9375**	**38.43125**	**23.58571429**	**15.0875**	**54.0125**	**6.9375**	

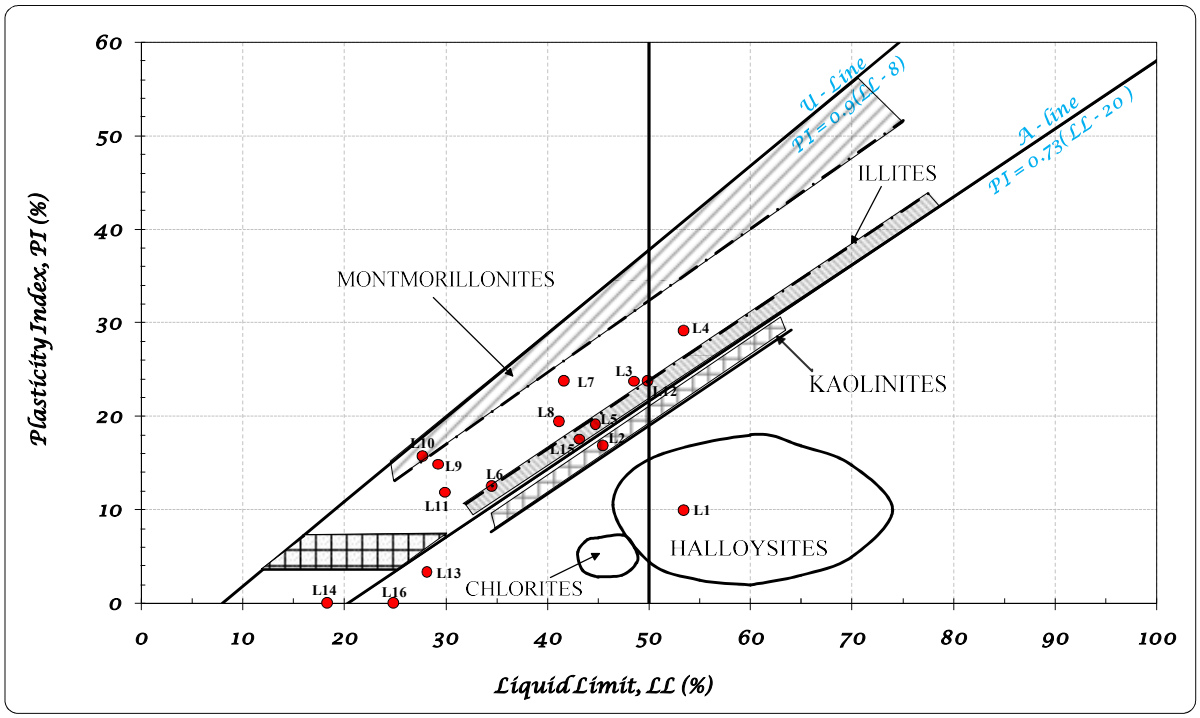


Figure 6: Clay Activity Chart Showing Inferred Clay Mineral Types

4.4 Mechanisms Responsible for Pavement Failure

Field observations indicate that the most severe pavement failures occur near river channels and poorly drained depressions(Figure 7). These areas remain saturated for prolonged periods, even during the dry season, thereby promoting the development and persistence of expansive clay minerals.The mechanism of failure observed in the study area is interpreted as a combination of geological, geotechnical, and hydrological processes. Weathering of granitic rocks produces clay-rich residual soils containing expansive minerals. Poor drainage and seasonal water infiltration increase soil moisture content and trigger swelling of the clay particles. This swelling reduces soil strength and bearing capacity, making the pavement susceptible to deformation under traffic loading Figure 8).

During the dry season, moisture loss results in shrinkage and the formation of mud cracks and crocodile cracks (Figure 9). These cracks subsequently provide pathways for further water infiltration during subsequent rainfall events. Repeated wetting and drying cycles progressively weaken the pavement structure, eventually leading to rutting, pothole formation, and complete pavement failure. Comparable interactions among geological conditions, poor drainage, seasonal moisture fluctuations, and subgrade instability have been documented in other Basement Complex terrains of southwestern Nigeria (Ademila, 2021; Oyedele et al., 2023), highlighting the importance of integrating geological and geotechnical considerations in pavement design and maintenance. The concentration of failure features such as potholes, rots and crocodile cracks around River Omifunfun and other poorly drained locations strongly suggests that ingress of water constitutes a critical factor controlling the development and severity of pavement deterioration within the study area.



Figure 7: Ruts and potholes on the failed road filled with water



Figure 8: The dried up ruts in the road



Figure 9: Mud cracks on the dried-up surface of some of the rutted portions

4.5 Further Studies

Clay mineral assemblages identified in this study were inferred using clay activity relationships and geotechnical behaviour rather than direct mineralogical techniques such as X-ray diffraction (XRD). Consequently, the mineralogical interpretations should be regarded as indicative rather than definitive. Future studies incorporating XRD, SEM, and geochemical analyses would provide more robust characterization of the clay mineral assemblages and their influence on pavement performance.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This study combined petrography, geotechnical testing, and clay mineral analysis to investigate pavement failure along the Ikere–Igbara-Odo road in southwestern Nigeria. The road is mainly underlain by migmatite and granitic rocks, whose weathered products have varying engineering properties. Subgrade soils showed high moisture content, moderate to high plasticity, low California Bearing Ratio (CBR) values, and generally poor suitability for pavement foundations.

Clay analysis identified halloysite, kaolinite, illite, and montmorillonite, with montmorillonitic soils linked to severe pavement damage, including rutting, potholes, cracking, and water logging. The shrink–swell behavior of these expansive clays, combined with seasonal moisture changes, weakened the subgrade and degraded the pavement. The worst damage occurred near river crossings and poorly drained depressions, where prolonged soil saturation led to clay swelling and subgrade weakening. Pavement performance is therefore influenced by the interplay of some of parent rock, clay minerals, moisture, and drainage. Recommendations include thorough geological and geotechnical investigations during highway planning and construction in Basement Complex terrains. Expansive clay soils should be removed, stabilized, or replaced, and effective drainage

systems incorporated, especially near rivers and depressions. Reconstruction of failed sections should use materials that meet Federal Ministry standards, alongside regular monitoring and maintenance to catch early defects.

Future studies should use mineralogical techniques like X-ray diffraction (XRD) and scanning electron microscopy (SEM) for better clay characterization and understanding of their effect on pavement performance in tropical climates. In summary, sustainable pavement in tropical Basement Complex areas requires integrating geological, geotechnical, mineralogical, and hydrological factors. This multidisciplinary approach can improve durability, reduce maintenance costs, and enhance long-term road performance in Nigeria and similar regions.

REFERENCES

Abam et al., (2005). Influence of Geology on Pavement Performance: A Case Study of Shagamu-Benin City Road, Southwestern Nigeria. Global *Journal of Geological Sciences*, vol. 3(1) https://doi.org/10.4314/gjgs.v3i1.18706

Ademila, O. (2021). Combined geophysical and geotechnical investigation of pavement failure for sustainable construction of Owo–Ikare highway, southwestern Nigeria. *NRIAG Journal of Astronomy and Geophysics*, vol. 10(1), p.183–201.

Adeyemi, G.O. (1995). The influence of parent rock factor on some engineering index properties of three residual lateritic soils in southwestern Nigeria. *Bulletin of the International Association of Engineering Geology.* vol. 52, p.3 - 8

Aghamelu, O.P. and Okogbue, C.O. (2011). Geotechnical assessment of road failures in the Abakaliki area, southeastern Nigeria. *International Journal of Civil and Environmental Engineering*, vol. 11(2), p.12–24.

Ajiboye, O.B., Oluwasegunfunmi, V. and Olododo, A. (2023). Engineering geological properties of subgrade soils to premature failure of major highways in southwestern Nigeria: A case study of Akure–IkereEkiti highway. *Journal of Physical Science and Application*, vol. 13(1). https://doi.org/10.17265/2159-5348/2023.01.004

Bowles, J.E. (1981). *Engineering Properties of Soils and Their Measurement*. 4th ed. New York: McGraw-Hill, p. 134-140

BSI (1990). *BS 1377: Methods of Test for Soils for Civil Engineering Purposes*. London: *British Standards Institution*.

Casagrande, A. (1948). Classification and identification of soils. *Transactions of the American Society of Civil Engineers, vol. 113(1),* p.901-930.

Daramola, S.O., Malomo, S. and Asiwaju-Bello, Y.A. (2018). Premature failure of a major highway in southwestern Nigeria: The case of Ipele–Isua highway. *International Journal of Geo-Engineering*, vol. 9, p.28- 32.

Das, B.M. (2018). *Principles of Geotechnical Engineering*. *Stamford, CT: Cengage Learning*, 683p

Emmanuel, U.O., Igwe, O. and Ukah, B.U. (2021). An investigation into the cause of road failure along the Sagamu–Papalanto highway, southwestern Nigeria. *Geoenvironmental Disasters*, vol. 8, p.3-10.

Federal Ministry of Works and Housing (FMWH) (2016). *General Specifications for Roads and Bridges, vol. II*: *Federal Ministry of Works and Housing*, *Abuja.*

Mesida, E.A. (1987). The relationship between geology and lateritic engineering soils in the humid tropical environment of Nigeria. *Engineering Geology*, vol. 42, p.65–91.

Obasaju, D.O., Oloruntola, M.O., Oladele, S., Ojekunle, V. and Baiyegunhi, C. (2025). Geophysical, geotechnical, and mineralogical characterization of subgrades: Implication for pavement stability and machine learning prediction. *Discover Applied Sciences*, vol.

7(10), p.1170: https://doi.org/10.1007/s42452-025-07415-1

Ogunribido, T.H.T. and Fadairo, T.E. (2020). Geotechnical investigation of road pavement failure along Arigidi–OkeAgbeAkoko, southwestern Nigeria. *International Journal of Physical Research*, vol. 8(2), p.35–39.

Oyedele, A.A., Adesola, B.M., Akinwamide, J.O., et al. (2023). Integration of VLF-EM and VES data for pavement failure investigation in a typical basement complex terrain of southwestern Nigeria. *Materials and Geoenvironment*, vol. 69(2), p.105–117.

Skempton, A.W. (1953). The colloidal activity of clays. *Proceedings of the Third International Conference on Soil Mechanics and Foundation Engineering*, vol. 1, p.57–61.

Ukor, K.P., Igwe, O., Onwuka, O.S., Nzereogu, S.K., Eze, K.N. and Echezona, P.E. (2023). Integrated geotechnical and mineralogical evaluation of the subgrade of some failed pavements along the Enugu–Onitsha expressway, southeastern Nigeria. *Scientific Reports*, vol. 13, p.14001. https://doi.org/10.1038/s41598-023-41289-w

World Topographic Map. (https://en-bw.topographic-map.com/map-v5kl51/Ekiti-State/?center=7.49864%2C5.1931&zoom=12&base=2)