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Geomorphological and Geotechnical Characterizations of Residual Soils along Ado-Akure F209 Highway, Southwestern Nigeria

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ABSTRACT

This investigation evaluates the engineering behavior and near-surface ground conditions of residual soils developed along the Ado–Akure segment of the F209 highway in Ondo State, southwestern Nigeria, with the objective of producing dependable geotechnical data for informed pavement design and performance assessment. Both field and laboratory analyses were conducted. Field investigations comprised detailed geological mapping and in-situ strength evaluation using the dynamic cone penetrometer (DCP). The predominant bedrock comprises Charnockite (Ch) and Granites, including intermediate and large crystals feature texture. This implies complex and discrete stages of crystallizations. Two distinct geomorphological terrain s were observed. Soils derived from Charnockite exhibited the highest fine and clay contents, as well as water content (WC), subsequent by OGe and OGp-derived soils. Based on plasticity classification, Ch-, OG, and OGp-formed soils were categorized as CH, CI, and CL, respectively. Laboratory and field assessments indicated that OGp-derived soils possess less best water content (BWT) also peak maximum dry density (MDD), highlighting their superior densification potential, whereas Ch-derived soils showed the opposite trend, reflecting suboptimal compaction characteristics. DCP outcome showed that soil formed from Charnockite exhibited the most penetration index, indicating lower resistance and shear strength, while OGp-derived soils recorded lowest penetration index sounding data. Statistical correlation confirmed a strong and significance consequential association of laboratory (CBR) and field CBR measurements. Overall, granite-derived soils displayed more favorable engineering properties compared to Charnockite-derived soils, attributable to variations in textural, mineralogical, and geotechnical characteristics.

Keywords: *Geotechnical properties, Soil texture, Penetration index, Subgrade conditions.*

1.0 Introduction

The performance, durability, and structural integrity of road infrastructure are strongly controlled by geological, geotechnical, and geomorphological conditions. Among these, subgrade soils play a critical role as the foundational support layer of pavement systems, governing load transfer, deformation behavior, and long-term serviceability. Inadequate or erroneous characterization of subgrade materials often results in inappropriate design assumptions, leading to premature pavement distress and failure.

The subgrade materials investigated in this study are predominantly residual lateritic soils formed through prolonged chemical weathering of basement rocks. Owing to spatial variability in parent lithology, climatic regime, geomorphic setting, and mineral composition, lateritic soils exhibit pronounced heterogeneity in their geotechnical behavior. Their structured fabric and degree of weathering exert significant influence on pavement response under traffic loading.

Persistent pavement failures in many developing regions have been widely linked to limited understanding of subgrade properties and non-compliance with established design specifications. Subgrades exhibiting high compressibility, low strength, or unfavorable moisture–density relationships have been identified as major contributors to structural deterioration.

Consequently, comprehensive and reliable subgrade characterization remains a fundamental requirement in pavement engineering practice. The integration of laboratory testing with in-situ evaluation techniques has been shown to significantly improve the reliability and representativeness of subgrade assessments.

Flexible pavements rely on accurate determination of subgrade parameters, typically using the California Bearing Ratio (CBR) at the soil's lowest moisture content. However, in-situ soaked CBR testing is often constrained by practical challenges arising from variations in moisture condition, particle-size distribution, density, and soil type. To overcome these limitations, in-situ method for assessing pavement and subgrade strength was reported by Indian Roads Congress (IRC: SP 72, 2015). DCPT offers advantages over other in-situ methods, including Sand Cone, Nuclear Density Gauge, Pocket Penetrometer, Falling Weight Deflectometer, and Lightweight Deflectometer, particularly in evaluating deeper soil layers and a broader range of soil types. Accordingly, this study integrates standard laboratory tests with DCP field assessments to capture a comprehensive understanding of subgrade soils, ground conditions, and soil-structure behavior.

2.0 Location and Geology of the Study Area

The study covers selected sections of the federal highway connecting Ondo and Ekiti states in southwestern Nigeria see figure 1.

The terrain along the route is characterized by undulating topography, with relatively steep slopes toward the southwestern segment and flatter to gently rolling ground in the northern portion. Field observations indicate widespread pavement distress manifested as surface cracking, rutting, incisions, potholes, and localized structural failures.

Geologically, the highway transects the Precambrian Basement Complex, a suite of crystalline rocks that display considerable variability in texture, structure, mineral composition, and fabric as a result of multiple tectono-metamorphic events. The dominant lithological units encountered along the alignment include Charnockite and granite. These rock types exert a strong control on the nature, distribution, and engineering behavior of the overlying residual soils.

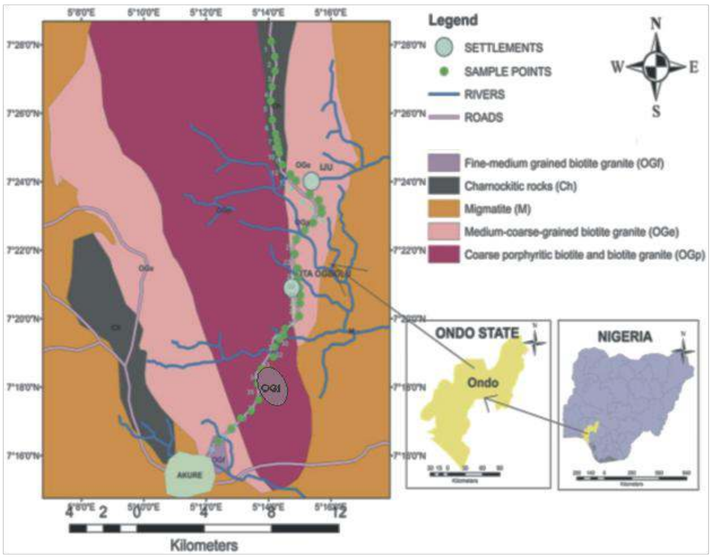

Figure 1: lithological map showing the rock types within the locality (after [33], modified)
showing the dominant basement lithologies and their spatial relationships along the Ado–Akure corridor

3.0 Materials and Methods

Geological Mapping

A longitudinal road-traverse methodology systematically catalogued lithological units along the 20-km study corridor, with GPS waypoints logged at 100-m intervals to generate a high-resolution geomorphological base map.

In-Situ Geotechnical Testing

Field assessments occurred at 500-m chainage intervals across 40 stations, employing core cutter density determinations and dynamic cone penetrometer (DCP) profiling per ASTM D6951 and IS 2720 protocols. Sampling targeted 450 mm, 650 mm, and 900 mm horizons along shoulders (2 m offset from pavement edge) to quantify moisture-depth gradients and shear stratigraphy. Penetration resistance indices (PI) yielded field CBR surrogates via UK DCP version 3.1 correlations, while disturbed aliquots underwent BS 1377 laboratory scrutiny for Atterberg limits, Proctor compaction, and sieve-hydrometer grain size distribution.

3.1. Geological Mapping

A systematic road-traversing approach was employed to identify and document the various lithologies along the study corridor. Geographical coordinates were recorded at regular intervals to facilitate the construction of a detailed geomorphological map, capturing the terrain's spatial variation.

3.2. In-Situ Geotechnical Investigation

Field investigations were conducted at 500-meter intervals using the core cutter and dynamic cone penetrometer (DCP), in strict accordance with the relevant international standard for shallow foundation. Tests were performed at the route's edge, approximately (2m) meters beyond the route edge, at 40 predetermined stations. Disturbed representation materials were extracted at horizons 450 mm, 650 mm, and 900 mm to assess variations in moisture content and their effects on soil strength throughout the profile. Distinct strength layers were identified, and California Bearing Ratio (CBR) data were appraised using the penetration index (PI) derived. Disturbed samples were subsequently analyzed in the laboratory for compaction characteristics, consistency limits, and particle size distribution in accordance with BS 1377 procedures.

A systematic road-traversing approach was employed to identify and document the various lithologies along the study corridor. Geographical coordinates were recorded at regular intervals to facilitate the construction of a detailed geomorphological map, capturing the terrain's spatial variation.

4.0 Results and Discussion

4.1. Lithology and Field Relationships

Table 1 summarizes lithologic mineralogical constituent, while petrographic reveal detailed mineral distribution.
Charnockitic rocks (Ch) are characterized by high concentrations of feldspar and pyroxene, with comparatively low quartz content, corroborating findings by [33] and [27].

Mineralogical Profiles

Charnockite (Ch) features elevated plagioclase (34%) and pyroxene (11%), subdued quartz (17%), and moderate microcline (20%), consistent with orthopyroxene-bearing charnockitic paragenesis. Medium-to-coarse-grained granite (OGe) balances quartz (28%), microcline (30%), and plagioclase (20%), augmented by muscovite (6%); porphyritic granite (OGp) mirrors this with minor hornblende variance (4%). Fine-grained granite (OGf) parallels OGp/OGe but lacks muscovite, emphasizing biotite-hornblende stability.

Field and Structural Relations

Charnockite manifests as massive, unfoliated low-relief outcrops or boulders with cross-cutting margins, evincing magmatic emplacement. Granites prevail as inselbergs or domical forms, reflecting protracted exhumation. These contrasts underpin Pan-African charnockite-granite suites across southwestern Nigeria, where Ch signals hypersthene dehydration amid tonalitic anatexis.

Table 1. Modal compositions

Parent Rock/ Minerals	OGe (3)	Ch (3)	OGp (3)	OGf (3)
Quartz (**Q**)	28	17	30	28
Microcline (**Mc**)	30	20	27	22
Plagioclase feldspar (**Pf**)	20	34	24	21
Biotite (**B**)	8	6	7	6
Hornblende (**H**)	5	7	4	7
Muscovite (**Ms**)	6	5	6	
Pyroxene (**P**)	-	11		

Number in brackets = number of analyses.

4.2. Topography

The Topography of the study area is illustrated in Figure 2, revealing two distinct landscape types. The southwestern portion exhibits an inselberg-dominated terrain, while the northeastern section is characterized by nearly flat to gently undulating relief. Road segments overlying Ch, OGe, and OGp were observed at elevations ranging from 374–420 m, 349–381 m, and 333–375 m, respectively. This indicates that Charnockite-dominated areas generally occupy higher elevations with relatively level surfaces in the northeastern portion, whereas OGe and OGp sections occur at lower elevations in the southwestern areas.

Topography and drainage patterns suggest that groundwater naturally flows toward the OGe and OGp segments, whereas the relatively flat Charnockite surfaces may encourage water accumulation. Such conditions promote deeper weathering and saturation, which can reduce the bearing capacity of the overlying soils. Soils derived from Charnockite exhibit a lateritic, fine-to-medium-grained texture, with high plasticity that makes them sticky and moldable when wet. These characteristics limit permeability, impede drainage, and facilitate the accumulation of illite clay minerals, thereby diminishing shear strength. Illite deposits are typically associated with flat terrains, further contributing to the elevated plasticity of Charnockite-derived soils.

In contrast, soils originating from OGp and OGe granites display a medium-to-coarse-grained texture, derived from undigested feldspar grains and free quartz. Coupled with the undulating terrain, these textural characteristics promote enhanced drainage and increased susceptibility to erosional processes. The observed geomorphic differences reflect the geological emplacement of the bedrock, suggesting that OGp and OGe areas are more extensively lateralized and better drained than Charnockite zones. Consequently, soils from granite-derived segments are likely to exhibit lower plasticity and improved engineering performance relative to those derived from Charnockite.

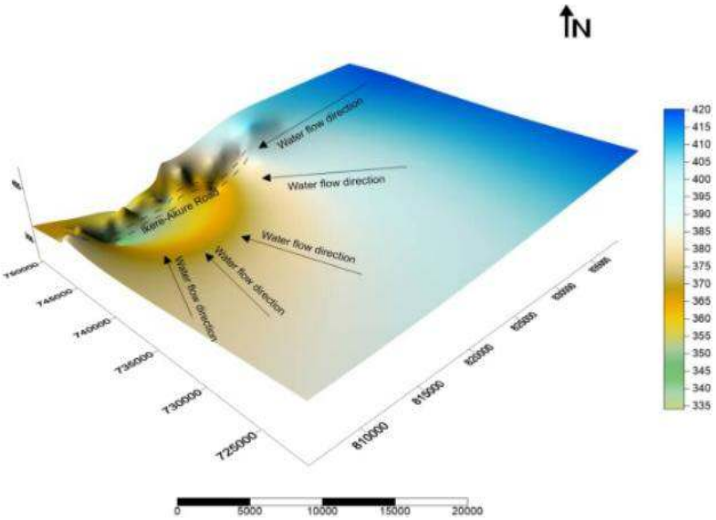

Figure 2. land formed map

4.3. Moisture Content (MC)

Natural moisture content (NMC) profiles across soil profiles reveal pronounced lithological distinctions Table 2, with Charnockite-derived soils averaging 18–27% (range: 16.3–26.7%), porphyritic granite (OGp) materials 8–16% (range: 7.6–15.7%), and medium-to-coarse-grained granite (OGe) soils 8–18% (range: 8.1–18.3%).

Hydrogeotechnical Controls

Charnockite-derived soils consistently displayed the highest NMC values throughout the profiles, reflecting a greater hydrophilic potential relative to granite-derived soils. In contrast, soils from OGe and OGp granites recorded comparatively lower NMC values, indicating reduced water retention capacity. The elevated hydrophilicity of Charnockite soils has been linked to presence of as vermiculite with higher proportion of fine particles, resulting from the elevated feldspar content in the parent rock [23].

Pavement Design Implications

Such hydrophilic disparities predispose Charnockite subgrades to desiccation delays and shear weakening during monsoonal saturation, amplifying rutting susceptibility relative to the drier, stable OGp profiles. Lithology-specific drainage augmentation emerges essential for equitable pavement longevity across the heterogeneous basement terrain.

Table 2: Summary of Water Content

SN	Depth			Average	Rock Type
	45mm	65mm	90mm		
1	20	28	32	26.66	Ch
2	25	23	24	24.00	Ch
3	21	21.3	22	21.43	Ch
4	17.5	22	21	20.17	Ch
5	18	21.3	22.5	20.60	Ch
6	14	16	19	16.31	Ch
7	16.19	17.49	17.06	16.91	Ch
8	16.32	17.48	17.62	17.14	Ch
9	14.9	15.82	24.99	18.57	Ch
10	27.69	21.65	17.31	22.15	Ch
11	14	18.98	20.04	17.67	Ch
12	7.62	8.95	8.3	8.29	OGp
13	15.7	15.61	15.70	15.67	OGp
14	12.74	11.72	12.75	12.40	OGp
15	10.8	10.07	12.08	11.02	OGp
16	9.7	8	7.9	8.53	OGp
17	6.88	11.9	13.88	10.89	OGp
18	4	6.97	11.58	7.52	OGp
19	8.5	9.7	9.7	9.30	OGp
20	14.75	14	14.70	14.48	OGp
21	14.27	14.69	14.00	14.42	OGp
22	7.89	8	8.4	8.10	OGp
23	9.35	11.7	11.7	10.92	OGp
24	9	9	7.79	8.60	OGe
25	9	11	16.41	12.14	OGe
26	6.83	6.45	10.98	8.09	OGe
27	11.04	11.27	11.04	11.08	OGe
28	5.69	8.18	12.7	10.19	OGe
29	6.9	11.3	12.7	10.30	OGe
30	15.6	16.06	16.2	15.95	OGe
31	11.7	13.87	14.1	13.22	OGe
32	7.14	10.19	12.95	10.09	OGe
33	14	15.06	16.19	15.08	OGe
34	17	18	20	18.30	OGe
35	15.3	17.76	18.58	17.21	OGe
36	15.27	14.89	15.04	15.07	OGe
37	15.8	16.96	15.47	16.41	OGe
38	20	18	18.36	19.45	OGf
39	16.5	17	18.25	17.42	OGf
40	21	25	25	23.67	OGf

4.4. Fractional Distribution of Grain Sizes

Table 3 summarizes particle size distribution (PSD) results, which corroborate patterns identified in natural moisture content evaluations. Charnockite-derived (Ch) soils register the highest fines and clay contents, followed by medium-to-coarse-grained granite-derived (OGe) soils and porphyritic granite-derived (OGp) soils in descending order. By contrast, OGp materials exhibit peak sand fractions, with OGe and Ch soils displaying successively reduced sand proportions.

Lithological Influences

These disparities stem from inherent mineralogical and textural attributes of parent materials.

Quartz-rich OGp granites, with subdued feldspar weathering, yield lower fines and enhanced coarse fractions; quartz durability sustains particle integrity across pedogenic regimes, consistent with observations by [27]. Conversely, Charnockite and OGe-derived soils suffer elevated fines dominance and grading deficiencies, compromising geotechnical efficacy through sparse coarse skeletal support.

Engineering Ramifications

Charnockite soils manifest excessive fines (>57% average), precipitating A-7-6 AASHTO ratings and inherent instability, whereas OGp's coarser matrix bolsters subgrade resilience. Such gradational contrasts dictate selective sourcing imperatives for pavement longevity in basement terrains. 0

Table 3: Summary of fractional distribution

Property SN	Ch 11	OGp 12	OGe 14
Gravel (%)	Range: 4.0–32.7 Avg: 11.6	16.9–50.2 31.8	2.4–37.3 14.4
Sand (%)	Range: 16.5–41.5 Avg: 30.2	23.1–52.4 34.6	15.0–52.5 34.3
Silt (%)	Range: 20.6–60.6 Avg: 37.4	11.8–43.4 25.1	22.3–60.6 40.4
Clay (%)	Range: 10.5–32.4 Avg: 20.0	1.3–17.6 Avg: 8.5	0.4–26.1 10.9
Fines (%)	Range: 39.6–73.8 Avg: 57.3	19.0–45.0 33.6	35.0–68.0 51.4
Grading	Mostly well/gap graded	Mostly well/gap graded	Predominantly gap graded

Ch soils consistently show poor stability due to excessive fines (>57% avg), correlating with A-7-6 AASHTO classification and unstable remarks, while OGp materials' coarser fractions support superior subgrade performance.

4.5. Plasticity Characteristics

Figure 3 illustrates the plasticity characteristics of subgrade soils according to AASHTO classification criteria. Charnockite-derived (Ch) and medium-to-coarse-grained granite-derived (OGe) soils are categorized as A-7-6, signifying inferior subgrade quality, whereas porphyritic granite-derived (OGp) soils are designated A-6, indicative of moderate suitability. The suboptimal engineering properties of Ch- and OGe-derived soils are likely contributors to the recurrent pavement failures along this roadway [4, 28].

Plasticity and Compressibility Variation

OGp soils manifest the least plasticity and compressibility, OGe soils exhibit intermediate characteristics, and Ch soils display the greatest values in both attributes. These distinctions correspond directly to prior findings on particle size distribution and natural moisture content, underscoring fines content and mineralogical composition as primary controls on deformability.

Subgrade Performance Implications

Charnockite laterites, dominated by clay fractions, demonstrate elevated plasticity relative to kaolinite-rich OGp soils with constrained flexibility. During rainy periods, high plasticity coupled with sustained in-situ moisture in Ch soils delays desiccation, further diminishing shear strength and amplifying pavement distress susceptibility along the corridor.

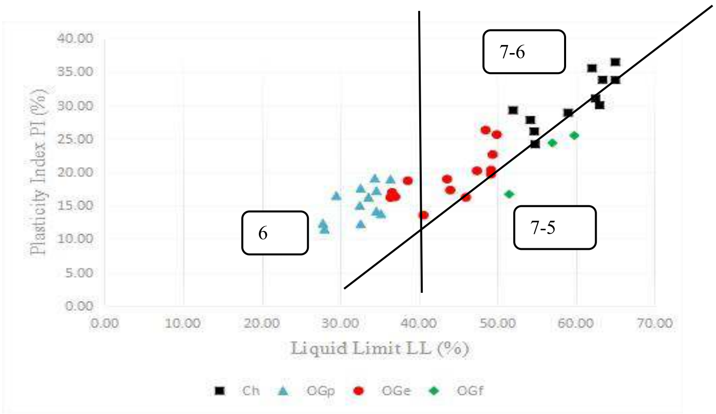

Figure 3. Plot of PI against LL

4.6. Moisture–Density Relationship

Table 4 illustrates the moisture-density relationships characterizing the compaction properties of lateritic subgrade soils collected along the study corridor. Porphyritic granite-derived (OGp) soils demonstrated the highest maximum dry density (MDD) and lowest optimum moisture content (OMC), contrasting sharply with Charnockite-derived (Ch) soils, which exhibited the lowest MDD and highest OMC; medium-to-coarse-grained granite-derived (OGe) soils displayed intermediate values.Mean MDD values reached 2,124 kg/m^3 for OGp soils, 1,832 kg/m^3 for Ch soils, and 1,974 kg/m^3 for OGe soils, with corresponding OMC values of approximately 13%, 19%, and 14%, respectively. The superior densification of coarser, better-graded OGp soils versus fine-grained, clay-rich Ch soils aligns with established Proctor compaction principles, where particle size distribution and clay mineralogy govern achievable dry density and lubrication effects at OMC. Ch-derived soils' poor compaction response heightens infiltration risks, undermining subgrade shear strength and stability. Per standard foundation grading criteria, laboratory MDD classifies Ch soils as fair, OGp as excellent, and OGe as good; moreover, Ch soils' OMC marginally exceeds the 18% subgrade threshold recommended by international guidelines (e.g., FMWH and AASHTO), while OGp and OGe comply fully, corroborated by Fatoyinbo et al. (2024), who documented analogous MDD superiority (up to 2053 kg/m^3) in porphyritic granite soils versus Charnockite (down to 1430 kg/m^3) across multiple compaction cycles in Akure, Nigeria. These lithological disparities necessitate selective soil sourcing and stabilization for Ch materials to avert premature pavement distress in basement complex terrains.

4.7. Field Strength Parameters

Field Density

Table 4 delineates field compaction outcomes for lateritic subgrade soils along the study corridor, revealing pronounced lithological influences on densification efficacy. Undisturbed OGp-derived materials demonstrated superior densification, attaining the highest maximum dry density (MDD) concurrent with the lowest optimum moisture content (OMC). This profile signifies exceptional subgrade suitability under AASHTO and FMWH specifications, as diminished OMC simplifies field moisture regulation relative to higher-plasticity lithologies (AASHTO, 2020; FMWH, 1997). In contrast, Charnockite (Ch)-derived soils manifested inferior MDD and elevated OMC, mirroring laboratory Proctor metrics and affirming the primacy of texture and clay mineralogy in governing compaction response (Bowles, 1996). The subdued MDD and protracted OMC of Ch soils predispose subgrades to heightened infiltration, eroding structural resilience as elaborated in Section 4.6.

Empirical field moisture contents for Ch materials remained subthreshold at <18% OMC, yet attendant California Bearing Ratio (CBR) and penetration index (PI) deficits corroborate compromised foundation capacity (Das, 2019). These disparities—attributable to kaolinite prevalence in granitic laterites versus quartz-clay aggregates in Charnockites—underscore the imperative for lithology-specific stabilization to forestall pavement distress. Field compaction results are presented in Table 4. The findings indicate that OGp-unconsolidation materials exhibit optimum densification potential, Soils from OGp exhibit the greatest maximum dry density (MDD) alongside the smallest optimum moisture content (OMC). This compaction profile indicates superior subgrade quality for OGp-derived materials under AASHTO and FMWH guidelines, as lower OMC facilitates easier field moisture control during construction compared to higher-plasticity lithologies. Recent Nigerian studies confirm that granite-derived laterites with dominant kaolinite achieve peak MDD values around 1.8-2.0 Mg/m^3 at OMC below 12%, enhancing pavement stability. whereas Charnockite (Ch)-derived soils display the poorest compaction characteristics, with the lowest MDD and highest OMC. These field observations are consistent with the laboratory-determined MDD and OMC values (Table 4), underscoring the influence of soil texture and clay mineralogy on compaction behavior. The lower MDD and elevated OMC of Ch soils may facilitate excessive water infiltration into the subgrade, compromising its structural integrity, as discussed in Section 4.6. Variations in compaction performance among the soils are primarily attributed to differences in clay mineral content and particle size distribution. Notably, the field moisture content (MC) of Ch-derived soils remains below the recommended 18% OMC limit for subgrade soils [18]. The field CBR and penetration index (PI) results further support the assessment of foundation characteristics, reinforcing the conclusion that inadequate densification and subgrade strength in Ch-derived soils can contribute to pavement deterioration and discomfort.

Field Dynamic Cone Penetration Index (FDCPI)

Table 5 summarizes in-situ DCP sounding results, highlighting penetration index data across study area. Unconsolidation materials form out in-situ weathering of Charnockite-derived soils exhibit the highest plasticity index (PI) values among the tested lithologies, followed closely by those derived from OGe granite, while soils originating from OGp granite record the lowest PI values. This trend aligns with recent geotechnical investigations in southwestern Nigeria, where Charnockite parent rocks produce more plastic clays due to higher-activity minerals like vermiculite and illite, contrasting with the low-plasticity kaolinite-dominant soils from granites.

These PI differences have critical implications for subgrade suitability under standards like AASHTO, rendering Charnockite-derived soils less ideal without stabilization, while OGp-derived options show superior performance. These trends are in agreement with both field and laboratory MDD/OMC results.

Higher PI values in Ch soils indicate lower shear strength and reduced load-bearing capacity, whereas lower PI values in OGp soils correspond to greater in-situ strength and stiffness. Variations in PI are influenced by soil texture, clay mineral type, particle size distribution, and moisture content, all of which are controlled by the parent rock.

Minor fluctuations in PI with depth suggest a decline in soil strength through the profile, potentially explaining recurrent pavement failures along the roadway.

The mechanical response observed during DCP testing reflects the in-situ shear strength of soils, aligning with laboratory measurements for similar materials and confirming observations by [20]. The heterogeneous nature of the lateritic soils is evident in DCP data, which demonstrate that subgrade characteristics—including density, gradation, moisture content, and soil type—significantly affect penetration resistance. In particular, fine-grained, clay-rich Ch soils with higher moisture content exhibit best in-situ DCP sounding data, indicating low shear resistances, whereas larger grain, properly fractions which give rise to proper interlocking materials of OGp with less water affinity data display less in-situ DCP sounding data, reflecting superior stiffness and structural competence.

These findings correspond with unconsolidation materials fitness groupings obtained from compressibility indices [13]. Consistent with previous studies [25, 32], subgrade stiffness and competence play a critical role in pavement performance, and the observed failures in the study area can be attributed to the low stiffness and strength characteristics of the Charnockite-derived soils.

Table 5: Field Dynamic Cone sounding (PI) & Field Density

	P I (mm/blow)			Profile			
SN	45mm	65mm	90mm	Ave	MC	FDD (kg/m^3)	Rock Types
1	18	28	34	27	24.00	1400	Ch
2	22	18	20	20	24	1339	Ch
3	12	12	14	18	21.3	1500	Ch
4	8	15	14	12	20	1749	Ch
5	9	21	24	18	23.7	1681	Ch
6	9	16	17	14	18.9	1751	Ch
7	12	15	14	14	17.56	1609	Ch
8	22	23	24	23	18.78	1587	Ch
9	17	21	30	23	15.82	1647	Ch
10	38	27	19	28	17.65	1718	Ch
11	19	20	21	20	14.98	1653	Ch
12	5	6	5	5	8.3	1925	OGp
13	17	17	16	17	15.37	1883	OGp
14	7	6	7	7	12.75	1765	OGp
15	7	6	8	7	10.8	1922	OGp
16	8	7	7	7	7.9	1871	OGp
17	5	7	10	7	13.88	1770	OGp
18	4	5	7	5	11.58	1913	OGp
19	5	5	5	5	9.7	1898	OGp
20	16	14	16	15	14.7	1763	OGp
21	15	15	14	15	14.9	1921	OGp
22	5	5	6	5	8	1991	OGp
23	7	8	8	8	11.7	1851	OGp
24	9	9	6	8	7.79	1830	OGe
25	7	8	19	11	16.41	1637	OGe
26	6	6	17	10	13.98	1736	OGe
27	7	7	7	7	11.5	1709	OGe
28	6	5	12	8	11.18	1677	OGe
29	5	8	10	8	12.7	1752	OGe
30	14	16	17	15	16.2	1618	OGe
31	12	16	16	15	14.1	1729	OGe
32	4	7	10	7	12.95	1811	OGe
33	14	17	18	16	14.19	1505	OGe
34	18	24	26	24	15	1810	OGe
35	13	20	21	18	18.79	1695	OGe
36	13	11	12	12	15.04	1604	OGe
37	28	35	27	30	16.47	1806	OGe
38	12	10	11	11	20.36	1584	OGf
39	9	10	14	11	17.75	1648	OGf
40	27	37	37	34	25	1510	OGf

Summary of consistent connections between field and laboratory results obtained were revealed see (Figs. 4a & 4b). According to statistical analysis, high coefficients determination (R^2 = 0.8721), there is a significant link between the FDCPI values and the LCBR of the soils under investigation. The plot of CBR (laboratory verse Field predicted FCBR data), revealed statistically, strong pact for the twins. This is was exhibited in the direct proportion variation as shown see (Fig. 4b). Henceforth, increases in one variable independent result also in consequential effect in the dependent (Fig. 4b). Meanwhile, the obtained outcome statistically signified sound, strong and reliable data that is suitable for accurate CBR prediction values that is generally adequate.

The corresponding connections between field and laboratory results are shown in Figures 4a and 4b. According to the high coefficients of determination ($R^2 = 0.8721$), there is a significant link between the FDCPI values and the LCBR of the soils under investigation. While the plotting (Figure 4b), reveal strong correlation between measured and predicted CBR values which is generally adequate and reliable.

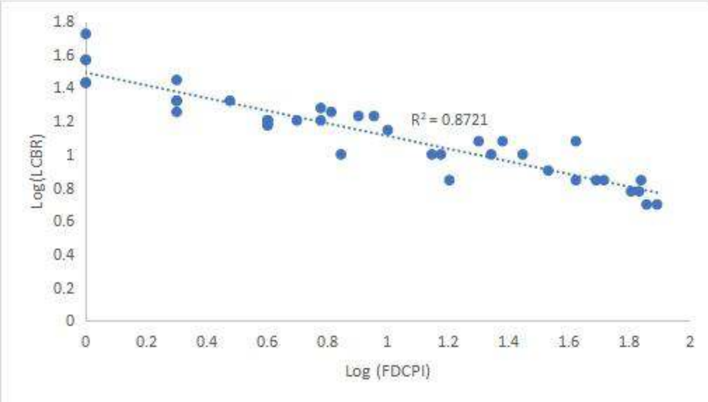

Fig 4a: Chart showing plot of logs data

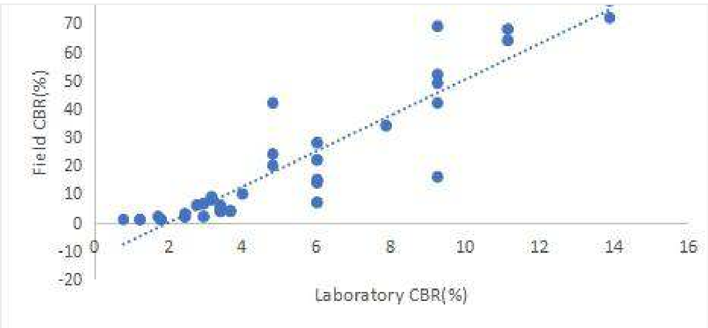

Figure 4b: Showing plot of CBRs data

5. Conclusion

The subgrade soils along the Akure–Ado highway, derived from charnockite (Ch) and granite (OGp, OGe) parent rocks, show statistically significant geotechnical variations that align with local geology and terrain.

Geological and Terrain Influence

Charnockite areas feature nearly flat terrain, while granite zones exhibit undulating surfaces. AASHTO classification rates these chemically weathered, unconsolidated materials as poor to fair pavement foundations, primarily high-plasticity clayey soils.

CBR and Strength Performance

Field and lab CBR values follow similar trends, with lab results slightly higher. OGp-derived soils provide the best strength data, yet 75% of field CBRs and 63% of lab CBRs fall below minimum specs. This matches compaction, grading, and plasticity patterns: coarser, well-graded OGp soils compact better than finer, poorly graded, clay-rich Ch soils.

Plasticity and Failure Factors

Clay-richer soils show elevated plasticity index (PI) values, signaling lower shear strength. Field data proves more reliable than lab results, with PI variations across horizons explaining repeated pavement failures. Local lithology thus governs residual soil behavior and engineering suitability.

6. Recommendations

Highway design and construction should account for underlying geology, geomorphology, and hydrology. Lithology, mineralogy, and terrain variations must inform structural design decisions to improve subgrade performance.

In-situ geotechnical testing should be compulsory for pavement and structural designs, as laboratory tests alone may not capture the full range of ground conditions and comprehensive subgrade behavior for reliable engineering design outcomes.

Field investigations under varying climatic conditions are recommended to evaluate the impact of seasonal moisture fluctuations on soil engineering properties, particularly in lateritic and clay-rich subgrades. Differential strength characteristics within soil horizons and profiles should receive increased attention during site investigations, as variations can significantly influence subgrade performance and the risk of pavement failure.

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