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Geotechnical Characterization and Deformation Susceptibility Assessment of Lateritic Subgrade Materials along Six Road Corridors in Ondo and Edo States, Southern Nigeria

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Abstract
Residual soils formed by in-situ weathering are widely used as pavement subgrade in humid tropical regions, yet the reliability of plasticity-based classification for anticipating subgrade competence across contrasting weathering regimes remains poorly quantified outside site-specific case studies. This study examines ninety-five subgrade soil samples collected along six road corridors totalling approximately 180 km in Ondo and Edo States, southern Nigeria, forming two geographically separate corridor networks that span basement-complex (schist belt) and coastal-plain sedimentary terrains. Particle size distribution, Atterberg limits, compaction characteristics and California Bearing Ratio were determined in accordance with BS 1377:1990, using British Standard heavy compaction, and soils were classified using the AASHTO system. Liquid limit ranged from 15.2 to 65.2%, plasticity index from 7.3 to 45.1%, maximum dry density from 1.13 to 2.43 g/cm³, and four-day soaked CBR from 1 to 47%. Thirty-six samples (38%) classified as A-7-6, with a mean soaked CBR of 5.9%, and 61 of 95 samples (64%) recorded soaked CBR below the 10% benchmark adopted here for subgrade assessment. Soaked CBR differed significantly among AASHTO groups (Kruskal–Wallis $H = 23.3$, $p < 0.001$), although the ordering was partial rather than monotonic, with adjacent groups statistically indistinguishable. Plasticity index showed a stronger bivariate correlation with soaked CBR ($r = \quad 0.49$) than the clay-size fraction ($r = +0.39$), the latter being positive and sensitive to influential observations. The results indicate that plasticity indices, rather than grain-size composition alone, provide the more dependable first-order screening of subgrade risk in this terrain.

Keywords: *Lateritic soil; Subgrade strength; California Bearing Ratio; Atterberg limits; AASHTO classification; Southern Nigeria*

Introduction

Road transport carries the overwhelming majority of freight and passenger movement in many developing economies, and the condition of the road network is consequently a direct determinant of economic productivity, road safety and quality of life (Ighodaro, 2009; Rodrigue et al., 2016). In Nigeria, as in much of humid tropical Africa, South and Southeast Asia and Central America, flexible pavements are commonly founded on residual soils formed by in-situ weathering of the underlying basement or sedimentary lithology. Where these soils are fine-grained and plastic, they are prone to shrink–swell behaviour that compromises subgrade support and drives premature pavement failure (Adiat et al., 2009; Aigbedion, 2007; Momoh et al., 2008).

Subgrade competence for flexible pavement design is expressed through the California Bearing Ratio (CBR), and design codes worldwide rely on index classification systems such as AASHTO and the Unified Soil Classification System as a rapid proxy for CBR, on the assumption that particle size and plasticity indices carry sufficient predictive power without exhaustive CBR testing at every point; direct CBR determination at the sample density required for reliable design is invasive, slow and costly (Siddiqui & Osman, 2012). This assumption continues to attract active research interest: recent studies have sought robust CBR–index property correlations in tropical residual soils (Katte et al., 2019) and have combined geophysical, geotechnical and mineralogical data with machine-learning prediction of subgrade parameters (Obasaju et al., 2025), yet these efforts remain confined to individual sites rather than testing predictive reliability across contrasting weathering regimes within a single, internally consistent dataset. Most existing studies linking subgrade geotechnics to pavement performance are similarly confined to a single road, a short segment or a single lithological setting (e.g., Adeyemi & Oyeyemi, 2000, on the Lagos–Ibadan expressway; Meshida, 2006, on the Ife–Ilesha highway), leaving open the broader question of whether index-based classification remains reliable when parent lithology changes along a single route.

Parent lithology and clay mineralogy are related but distinct properties. Mineral assemblages in tropical

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residual soils depend not only on the mapped parent rock but also on weathering intensity, drainage and pedogenic history, and mineralogy was not measured directly in the present study. Where clay mineralogy is referred to below, it is therefore treated as an untested mechanism inferred from plasticity and activity indices, not as an established property of the sampled materials.

This raises a question of interest beyond the immediate study area: to what extent do standard plasticity-based classification systems retain their value for anticipating subgrade strength across contrasting weathering regimes within a single humid-tropical terrain, and is grain-size composition alone a sufficient indicator of subgrade riskρ Answering this matters for any humid-tropical setting where road networks cross lithological boundaries, since it determines whether engineers can rely on geological mapping and index testing to anticipate subgrade risk, or whether dense CBR sampling is required regardless of known lithology.

This paper addresses the question using a dataset of ninety-five samples spanning six road corridors in two geographically separate corridor networks and two contrasting geological terrains, with the specific objectives to: (i) determine the particle size distribution, Atterberg limits, compaction characteristics and CBR of subgrade soils along the six studied corridors; (ii) classify the soils using the AASHTO system and evaluate, with formal inferential tests, the relationship between classification, plasticity and measured CBR; and (iii) compare subgrade behaviour between basement-complex and coastal-plain corridors to test whether lithology alone anticipates subgrade risk.

Location of Study

Location, access and corridor networks

The study area comprises six road corridors totalling approximately 180 km, distributed between two geographically separate corridor networks (Figures 1a and 1b). The western network lies within Ondo State and comprises the Ondo–Ore (54 km) and Ore–Irele (35 km) corridors, spanning longitudes 4.825° E to 4.897° E. The eastern network lies within Edo State and comprises the Auchi–Okpella (26 km), Auchi–Igarra (32 km), Igarra–Ibillo and Ibillo–Okene corridors, spanning longitudes 6.069° E to 6.390° E. The two networks are separated by approximately 130 km of longitude and were selected to provide contrasting parent geology — coastal-plain sedimentary terrain in the west and basement-complex terrain in the east — while remaining within a single humid-tropical climatic regime, so that lithological contrast rather than climatic contrast is the principal variable distinguishing them.

All 95 sampled stations lie between latitudes 6.490° N and 7.493° N and longitudes 4.825° E and 6.390° E. The Ibillo–Okene corridor is named for the road it follows, but sampling along it terminated at 7.493° N, short of Okene itself; all sampled stations on that corridor therefore lie within Edo State, approaching but not crossing the Edo–Kogi boundary. Station coordinates were recorded with a Garmin GPS MAP 64SC and are reported in full in the accompanying dataset. Coordinates for two stations (C4 and D14) were not recovered from the field record and are omitted.

Geological setting

Climate, Relief and Drainage

The area experiences a tropical wet-and-dry climate with distinct wet and dry seasons. Indicative mean monthly temperature ranges from about 27 °C in the south to 30 °C in the north, and indicative mean annual rainfall from approximately 1,150 mm in the northern Auchi–Igarra area to 2,000 mm in the southern Ondo–Ore area.

These values are quoted from the national highway design manual (Federal Republic of Nigeria, 2013); that source does not document the underlying meteorological dataset or the averaging period, and the figures should therefore be read as indicative of the regional climatic gradient rather than as formal climatological normals.

The four eastern corridors (Auchi–Okpella, Auchi–Igarra, Igarra–Ibillo, Ibillo–Okene) traverse the basement-complex Igarra Schist Belt, comprising granite gneiss, calc-silicate gneiss, garnet-biotite schist, quartzite, banded iron formation and marble, locally intruded by granite and pegmatite (Figure 1a). Soils in this terrain are residual, derived from in-situ weathering of these lithologies. The two western corridors (Ondo–Ore, Ore–Irele) traverse coastal-plain sands and bedded sandstone (Figure 1b), with older sand ridges giving brown-to-orange sandy soils inland and lighter grey sandy soils near Irele.

Materials and Methods

Field Sampling

Ninety-five disturbed soil samples were collected by

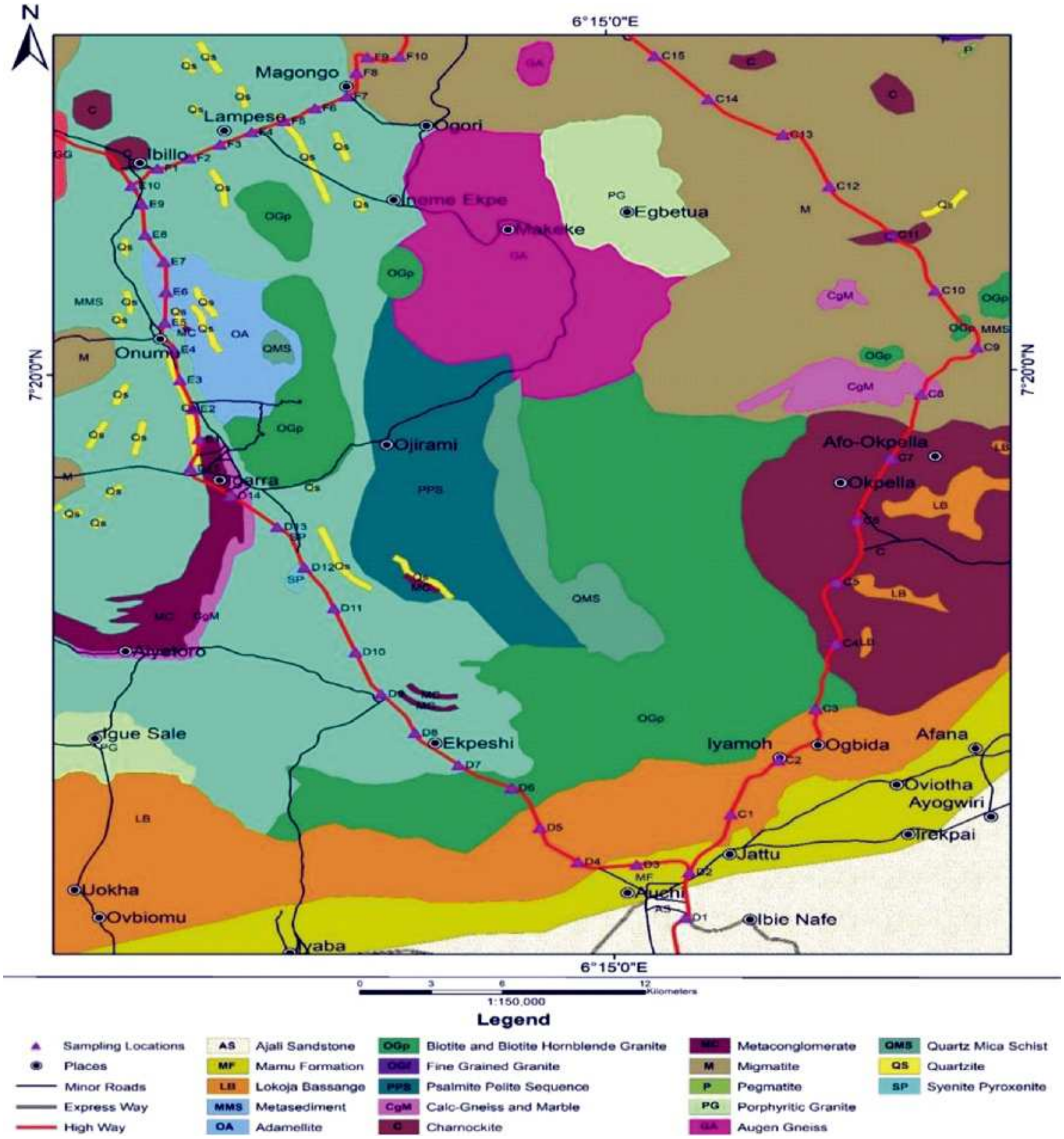

Fig. 1a: Geological map of the eastern corridor network (Auchi–Okpella, Auchi–Igarra, Igarra–Ibillo and Ibillo–Okene), basement-complex terrain, showing sample locations C1–C15, D1–D15, E1–E10 and F1–F10. Adapted from the Nigerian Geological Survey Agency (2006) geological map of Nigeria.

hand-excavated pitting at an inter-sample spacing of 1.0–3.7 km along the six road corridors, one sample per station. Sampling was carried out in a single field campaign between March and July, a window that spans the end of the dry season and the first half of the wet season in this part of southern Nigeria. Natural moisture content at the moment of sampling therefore varied through the campaign, and because corridors were worked sequentially, sampling date is not fully independent of corridor. This has limited bearing on the results reported here, because every test was performed on remoulded material compacted to a fixed standard effort (Section 3.2) and the strength measure carried through the analysis is the four-day soaked CBR, both of which impose a controlled moisture state that is independent of field moisture at sampling. It does mean that no inference about in-situ or seasonally varying subgrade strength can be drawn from this dataset, a point returned to in Section 5.4.

Samples were taken from the B horizon of the soil profile, at 1.0–1.5 m below existing ground surface (mean 1.2 m). Pits were excavated by hand using digger and shovel to a plan diameter of 0.5–1.0 m, sufficient for

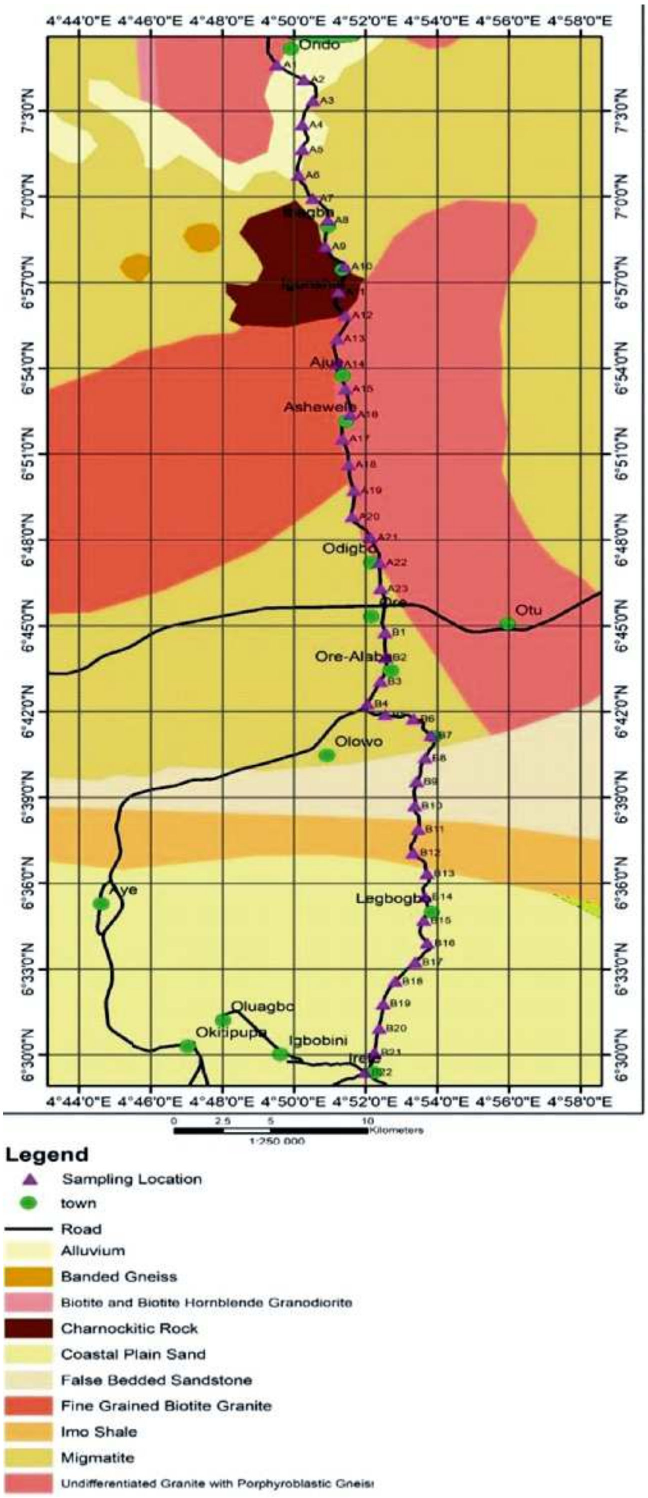

Fig. 1b: Geological map of the western corridor network (Ondo–Ore and Ore–Irele), coastal-plain terrain, showing sample locations A1–A23 and B1–B22. Adapted from the Nigerian Geological Survey Agency (2006) geological map of Nigeria.

a working face to the full sampling depth, and were sited off the running surface on undisturbed ground adjacent to the road, so that no existing pavement layers were present in the sampled profile. The B horizon was identified in the pit face by the change in colour and texture marking the base of the dark, organic-rich topsoil (A horizon) and the passage into the underlying lighter, denser and more clay-enriched material; sampling was taken from below this boundary in every pit. This sampling depth corresponds to the horizon that would form the subgrade following removal of topsoil and unsuitable material during construction.

Samples were coded by corridor: A1–A23 (Ondo–Ore, n = 23), B1–B22 (Ore–Irele, n = 22), C1–C15 (Auchi–Okpella, n = 15), D1–D15 (Auchi–Igarra, n = 15), E1–E10 (Igarra–Ibillo, n = 10) and F1–F10 (Ibillo–Okene, n = 10) (Table 1). Each sample was bagged (25 kg) and transported to the Soil Mechanics Laboratory, Department of Civil Engineering, University of Benin, for testing.

Laboratory Testing

All tests were carried out in accordance with BS 1377, Methods of Test for Soils for Civil Engineering Purposes, using the parts and clauses listed below (British Standards Institution, 1990a, 1990b, 1990c).

Moisture content was determined by the oven-drying method (BS 1377-2:1990, clause 3.2). Particle density was determined by the density-bottle method (BS 1377-2:1990, clause 8.3). Liquid limit was determined using the Casagrande apparatus and plastic limit by the thread-rolling method (BS 1377-2:1990, clause 4.3 and clause 5.3 respectively), with plasticity index taken as the difference; linear shrinkage was determined in accordance with BS 1377-2:1990, clause 6.5. Particle size distribution was determined by wet sieving for the fraction coarser than 63 μm and by hydrometer sedimentation for the finer fraction (BS 1377-2:1990, clause 9.2 and clause 9.5 respectively). Compaction characteristics, expressed as maximum dry density and optimum moisture content, were determined in accordance with BS 1377-4:1990, clause 3.6. California Bearing Ratio was determined in accordance with BS 1377-4:1990, clause 7, in both unsoaked and four-day soaked conditions.

The compaction effort applied throughout was British Standard heavy compaction (BSH), the 4.5 kg rammer method of BS 1377-4:1990, clause 3.6. A 4.5 kg rammer was dropped through 450 mm onto soil compacted in five equal layers. The moisture–density relationship was determined in the standard BS compaction mould of 1 litre nominal volume (105 mm internal diameter, 115.5 mm internal height) at 27 blows per layer, giving a nominal compactive energy of approximately 2,680 kJ/m³. CBR specimens were compacted at the same nominal energy in the 152 mm diameter CBR mould at 62 blows per layer, so that CBR was measured at the same compaction state as that at which maximum dry density and optimum moisture content were determined.

Classification, Data Screening and Statistical Analysis

Soils were classified using the AASHTO system (American Association of State Highway and Transportation Officials, 1991). The activity ratio was computed as plasticity index divided by the clay-size fraction, following Skempton (1953), who classified clays as inactive ($A < 0.75$), normal ($0.75 \leq A \leq 1.25$) or active ($A > 1.25$).

Before analysis, the particle size records were screened for internal consistency. The clay-size fraction is defined as the percentage finer than 2 µm, and the silt fraction as the percentage finer than 63–75 µm less the percentage finer than 2 µm. Records were retained for clay-based analysis only where the tabulated clay and silt fractions were reproducible from the sedimentation curve on this definition, within a tolerance of 0.6 percentage points. Forty-nine of the 95 records satisfied this criterion and form the basis of all clay and activity statistics reported below; the remaining 46 records, in which the tabulated clay and silt fractions could not be reconciled with the sedimentation data, are excluded from clay-based analysis but retained for all analyses not involving the clay fraction. All parameters other than clay fraction, silt fraction and activity ratio are reported for the full set of 95 samples. Because activity is undefined where the clay fraction is zero, and because all 49 retained records have a non-zero clay fraction, no further exclusions were required for the activity statistics.

Descriptive statistics were computed for all measured parameters, disaggregated by road corridor and by AASHTO group; group means are reported with 95% confidence intervals. Differences in soaked CBR among AASHTO groups were tested by one-way analysis of variance and by the Kruskal–Wallis test, with pairwise comparisons by the Mann–Whitney U test. Pearson correlation coefficients are reported with sample size, two-sided p-value and 95% confidence interval obtained by Fisher z-transformation; Spearman rank correlation is reported alongside where the linearity of a relationship is in question. Influential observations were identified using Cook's distance against a 4/n threshold, and correlations are reported both with and without them. Analyses were performed in Python 3 using NumPy and SciPy.

Results

Sample Distribution

The distribution of samples by corridor and dominant geological setting is given in Table 1.

Table 1: Sample distribution by road corridor, corridor network and dominant geological setting

Road Corridor	Sample Codes	n	Network	Dominant geology
Ondo–Ore	A1–A23	23	Western	Coastal-plain sand / bedded sandstone
Ore–Irele	B1–B22	22	Western	Coastal-plain sand / bedded sandstone
Auchi–Okpella	C1–C15	15	Eastern	Basement complex (Igarra Schist Belt)
Auchi–Igarra	D1–D15	15	Eastern	Basement complex (Igarra Schist Belt)
Igarra–Ibillo	E1–E10	10	Eastern	Basement complex (Igarra Schist Belt)
Ibillo–Okene	F1–F10	10	Eastern	Basement complex (Igarra Schist Belt)
Total		95		

Total n = 95.

Particle Size, Atterberg Limits, Compaction and CBR

Summary statistics for all measured parameters are given in Table 2. Liquid limit ranged from 15.2% to 65.2% (mean 36.2%), plasticity index from 7.3% to 45.1% (mean 18.7%), maximum dry density from 1.13 to 2.43 g/cm³ (mean 1.62 g/cm³) at optimum moisture contents of 7% to 26.8%. Unsoaked CBR ranged from 2% to 53% (mean 17.2%) and four-day soaked CBR from 1% to 47% (mean 11.6%).

Within the 49 records retained for clay-based analysis, the clay-size fraction ranged from 4.5% to 71.2% (mean 14.3%) and the activity ratio from 0.18 to 4.01 (mean 2.07, SD 0.94). On Skempton's (1953) classification, 38 of these 49 samples (78%) plot as active, 5 (10%) as normal and 6 (12%) as inactive. These proportions apply to the screened subset only and should not be read as proportions of the full 95-sample dataset.

Table 2: Summary statistics of geotechnical parameters

Parameter	*n*	*Min*	*Max*	*Mean*	*SD*
Gravel (%)	95	0.0	82.4	13.8	19.2
Sand (%)	95	0.0	91.7	43.1	19.9
Silt (%)	49	0.0	63.6	29.1	19.1
Clay, % < 2 μm	49	4.5	71.2	14.3	15.5
Liquid limit (%)	95	15.2	65.2	36.2	11.6
Plastic limit (%)	95	2.3	32.1	17.4	6.2
Plasticity index (%)	95	7.3	45.1	18.7	8.8
Activity ratio	49	0.18	4.01	2.07	0.94
Max. dry density (g/cm³)	95	1.13	2.43	1.62	0.26
Optimum moisture content (%)	95	7.0	26.8	16.8	3.3
Unsoaked CBR (%)	95	2.0	53.0	17.2	10.4
Soaked CBR (%)	**95**	**1.0**	**47.0**	**11.6**	**10.9**

Clay fraction, silt fraction and activity ratio are reported for the 49 records that satisfied the particle-size consistency screen described in Section 3.3; all other parameters are reported for the full 95 samples.

AASHTO Classification and CBR

The 95 samples distributed across five AASHTO groups (Table 3): A-7-6 (36 samples, 38%), A-6 (31, 33%), A-2-6 (18, 19%), A-4 (8, 8%) and A-2-4 (2, 2%). Sixty-one of the 95 samples (64%) recorded four-day soaked CBR below 10%, the benchmark adopted here for subgrade assessment (Section 4.4); within the A-7-6 group, 32 of 36 samples (89%) fell below this value.

Soaked CBR differed significantly among the five groups (one-way ANOVA F = 7.332, $p < 0.001$; Kruskal–Wallis H = 23.264, $p < 0.001$). The ordering of group means was, however, partial rather than monotonic. Mean soaked CBR for A-4 (22.4%) marginally exceeded that for A-2-4 (22%), and mean soaked CBR for A-6 (15.2%) exceeded that for A-2-6 (10.7%). Neither reversal was statistically significant: A-2-4 versus A-4 gave p = 0.89, and A-2-6 versus A-6 gave p = 0.60 (Mann–Whitney U, two-sided). The separations that were significant were A-4 versus A-2-6 (p = 0.021) and A-6 versus A-7-6 ($p < 0.001$). Group confidence intervals overlap substantially (Table 3, Figure 2c), and the A-2-4 group contains only two samples, so its mean cannot support any ordering claim.

Plasticity index correlated negatively with soaked CBR (r = −0.491, 95% CI [−0.63, −0.321], $p < 0.001$, n = 95); liquid limit correlated more strongly still (r = −0.607, 95% CI [−0.72, −0.462], $p < 0.001$, n = 95). Within the screened subset, the clay-size fraction correlated positively with soaked CBR (r = +0.392, 95% CI [0.125, 0.607], p = 0.005, n = 49). This positive sign is contrary to the expectation that greater clay content accompanies lower strength, and is examined in Section 5.2. Five observations (C2, E3, F4, F5, F6) exceeded the 4/n Cook's distance threshold; excluding them, the correlation was not significant (r = +0.055, p = 0.72, n = 44). The rank correlation over the full screened subset remained significant (Spearman ρ = +0.332, p = 0.020), and the partial correlation controlling for plasticity index was stronger than the bivariate value (r = +0.544, $p < 0.001$). Relationships are shown in Figure 2.

Table 2: Laboratory tests and standards

AASHTO group	n	% of samples	Unsoaked CBR mean (min–max)	Soaked CBR mean (SD)	Soaked CBR 95% CI	Soaked CBR min–max
A-2-4	2	2%	22.5 (18–27)	22.0 (4.2)	not estimable (n = 2)	19–25
A-4	8	8%	28.1 (9–41)	22.4 (12.0)	[12.3, 32.4]	3–38
A-2-6	18	19%	18.3 (4 35)	10.7 (7.0)	[7.2, 14.1]	3 24
A-6	31	33%	17.3 (9–53)	15.2 (13.7)	[10.1, 20.2]	3–47
A-7-6	36	38%	14.0 (2–47)	5.9 (5.0)	[4.2, 7.6]	1–25

CBR values in per cent. Confidence intervals are two-sided 95% intervals for the group mean. One-way ANOVA F = 7.332, $p < 0.001$; Kruskal–Wallis H = 23.264, $p < 0.001$.

The 10% Assessment Benchmark

Throughout this paper, a four-day soaked CBR of 10% is used as the benchmark against which subgrade competence is assessed. This value is adopted from Ashworth and Overgaard (1996) as a widely used screening threshold for fine-grained subgrade material in developing-country road practice, and is applied here to soaked specimens compacted at the effort described in Section 3.2. It is used as an assessment benchmark for comparison across the dataset and is not presented as a universal statutory minimum; project-specific requirements in Nigerian practice vary with pavement class, design traffic and material category, and the governing project specification should take precedence in design.

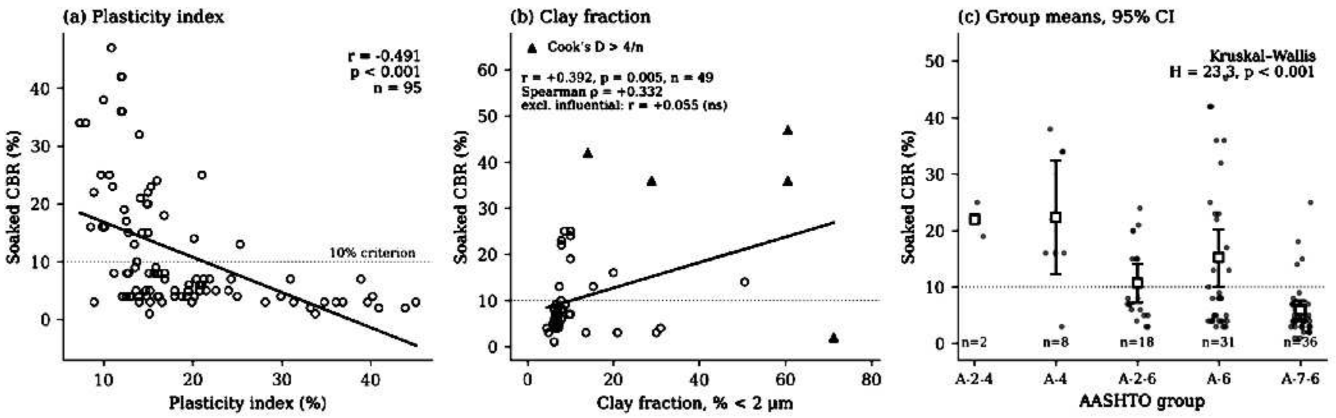

Fig. 2: Relationships between index properties and four-day soaked CBR. (a) Plasticity index against soaked CBR, all 95 samples. (b) Clay-size fraction against soaked CBR, 49 screened samples; triangles mark the five observations exceeding the 4/n Cook's distance threshold. (c) Mean soaked CBR by AASHTO group with 95% confidence intervals; grey points are individual samples. The dotted line marks the 10% assessment

Variation between corridors

Disaggregating by corridor (Table 4), the Ore–Irele corridor recorded the lowest mean soaked CBR (4.1%) and the Auchi–Okpella corridor the highest (17.1%). Mean plasticity index was lowest on the two western coastal-plain corridors (16.1% and 16.2%) and highest on the Igarra–Ibillo and Ibillo–Okene corridors (22.9% and 25.6%). Mean clay-size fraction, computed only over the screened records available in each corridor, was likewise highest on Igarra–Ibillo and Ibillo–Okene. Corridor clay means rest on small and unequal numbers of screened records (as few as four on Auchi–Okpella) and should be treated as indicative only.

Table 4: Mean particle size, plasticity and CBR by road corridor

Road corridor	n	Gravel (%)	Clay (%)	n (clay)	LL (%)	PI (%)	Unsoaked CBR (%)	Soaked CBR (%)
Ondo Ore	23	19.0	7.1	15	38.0	16.1	15.5	10.5
Ore–Irele	22	5.5	6.6	10	35.1	16.2	10.1	4.1
Auchi–Okpella	15	8.4	15.5	4	31.2	17.3	21.0	17.1
Auchi–Igarra	15	19.0	8.9	6	35.2	20.5	24.2	15.5
Igarra Ibillo	10	22.1	26.4	6	38.3	22.9	16.3	11.1
Ibillo–Okene	10	12.6	32.0	8	41.0	25.6	21.8	16.5

Clay means are computed over the screened records available in each corridor (column "n (clay)"); all other means are computed over the full corridor sample.

Sample-level data

The measured properties of all 95 samples are listed in Table 5, so that the classification and strength relationships reported above can be checked directly against the underlying measurements. Clay fraction is reported only for the 49 records that satisfied the particle-size consistency screen defined in Section 3.3; a dash indicates a record excluded by that screen. Coordinates for C4 and D14 were not recovered from the field record.

Discussion of Results

Plasticity as an Indicator of Subgrade Competence

The results indicate that subgrade weakness in this network is associated more consistently with plasticity than with grain-size composition or compaction response. Liquid limit and plasticity index both correlate negatively and significantly with soaked CBR across the full 95-sample dataset, whereas the clay-size fraction does not behave as a straightforward indicator of weakness. This association-based finding is consistent with reports elsewhere that clay content alone is an incomplete indicator of soil behaviour: swelling potential has been shown to depend more strongly on montmorillonite content than on total clay content (Reddy et al., 2020), and clay content interacts non-linearly with compaction and Atterberg limit behaviour in artificial soil mixtures (Zhang & Frederick, 2017). It should be emphasised that the present study measured no mineralogy directly; the activity ratio is an index-based proxy, and the proportion of samples plotting as active in the screened subset is suggestive of expansive clay minerals but does not establish their presence. Direct mineralogical determination would be required to convert this inference into a tested mechanism.

Table 5: Measured geotechnical properties of the 95 subgrade soil samples

ID	Lat (°N)	Long (°E)	Gravel (%)	Clay (%)	LL (%)	PI (%)	MDD (g/cm³)	OMC (%)	AASHTO	CBR-U (%)	CBR-S (%)
A1	7.0768	4.8252	11.2	6.2	29.4	12.6	1.54	22.6	A-6	12	8
A2	7.0682	4.8379	13.2	6.6	27.9	13.6	1.57	22.5	A-6	13	9
A3	7.0560	4.8422	15.2	7.0	26.2	12.8	1.57	22.7	A-6	12	8
A4	7.0418	4.8372	17.2	7.4	28.7	13.5	1.56	22.4	A-6	17	13
A5	7.0275	4.8372	19.2	7.8	27.4	13.8	1.55	22.6	A-6	14	10
A6	7.0124	4.8355	12.4	6.2	44.4	16.2	1.73	18.9	A-7-6	12	4
A7	6.9989	4.8420	12.8	6.5	45.7	20.2	1.75	18.2	A-7-6	12	4
A8	6.9863	4.8491	13.2	6.8	47.9	18.8	1.76	18.7	A-7-6	12	4
A9	6.9711	4.8478	13.6	7.1	41.6	14.8	1.78	18.5	A-7-6	13	5
A10	6.9593	4.8569	5.8	6.2	39.3	15.1	1.62	18.7	A-6	16	8
A11	6.9445	4.8541	6.1	8.2	44.4	15.7	1.53	18.3	A-7-6	16	8
A12	6.9309	4.8572	6.6	8.7	41.2	15.9	1.65	18.5	A-7-6	17	9
A13	6.9172	4.8534	10.4	6.3	48.3	21.1	1.63	17.9	A-7-6	14	6
A14	6.9023	4.8534	11.6	6.7	47.9	21.5	1.61	18.2	A-7-6	13	5
A15	6.8879	4.8573	12.8	–	49.0	20.4	1.66	19.1	A-7-6	15	7
A16	6.8729	4.8596	1.9	8.6	50.3	21.0	1.58	19.6	A-7-6	27	25
A17	6.8588	4.8559	32.9	–	34.3	14.9	1.66	16.7	A-2-6	22	20
A18	6.8438	4.8588	34.0	–	32.5	15.0	1.62	16.5	A-2-6	22	20
A19	6.8288	4.8614	35.1		31.4	14.3	1.67	17.1	A-2-6	17	15
A20	6.8135	4.8604	36.2	–	34.6	15.0	1.66	16.6	A-2-6	17	15
A21	6.8014	4.8689	37.3	–	35.3	15.0	1.65	16.3	A-2-6	17	15
A22	6.7868	4.8731	38.4	–	32.1	14.1	1.64	16.9	A-2-6	23	21
A23	6.7714	4.8736	39.5	–	34.7	15.2	1.62	16.7	A-2-6	4	3
B1	6.7460	4.8757	12.4	6.2	41.3	15.2	1.74	18.8	A-7-6	7	1
B2	6.7315	4.8761	13.6	6.4	44.6	16.1	1.78	18.9	A-7-6	10	4
B3	6.7175	4.8736	14.8	–	47.2	18.0	1.78	18.4	A-7-6	10	4
B4	6.7044	4.8674	16.0	7.3	46.9	19.5	1.76	18.4	A-7-6	11	5
B5	6.6982	4.8758	17.2	–	42.5	16.2	1.74	18.7	A-7-6	10	4
B6	6.6956	4.8890	18.4	7.2	48.5	19.3	1.72	17.9	A-7-6	10	4
B7	6.6860	4.8973	6.3	6.7	40.0	20.8	1.59	21.4	A-2-6	11	5
B8	6.6727	4.8945	6.7	7.1	40.2	20.7	1.58	21.9	A-2-6	12	6
B9	6.6591	4.8905	7.1	7.5	43.2	22.6	1.67	21.7	A-2-6	11	5
B10	6.6449	4.8896	7.5	7.9	41.3	19.6	1.62	21.9	A-2-6	12	6
B11	6.6312	4.8912	0.0	–	32.5	16.6	1.75	15.7	A-6	9	3
B12	6.6176	4.8888	0.0	–	29.6	13.2	1.74	15.2	A-6	10	4
B13	6.6055	4.8953	0.0	–	35.6	19.9	1.77	15.8	A-6	9	3
B14	6.5921	4.8943	0.0	–	27.5	13.9	1.76	16.3	A-6	10	4
B15	6.5783	4.8937	0.0	4.9	26.9	14.0	1.75	16.9	A-6	9	3
B16	6.5651	4.8955	0.0	4.5	24.9	12.1	1.72	16.7	A-6	10	4
B17	6.5539	4.8897	0.0	–	29.4	15.2	1.73	17.1	A-6	11	5
B18	6.5428	4.8805	0.0		24.3	13.0	1.78	17.3	A-6	10	4
B19	6.5297	4.8749	0.0	–	23.5	8.9	1.77	17.2	A-4	9	3
B20	6.5154	4.8730	0.0		26.3	12.5	1.76	16.5	A-6	10	4
B21	6.5012	4.8707	0.0	–	27.9	13.7	1.74	14.9	A-6	11	5
B22	6.4898	4.8663	0.0	–	28.3	14.9	1.77	14.4	A-6	10	4
C1	7.1109	6.2949	0.0	–	15.2	10.0	2.19	8.9	A-4	40	38
C2	7.1379	6.3131	0.0	28.9	17.5	11.9	2.14	9.2	A-6	38	36
C3	7.1636	6.3276	0.0		20.9	10.7	1.85	12.2	A-6	27	25
C4	–	–	0.0	–	20.3	11.2	1.36	11.5	A-6	10	8
C5	7.2274	6.3358	19.7	–	21.2	8.9	1.77	13.7	A-4	24	22
C6	7.2582	6.3438	43.0	–	22.3	11.0	1.75	13.0	A-6	25	23
C7	7.2896	6.3572	9.1	20.0	21.8	8.6	1.57	14.2	A-4	18	16
C8	7.3216	6.3687	11.1	–	24.7	12.6	1.53	13.5	A-6	19	17
C9	7.3448	6.3902	0.0	6.0	39.2	18.0	1.26	19.5	A-6	12	5
C10	7.3735	6.3745	0.0	7.0	41.2	21.9	1.35	18.3	A-7-6	14	7

C11	7.4016	6.3579	0.0	–	54.3	39.7	1.16	15.2	A-7-6	10	3
C12	7.4262	6.3347	0.0	–	35.2	14.0	1.51	22.1	A-6	39	32
C13	7.4523	6.3172	22.3	–	58.2	40.9	1.14	16.9	A-7-6	2	2
C14	7.4703	6.2889	20.2	–	49.2	31.0	1.35	17.6	A-2-6	14	7
C15	7.4922	6.2685	0.0	–	27.3	9.9	1.54	17.0	A-4	23	16
D1	7.0591	6.2771	0.0	–	21.2	8.0	2.02	14.2	A-4	41	34
D2	7.0819	6.2788	0.0	–	19.4	7.3	2.03	13.5	A-4	41	34
D3	7.0858	6.2588	0.0	–	21.4	12.1	2.27	11.7	A-6	49	42
D4	7.0874	6.2364	10.2	9.7	41.2	38.9	1.37	7.0	A-7-6	14	7
D5	7.1047	6.2220	12.2	10.0	42.5	21.2	1.33	19.6	A-7-6	14	7
D6	7.1247	6.2115	0.0	–	44.2	24.0	1.26	18.9	A-7-6	12	5
D7	7.1364	6.1913	0.0	–	61.3	40.2	1.25	19.5	A-7-6	11	4
D8	7.1527	6.1748	0.0	–	54.2	34.8	1.13	18.4	A-7-6	16	3
D9	7.1722	6.1621	0.0	–	45.2	25.0	1.25	18.9	A-7-6	15	4
D10	7.1933	6.1524	10.2	7.9	27.3	15.0	1.76	13.7	A-6	14	22
D11	7.2154	6.1443	12.2	7.9	30.7	15.3	1.79	15.6	A-6	15	23
D12	7.2360	6.1333	80.4	10.0	28.3	16.0	1.76	15.7	A-2-6	33	24
D13	7.2566	6.1230	82.4	8.0	30.4	16.9	1.33	14.5	A-2-6	34	8
D14	–	–	39.8	–	32.3	16.9	1.31	15.7	A-2-6	35	7
D15	7.2861	6.0901	37.8	–	28.5	16.1	1.56	19.6	A-2-6	19	8
E1	7.3009	6.0934	72.4	10.0	23.1	9.7	1.83	14.4	A-2-4	18	25
E2	7.3160	6.0915	70.4	10.0	22.6	12.3	1.86	12.3	A-2-4	27	19
E3	7.3306	6.0865	0.0	71.2	56.4	33.2	1.66	16.6	A-7-6	4	2
E4	7.3457	6.0843	0.0	–	59.2	43.9	1.13	15.6	A-7-6	4	2
E5	7.3595	6.0809	40.0	31.0	42.3	29.9	1.25	13.7	A-2-6	13	4
E6	7.3749	6.0815	38.0	30.0	49.5	36.1	1.70	18.8	A-2-6	13	3
E7	7.3901	6.0808	0.0	–	30.2	12.8	1.51	17.0	A-7-6	15	15
E8	7.4038	6.0738	0.0	–	28.9	16.8	1.64	13.5	A-7-6	14	18
E9	7.4191	6.0727	0.0	6.5	43.2	24.3	1.35	18.0	A-7-6	26	7
E10	7.4283	6.0686	0.0	–	27.3	10.1	1.56	16.9	A-4	29	16
F1	7.4369	6.0786	0.0	20.9	53.2	36.9	1.17	16.3	A-7-6	18	3
F2	7.4421	6.0909	0.0	21.0	65.2	45.1	1.74	16.5	A-7-6	27	3
F3	7.4489	6.1026	13.8	13.6	63.5	31.3	1.18	26.8	A-7-6	14	3
F4	7.4550	6.1147	15.7	14.0	22.3	12.0	2.22	12.3	A-6	14	42
F5	7.4604	6.1272	10.0	60.5	20.2	10.9	2.43	11.7	A-6	14	47
F6	7.4669	6.1389	12.0	60.5	24.2	12.1	2.16	13.5	A-6	53	36
F7	7.4728	6.1510	0.0	–	48.3	33.8	1.24	15.1	A-7-6	2	1
F8	7.4846	6.1548	0.0	–	43.5	28.1	1.17	15.6	A-7-6	47	3
F9	7.4924	6.1591	0.0	50.5	32.4	20.1	1.55	13.6	A-7-6	15	14
F10	7.4925	6.1713	74.0	15.3	36.8	25.3	1.48	13.1	A-6	14	13

Sample codes: **A**, Ondo–Ore; **B**, Ore–Irele; **C**, Auchi–Okpella; **D**, Auchi–Igarra; **E**, Igarra–Ibillo; **F**, Ibillo–Okene. **LL**, liquid limit; **PI**, plasticity index; **MDD**, maximum dry density; **OMC**, optimum moisture content; **CBR-U**, unsoaked California Bearing Ratio; **CBR-S**, four-day soaked California Bearing Ratio.
All CBR specimens were compacted at British Standard heavy effort.
A dash in the clay column marks a record excluded by the particle-size consistency screen (Section 3.3).

The positive clay–CBR association

The positive correlation between clay-size fraction and soaked CBR ($r = +0.392$) runs contrary to the conventional expectation and warrants explicit comment rather than being carried silently into interpretation. Three observations bear on it. First, the association is not robust: five influential observations account for it, and their removal reduces the coefficient to $r = +0.055$ ($p = 0.72$). Second, the rank correlation remains significant over the screened subset ($\rho = +0.332$, $p = 0.020$), indicating a weak monotone tendency rather than an artefact of a few extreme values alone. Third, and most informative, the partial correlation controlling for plasticity index is stronger than the bivariate coefficient ($r = +0.544$, $p < 0.001$): at a given plasticity, samples with a larger clay-size fraction tended to record higher soaked CBR.

A plausible interpretation, consistent with the lateritic character of these soils, is that the sub-2 μm fraction in a lateritic profile is not compositionally equivalent to active clay minerals. Sesquioxide cement, iron-oxide-coated fines and micro-aggregated particles all report to the clay-size fraction on a sedimentation analysis while contributing little plasticity and, in the case of sesquioxide cementation, contributing positively to strength. On this reading, plasticity indexes the mineralogically active component of the fines while the clay-size fraction indexes fines of mixed composition, which would explain why the two behave differently against CBR. This interpretation is offered as a hypothesis consistent with the data, not as a demonstrated mechanism; testing it requires mineralogical and micro-fabric analysis that was not part of this study.

AASHTO Classification as a Screening Tool

AASHTO group is significantly associated with soaked CBR in this dataset, and the A-7-6 group is clearly the weakest, with a mean soaked CBR of 5.9% and 89% of its members below the 10% benchmark. The classification does not, however, rank the groups reliably across their full range. Two adjacent-group reversals occur, neither statistically significant, and the confidence intervals of neighbouring groups overlap substantially. The defensible statement is therefore narrower than a monotonic ranking: AASHTO classification separates the most problematic material (A-7-6) from the rest with confidence, but does not resolve fine distinctions among the intermediate groups on this dataset. Used as a first-pass screen to flag where soaked CBR testing is most needed, it performs well; used as a substitute for CBR measurement in ranking intermediate materials, it does not.

Within-terrain variability reinforces this. The Auchi–Okpella corridor, sharing basement-complex parent geology with the adjoining Igarra–Ibillo and Ibillo–Okene corridors, recorded markedly lower plasticity and higher CBR, indicating that local weathering intensity and drainage history modulate soil behaviour at a finer spatial scale than corridor-level geological mapping resolves. These results are consistent with prior Nigerian subgrade studies linking specific failures to high-plasticity, schist-derived soils (Adeyemi & Oyeyemi, 2000; Meshida, 2006), and with comparable CBR–index correlations reported for tropical residual soils in Cameroon (Katte et al., 2019) and recent integrated characterisation work in southwestern Nigeria (Obasaju et al., 2025).

Limitations

Several limitations qualify these findings. Sampling was confined to disturbed material from a single soil horizon and to one field campaign running from March to July, so no inference about in-situ or seasonally varying subgrade strength can be drawn; the laboratory measures reported here are properties of remoulded material at a controlled compaction and moisture state, not of the ground in its field condition. Clay-based results rest on 49 of the 95 records, those for which the tabulated clay and silt fractions could be reconciled with the sedimentation data; the remaining 46 records are excluded from clay-based analysis, and the corridor clay means in Table 4 accordingly rest on small and unequal subsets. Mineralogy was not determined directly, so all mineralogical statements are inferential. The A-2-4 group contains two samples and supports no inference. Finally, corridor-level geological grouping averages over local heterogeneity that a higher sampling density would resolve.

Summary and Conclusion

This study examined whether standard plasticity-based classification retains value for anticipating subgrade strength across contrasting weathering regimes within a single humid-tropical terrain, using 95 subgrade samples from six road corridors in two geographically separate networks in Ondo and Edo States. Thirty-eight per cent of samples classify as AASHTO A-7-6, with a mean four-day soaked CBR of 5.9%, and 64% of all samples fall below the 10% benchmark adopted here for assessment. Soaked CBR differs significantly among AASHTO groups, but the ordering is partial rather than monotonic: A-7-6 is reliably separated as the weakest group, while adjacent intermediate groups are statistically indistinguishable and their confidence intervals overlap. Plasticity index and liquid limit both correlate negatively with soaked CBR across the full dataset, whereas the clay-size fraction correlates positively and non-robustly, a result attributed provisionally to the mixed composition of the sub-2 μm fraction in lateritic profiles.

The practical conclusion is that plasticity indices, not grain-size composition alone, should guide where subgrade risk is anticipated, and that AASHTO classification is best used as a first-pass screen rather than as a substitute for soaked CBR measurement.

On this basis the following are recommended. Corridor-specific confirmation testing should be carried out on the Ore–Irele corridor and on A-7-6 material generally, where measured soaked CBR is most often below the assessment benchmark. Where soaked CBR falls below the applicable project criterion, subgrade treatment, replacement or pavement redesign should be evaluated rather than assumed adequate on classification alone. Drainage conditions should be assessed along the affected corridors, given the sensitivity of these soils to the soaked condition. X-ray diffraction should be undertaken to test directly the mineralogical interpretation offered here, which the present index-based data can only infer. Seasonal and in-situ testing should be added to capture moisture variation not represented by single-season disturbed sampling. Finally, sample-level data should be released with any future work of this kind so that classification and strength relationships can be independently verified; the complete dataset underlying this paper is accordingly published in full as Table 5.

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Author Contributions

Amiwero, D. T.: conceptualization, methodology, investigation, formal analysis, writing – original draft. Ige, O. O.: supervision, conceptualization, writing – review and editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

All data underlying the findings of this study are contained within the article. The sample-level dataset — station coordinates, gravel and clay fractions, Atterberg limits, compaction characteristics, AASHTO classification and unsoaked and four-day soaked CBR for all 95 samples — is presented in full in Table 5, so that every result reported here can be verified directly against the measurements from which it was derived. Requests for the intermediate particle-size records, including the full sedimentation data, may be addressed to the corresponding author.

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