

# Geological and Geostatistical Appraisal of Disparities in Different Derived Lateritic Soils Around Akure, Southwestern, Nigeria

Ikubuwaje Chrisopher Olatunde<sup>1\*</sup>, Adeoye Aderemi Sunday<sup>2</sup> Arije Olajide Zaccheaus<sup>2</sup> Adewumi Olajumoke Abisola<sup>3</sup> and Ogunleye Abimbolu Akindele<sup>3</sup>

<sup>1 & 3</sup> Dept. of Minerals and Petroleum Resources Engineering Tech. Fed. Poly. Ado-Ekiti, Nigeria,

<sup>2</sup> Department of Geology, Ekiti State University, Ado-Ekiti, Nigeria

<sup>2 & 3</sup> Department of Geology, Federal University Oye-Ekiti, Nigeria

\*E-mail of the Corresponding author: [ikubuwaje\\_co@fedpolyado.edu.ng](mailto:ikubuwaje_co@fedpolyado.edu.ng).

## Abstract

This study evaluates the geological and geostatistical variability of lateritic soils derived from different parent rocks, with the aim of determining their suitability and reliability for engineering design applications. A total of forty (40) trial pits were excavated at 500 m intervals along the study corridor. Field investigations included moisture content determination, Dynamic Cone Penetrometer (DCP) testing, and bulk density measurements, while laboratory analyses comprised laboratory DCP and California Bearing Ratio (CBR) tests conducted on representative soil samples.

The analysis was based on comparative evaluation of field and laboratory results using geometrical curve assessment, coefficients of variation, percentage deviation, degrees of accuracy, and statistical correlations derived from CBR and Maximum Dry Density (MDD) parameters. Results indicate that increasing moisture content significantly influences geotechnical performance, particularly by reducing soil strength. Average coefficients of reduction in CBR values of 1.77 and 3.33 were obtained for field and laboratory data, respectively, demonstrating greater moisture sensitivity in laboratory-derived results. Statistical evaluation shows a strong correlation for field data ( $r = 0.80$ ;  $R^2 = 0.65$ ), whereas laboratory data exhibit a weak relationship ( $r = 0.17$ ;  $R^2 = 0.03$ ). Furthermore, an average percentage deviation of approximately 37% was observed between field and laboratory CBR results. Coefficients of variation of 64% and 117% were obtained for field and laboratory CBR data, respectively, while degrees of accuracy between CBR/MDD relationships were estimated at 90% for field data and 38% for laboratory data. These findings demonstrate that field-based measurements provide greater consistency and reliability for engineering design purposes than laboratory test results.

**Keywords:** Lateritic soils, Field testing, Laboratory testing, Coefficient of variation, Percentage deviation

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## 1. Introduction

Geotechnical engineering is a multidisciplinary field that underpins the safe and efficient design of civil infrastructure by providing an understanding of soil behavior and ground–structure interaction (Firoozi & Firoozi, 2023). Reliable characterization of subsurface materials is fundamental to the prediction of soil performance under imposed loads and environmental conditions. Consequently, the accuracy and representativeness of geotechnical data play a critical role in engineering decision-making.

Soil properties used in geotechnical design are commonly derived from laboratory testing and in-situ field measurements. Laboratory tests offer controlled conditions that allow for detailed evaluation of specific soil parameters; however, they are often constrained by issues related to sample disturbance, scale effects, and the inability to fully reproduce in-situ stress and moisture conditions. During sampling, transportation, and storage, soil specimens may undergo changes in structure, density, and water content, which can significantly influence measured strength and stiffness parameters. Additionally, laboratory tests typically assume homogeneity, whereas natural soils are inherently heterogeneous, exhibiting spatial variability in composition, fabric, and stress history (Fredlund et al., 2012).

In contrast, field-based tests provide direct assessment of soil behavior under natural conditions. In-situ methods capture the effects of stratification, anisotropy, groundwater conditions, and stress history, thereby offering a more representative evaluation of subsurface conditions over larger spatial scales. Continuous field measurements, such as dynamic cone penetration testing, enable the assessment of variability with depth and across sites, which is often impractical to achieve solely through laboratory testing (Da Fonseca et al., 2010)

An integrated approach that combines laboratory and field data is therefore essential for robust geotechnical characterization. Laboratory results often serve as preliminary estimates that must be validated or adjusted using field observations to ensure reliability. Comparative evaluation of these data sources allows engineers to identify discrepancies, assess uncertainty, and develop more accurate predictive models for soil behavior. Such integration is particularly important for lateritic soils, whose engineering properties are highly sensitive to moisture variations and degree of weathering (Ladeira et al., 2020).

This study examines the geological and geostatistical disparities between field and laboratory geotechnical data obtained from lateritic soils along a major transportation corridor in southwestern Nigeria. By evaluating statistical relationships, variability indices, and degrees of accuracy, the study aims to establish the relative reliability of field and laboratory measurements for engineering design applications.

## 2 Study Area

The investigation was conducted along an approximately 43 km stretch of the F209 highway connecting Ado-Ekiti and Akure in southwestern Nigeria. The corridor lies between latitudes 07°16.00'N and 07°28.00'N, and longitudes 005°10.00'E and 005°17.00'E. A total of forty (40) investigation points were established at regular intervals to adequately represent the spatial variability of the subgrade materials. The soils encountered along the route comprise residual lateritic deposits derived from three dominant lithological units. These soils are predominantly brownish in color and exhibit a wide range of textures, varying from fine-grained to coarse-grained materials. Geologically, the lateritic profiles have developed from granitic and charnockitic rocks belonging to the Precambrian Basement Complex, which constitutes the underlying bedrock framework of the study area.

## 3. Materials and Methods

### 3.1 Field Dynamic Cone Penetrometer (DCP) Testing

Field dynamic cone penetrometer (DCP) tests were conducted in accordance with ASTM D6951/D6951M-09 (2015) to a penetration depth of 1000 mm. The test was employed to evaluate the in-situ strength characteristics of the subgrade soils. In addition, field density measurements were carried out using a core cutter method. The core cutter consisted of a seamless steel tube with a wall thickness of 3 mm, a length of 130 mm, and an internal diameter of 100 mm, following the specifications outlined in IS Code 2720 (Part 20, CI: 2.1).

### 3.2 Soil Sample Collection

Soil samples were obtained from trial pits excavated at depths of 450 mm, 650 mm, and 900 mm in order to assess variations in moisture content and to evaluate the influence of moisture conditions on soil strength parameters. The collected samples were immediately sealed in airtight containers to minimize moisture loss and disturbance, and subsequently transported to the laboratory for detailed geotechnical testing.

### 3.3 Laboratory Geotechnical Testing

Laboratory investigations were performed to determine the engineering properties of the sampled soils. The tests included natural moisture content determination, compaction testing, California Bearing Ratio (CBR) testing, and laboratory dynamic cone penetration testing (DCPT). All laboratory procedures were carried out in accordance with the guidelines specified by the British Standards Institution (BSI, 1990).

### 3.4 Data Analysis and Evaluation

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) to assess the reliability, variability, and significance of differences between field and laboratory CBR results. Parameters evaluated included coefficients of variation, correlation strength, and measures of statistical significance. The coefficient of reduction in CBR with increasing moisture content was determined using a modified coefficient-of-change approach, which incorporates the highest and lowest CBR values and their corresponding moisture contents (Woods and Litehiser, 1937)

Furthermore, the degree of accuracy between CBR and Maximum Dry Density (MDD) ratings for both field and laboratory data was assessed by examining the level of agreement between the respective CBR and MDD classifications. The resulting degrees of agreement were subsequently used to quantify the overall accuracy of the field and laboratory datasets. Under ideal conditions, comparable trends are expected between field-derived

and laboratory-derived CBR/MDD relationships; deviations from this expectation provide insight into the reliability and limitations of each testing approach.

#### 4. Results and Discussion

##### 4.1 Coefficient of Reduction in CBR with Increasing Moisture Content

The ratios representing the reduction in California Bearing Ratio (CBR) values associated with increasing moisture content for the lateritic soils, as obtained from both field and laboratory tests, are presented in Tables 1 and 2. The computed average coefficients of reduction are 1.77 for field data and 3.33 for laboratory data. These results indicate that the derived soils are generally susceptible to moisture ingress, which leads to a corresponding decline in strength characteristics. Notably, the magnitude of reduction observed in laboratory results is significantly higher than that recorded from field measurements, suggesting that laboratory-derived CBR values are more sensitive to changes in moisture content than in-situ field results.

Table 1. Field coefficient of reduction in CBR and increase in MC of the studied soils

S/N	HMC	LMC	IMC (%)	HCBR	LCBR	RCBR (%)	RCBR/IMC	Lithology
1	26	18	30.77	11.2	5.7	49.11	1.6	Ch
2	25	23	8	11.2	9.3	16.96	2.12	Ch
3	22	21	4.55	18.6	15.2	18.28	4.02	Ch
4	22	17.5	20.45	27.4	14.1	48.54	2.37	Ch
5	22.5	18	20	26	8.3	68.08	3.4	Ch
6	20	16	20	26	12.6	51.54	2.58	Ch
7	17.49	16.19	7.43	18.4	14.1	23.37	3.14	Ch
8	17.62	16.32	7.38	9.3	8.3	10.75	1.46	Ch
9	20.99	14.9	29.01	12.6	6.5	48.41	1.67	Ch
10	27.69	17.31	37.49	10.5	2.6	75.24	2.01	Ch
11	16.04	10	37.66	26	12	53.85	1.43	Ch
12	8.95	7.62	14.86	48.1	36.9	23.28	1.57	OGP
13	15.7	15.61	0.57	13.4	13.4	0	0	OGP
14	7.75	6.72	13.29	36.9	33	10.57	0.8	OGP
15	12.08	10.07	16.64	36.9	27.2	26.29	1.58	OGP
16	9.7	7.9	18.56	33	27.2	17.58	0.95	OGP
17	13.88	6.88	50.43	48.1	22.2	53.85	1.07	OGP
18	11.58	4	65.46	57	33	42.11	0.64	OGP
19	9.7	9.7	0	52	52	0	0	OGP
20	14.75	14	5.08	15.2	13.1	13.82	2.72	OGP
21	14.69	14.09	4.08	15.2	14.1	7.24	1.77	OGP
22	8.4	7.89	6.07	48.1	40.9	14.97	2.47	OGP
23	11.7	9.35	20.09	33	27.2	17.58	0.88	OGP
24	9	7.79	13.44	33	26	21.21	1.58	OGe
25	16.41	9	45.16	33	10.5	68.18	1.51	OGe
26	13.98	6.45	53.86	36.9	12.5	66.12	1.23	OGe
27	11.27	11.2	0.62	33	33	0	0	OGe
28	12.7	8.18	35.59	48.1	18.6	61.33	1.72	OGe
29	12.7	6.9	45.67	48.1	22.2	53.85	1.18	OGe
30	16.2	15.6	3.7	15.2	13.5	11.18	3.02	OGe
31	14.1	11.7	17.02	18.6	13.1	29.57	1.74	OGe
32	12.95	5.14	60.31	57	22.2	61.05	1.01	OGe
33	14.19	12	15.43	15.2	11.2	26.32	1.71	OGe
34	20	17	15	11.2	7.7	31.25	2.08	OGe
35	18.58	15.3	17.65	16	9.5	40.63	2.3	OGe
36	16.27	14.89	8.48	20.6	16	22.33	2.63	OGe
37	16.96	15.47	8.79	7.4	5.4	27.03	3.08	OGe
38	21	18	14.29	22.2	16.6	25.23	1.77	OGf
39	18.75	16.5	12	20	15.2	24	2	OGf
40	25	21	16	7.4	5.1	31.08	1.94	OGf
Average							1.77	

HCBR = highest CBR, HMC = highest MC LCBR = lowest CBR, LMC = lowest MC, RCBR = Reduction in CBR, IMC = Increase in MC, Ch = charnockite, OGP = porphyritic granite, OGe = coarse-grained granite, OGF = fine-grained granite.

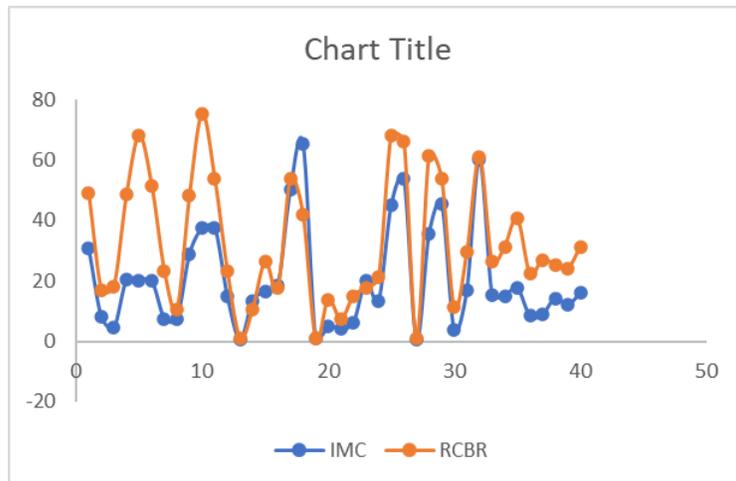
Table 2. Laboratory coefficient of reduction in CBR and increase in MC of the studied soils.

S/N	HMC	LMC	IMC	HCBR	LCBR	RCBR (%)	RCBR/IMC	Lithology
1	37	2	94.59	24	16.3	32.08	2.95	Ch
2	40	2	95	24	15.3	36.25	2.62	Ch
3	16	4	75	21.3	17.9	15.96	4.7	Ch
4	12	1	91.67	25	18.2	27.2	3.37	Ch
5	6	2	66.67	21.24	19.7	7.25	9.19	Ch
6	14	2	85.71	18.9	14.5	23.28	3.68	Ch
7	56	4	92.86	17.56	12.5	28.82	3.22	Ch
8	43	1	97.67	18.78	14.8	21.19	4.61	Ch
9	57	1	98.25	16	12	25	3.93	Ch
10	19	1	94.74	17.65	14.4	18.41	5.14	Ch
11	41	4	90.24	14.98	13.5	9.88	9.13	Ch
12	72	18	75	15.8	8.3	47.47	1.58	OGP
13	57	5	91.23	15.37	11.03	28.24	3.23	OGP
14	62	20	67.74	12.75	7.9	38.04	1.78	OGP
15	34	11	67.65	12.5	10.8	13.6	4.97	OGP
16	69	52	24.64	15	7.9	47.33	0.52	OGP
17	41	18	56.1	15.5	10.4	32.9	1.7	OGP
18	75	42	44	11.58	6.81	41.19	1.07	OGP
19	78	9	88.46	13.6	9.7	28.68	3.08	OGP
20	28	16	42.86	14.7	13.8	6.12	7	OGP
21	68	10	85.29	14.9	6.5	56.38	1.51	OGP
22	64	35	45.31	12.6	8	36.51	1.24	OGP
23	66	34	48.48	13	10.6	18.46	2.63	OGP
24	68	28	58.82	16	7.79	51.31	1.15	OGe
25	22	4	81.82	17.9	5.8	67.6	1.21	OGe
26	44	9	79.55	13.98	7.75	44.56	1.78	OGe
27	49	27	44.9	13.82	11.5	16.79	2.67	OGe
28	52	10	80.77	14.8	11.18	24.46	3.3	OGe
29	49	6	87.76	16.6	11.27	32.11	2.73	OGe
30	6	4	33.3	17	14.7	13.5	2.46	OGe
31	29	8	72.41	14.8	11.1	25	2.9	OGe
32	33	7	78.79	12.95	9.25	28.57	2.76	OGe
33	37	4	89.19	15	5.8	61.33	1.45	OGe
34	10	1	90	15	11	26.67	3.38	OGe
35	51	3	94.12	18.79	10.54	43.91	2.14	OGe
36	47	24	48.94	15.04	12.7	15.56	3.15	OGe
37	58	1	98.28	16.47	10.6	35.64	2.76	OGe
38	62	14	77.42	18.36	8.94	51.31	1.51	OGf
39	24	15	37.5	17.75	16.7	5.92	6.34	OGf
40	13	1	92.31	25	22.29	10.84	8.52	OGf
Average							3.33	

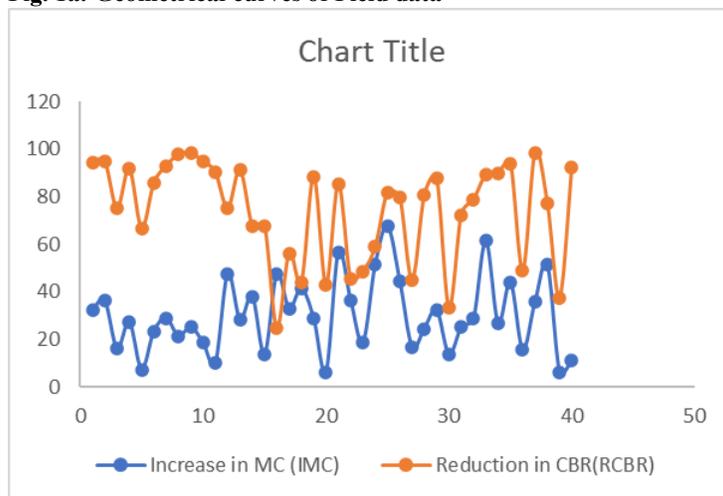
#### 4.2. Geometrical curves of IMC and RCBR

The plot of field and laboratory data from IMC and RCBR values are presented in figures 1a and 1b respectively. It was observed that the field result show geometry curves and surfaces with more closely related trend, pattern and more consistency in their series points in comparison to the laboratory data. This further confirm the reliability of the field test. This is attributed to the less disturbance of in-situ test and the ability of dynamic cone device to relate the soil behaviors.

Lithologically, it observed that OGP and OGe sections of the plots which lies within x axis 12 -34 have more match fit and more related trend in comparisons with Ch and OGf for both field and laboratory results. This may be due to lower moisture content in OGP and OGe derived soils tables 1 and 2 and the sensitivity of shear strength values to variations in moisture content. Hence, increase in moisture content especially in relation to strength parameters may give rise to more error in geotechnical analyses particularly for the laboratory test. This is in agreement with findings of Ikubuwaje (2023).



**Fig. 1a: Geometrical curves of Field data**



**Fig. 1b: Geometrical curves of laboratory data**

#### 4.3 Cross Plotting of IMC and RCBR

Figures 2a and 2b illustrate the relationship between the increase in moisture content (IMC) and the reduction in California Bearing Ratio (RCBR) for both field and laboratory measurements (Adeyemi 2013; Ikubuwaje (2023). Analysis of the field data produced a coefficient of determination ( $R^2=0.65$ ) and a regression coefficient (RRR) of 0.8, while the laboratory data yielded much lower values ( $R^2=0.03$ ,  $R=0.17$ ).

These results demonstrate that higher moisture content directly reduces the CBR of the lateritic soils, meaning that the soils lose strength when water infiltrates. The stronger correlation observed in the field data suggests that predictions derived from in-situ measurements are more reliable than those from laboratory tests. This highlights the limitation of laboratory data in capturing the true behaviour of the soil under natural conditions.

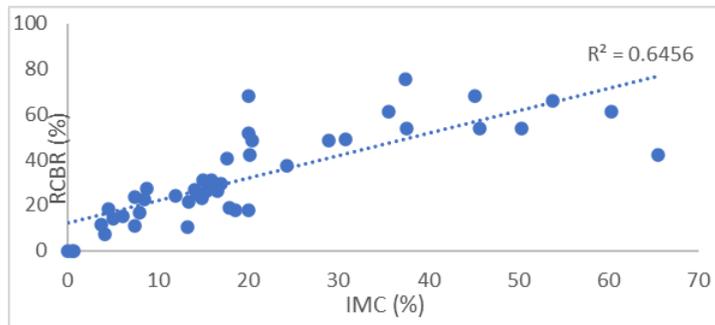


Fig. 2a: Cross plot of IMC against RCBR values for the field data

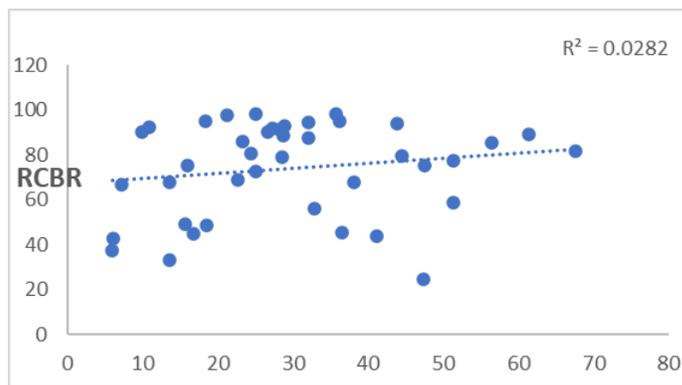


Fig. 2b: Cross plot of IMC against RCBR values for the laboratory data.

#### 4.4 Percentage Deviation between Field and Laboratory CBR Results

Table 3 presents the percentage deviation between field and laboratory CBR values for the lateritic soils. The results indicate similar trends in both field and laboratory CBR measurements. However, the average percentage deviation between field and laboratory results is 36%. This discrepancy may be attributed to the degree of disturbance during sample collection and transportation, as well as the challenges in replicating field conditions accurately in the laboratory. Consequently, laboratory CBR data may not be fully reliable for structural engineering design purposes.

Table 3: Percentage deviation between field and laboratory CBR values

S/N	Field RCBR/IMC		Laboratory RCBR/IMC		Percentage deviation (%)
	Range	Average	Range	Average	
Ch	1.16 - 6.78	3.15	2.62 - 9.13	4.78	34
OGp	0.58 - 2.93	1.56	0.52 - 7.00	2.53	38
OGe	0.71 - 6.55	2.68	1.15 - 3.38	2.42	11
OGf	1.05 - 3.53	2.21	1.15 - 8.52	5.46	60
Average					36

Where D is the percentage deviation (%),  $X_M$  is the measured value (lab),  $X_t$  is the true value.  
 $D = (X_M - X_t) / X_t \times 100$

#### 4.5 Degree of Accuracy between CBR/MDD Data for Field and Laboratory Measurements

Tables 4 and 5, along with Figure 2, present the degree of agreement and accuracy between CBR and MDD data for field and laboratory tests. These findings are consistent with the trends observed in the cross-plot analysis. The results indicate that field measurements exhibit greater consistency compared to laboratory data. This reliability reflects the ability of in-situ testing to capture the actual behavior of the soil. In contrast, the lower

consistency of laboratory results may explain why laboratory tests sometimes fail to accurately represent the soil's structural properties, which are critical for dependable engineering design (Ashioba & Udom, 2023).

**Table 4. Degree of Agreement between CBR and MDD (Woods & Litehiser 1937)**

S N	LCBR Rating	MDD Rating	DA	FCBR(kg/m <sup>3</sup> ) Rating	FDD(kg/m <sup>3</sup> ) Rating	DA	Lithology
1	VP	VP	0	P	VP	1	Ch
2	VP	VP	0	P	VP	1	Ch
3	VP	F	2	P	VP	1	Ch
4	VP	G	3	P	P	0	Ch
5	VP	F	2	P	P	0	Ch
6	VP	F	2	P	P	0	Ch
7	VP	F	2	P	P	0	Ch
8	VP	F	2	VP	VP	0	Ch
9	VP	F	2	P	P	0	Ch
10	VP	F	2	P	P	0	Ch
11	VP	F	2	P	P	0	Ch
12	VG	G	1	G	G	0	OGP
13	P	G	2	P	F	1	OGP
14	F	E	3	F	F	0	OGP
15	G	G	0	F	F	0	OGP
16	VG	G	1	G	F	1	OGP
17	F	E	3	F	F	0	OGP
18	G	E	2	F	F	0	OGP
19	VG	G	1	VG	F	2	OGP
20	F	F	0	G	F	1	OGP
21	P	E	4	F	F	0	OGP
22	VG	E	1	G	G	0	OGP
23	G	E	2	G	F	1	OGP
24	VG	F	2	G	F	1	OGe
25	P	F	1	P	P	0	OGe
26	P	G	2	P	P	0	OGe
27	G	F	1	G	P	2	OGe
28	VG	F	2	G	P	2	OGe
29	F	F	0	F	P	1	OGe
30	P	G	2	P	P	0	OGe
31	P	E	4	P	P	0	OGe
32	F	G	1	F	F	0	OGe
33	P	E	4	P	VP	1	OGe
34	VP	G	4	P	F	1	OGe
35	VP	F	2	P	P	0	OGe
36	F	P	1	F	P	1	OGe
37	VP	E	5	P	F	1	OGe
38	F	F	0	F	VP	2	OGf
39	F	G	1	F	P	1	OGf
40	VP	F	2	P	VP	1	OGf

Where VP=Very Poor, P=Poor, E=Excellent, F=Fair, G=Good, VG=Very Good, DA = Degree of Agreement.

Table 5. Degrees of Accuracy for field and laboratory data of the study area.

Designature	100%	80%	60%	40%	20%	0%
Field data	21	15	4	0	0	0
Laboratory data	6	9	17	3	4	1

Table 6. Modified CBR after AASHTO (2015)

CBR	Rating
< 5	Very poor
5 – 15	Poor
15 – 30	Fair
30 – 50	Good
50 – 75	Very Good
>75	Excellent

#### 4.6 Coefficient of Variation (CV) between Field and Laboratory CBR Results

Table 7 presents the Coefficient of Variation (CV) for both field CBR (FCBR) and laboratory CBR (LCBR) measurements of the lateritic soils. The CV values obtained were 64% for FCBR and 117% for LCBR. This indicates that the field data are under-dispersed, while the laboratory data are over-dispersed. Since precision is defined as the inverse of CV ( $1/CV1/CV1/CV$ ), the results suggest that field measurements are more precise than laboratory measurements. Consequently, in-situ testing provides more reliable results for assessing soil strength. The high CV observed in laboratory tests is one of the factors contributing to the unreliability of laboratory data when used alone for structural engineering design.

## 5. Conclusions

This study evaluated the reliability and discrepancies between field and laboratory geotechnical data for engineering design purposes. The findings confirm that field tests provide more reliable results than laboratory tests, primarily due to minimal disturbance during in-situ testing and the ability of the dynamic cone device to capture actual soil behavior.

The study further shows that increases in moisture content significantly influence soil strength parameters, leading to greater errors in laboratory-based analyses. Specifically, the average coefficient of reduction in CBR with increasing moisture content was 1.77 for field data and 3.33 for laboratory data, indicating an 88.14% higher reduction in the laboratory results.

Statistical analysis revealed a strong correlation for field measurements ( $R^2=0.65, r=0.8$ ) compared to a weak correlation in laboratory data ( $R^2=0.03, r=0.17$ ), highlighting the superior predictive reliability of field data. Additionally, a 36.80% average percentage deviation was observed between field and laboratory CBR values. The Coefficient of Variation was 64% for field CBR (FCBR) and 117% for laboratory CBR (LCBR), while the degree of accuracy and agreement between CBR/MDD values was 90% for field data and 38% for laboratory data. These results indicate that field measurements are more consistent, whereas laboratory results show greater variability.

Overall, the study concludes that in-situ (field) testing is a more dependable method for evaluating soil properties for structural engineering design. The high variability and reduced consistency of laboratory results are key factors limiting their reliability when used independently.

Table 7. Summary of field and laboratory Coefficient of Variations

S/N	FCBR	LCBR	Lithology
1	6.9	2	Ch
2	11.4	2	Ch
3	13.4	4	Ch
4	14.1	4	Ch
5	9.6	2	Ch
6	13.4	4	Ch
7	14.1	4	Ch
8	3.5	1	Ch
9	9.6	2	Ch
10	5.4	1	Ch
11	13.4	4	Ch
CV (%)	36	46.6	Significant
12	48.1	72	OGP
13	13.4	5	OGP
14	18.1	20	OGP
15	27.2	34	OGP
16	34.9	69	OGP
17	22.2	22	OGP
18	21.4	42	OGP
19	52	78	OGP
20	33	16	OGP
21	15.6	10	OGP
22	40.5	64	OGP
23	34.9	42	OGP
CV (%)	41.8	65.4	Significant
24	41.8	68	OGe
25	10.6	6	OGe
26	12.5	9	OGe
27	34.9	49	OGe
28	31.4	52	OGe
29	22.2	28	OGe
30	11.15	6	OGe
31	12.5	8	OGe
32	22.2	7	OGe
33	11.19	6.5	OGe
34	7.3	1	OGe
35	9.3	3	OGe
36	17.5	24	OGe
37	7.3	1	OGe
CV (%)	61.3	114.4	Significant
38	22.2	14	OGf
39	22.2	15	OGf
40	5.1	1	Of
CV	64	117	

Where CV = Coefficient of variation (%)

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#### **Ikubuwaje Chrisopher Olatunde Ph.D**

Ikubuwaje Chrisopher Olatunde (Engineering Geology/Hydrogeology) is a Principal Lecturer Department of Minerals and Petroleum Resources Engineering Technology; Engineering, Federal Polytechnic Ado-Ekiti. He specialized in in-situ assessment of shallow formations for civil engineering structures. Expertise spans geotechnical investigations, groundwater modeling, and site characterization to mitigate risks in foundation design, slope stability, and infrastructure projects. Proven track record in integrating field data with statistical analysis for sustainable urban development in sedimentary terrains. Committed to advancing resilient civil engineering through precise geological profiling.

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**Arije Olajide Zaccheaus**

Mr. Arije O. Z. is an Assistant Lecturer in the Department of Geology, Federal University Oye-Ekiti. He obtained his Master's degree in Hydrogeology/Engineering Geology whilst his Bachelor of Technology Degree is in Applied Geology through the Federal University of Technology, Akure at undergraduate level in 2013. His research interests span across Engineering Geology, Hydrogeology & Environmental Geology. He has successfully supervised undergraduate students. He has publications to his credit. He is a member of professional body like Nigerian Mining and Geosciences Society (NMGS).

**Mr. A.A. Ogunleye**

Mr. A.A. Ogunleye is also an Assistant Lecturer in the Department of Geology, Federal University Oye-Ekiti. He earned Master of Science in Geochemistry/Mineral Exploration Geology from the Ekiti State University. His areas of interest include geochemistry, petrology, mineralogy, geotechnical qualities, and possible industrial uses of Nigeria's marble reserves. In addition to having published some papers, he has mentored undergraduate students. He is a member of the Nigerian Mining and Geoscience Society (NMGS).