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Sub-soil Water and Structural Foundation Study in Ilaje Community School and United Grammar School, Irele, Ondo State, Nigeria

[1]Owoyemi, S. I.
[2]Popoola, F. A.
[3]Sanyaolu M. E.
[1]Department of Integrated Science, Adeyemi Federal University of Education, Ondo, Nigeria.
[2]Department of Mathematical and Physical Sciences, Glorious Vision University, Ogwa, Edo State.
[3]Department of Physical Sciences, Redeemer's University, Ede, Osun State, Nigeria.
Corresponding email: sheuisiaq.owoyemi7611@yahoo.com
owoyemisi@aceondo.edu.ng
owoyemisheuisiaq@gmail.com

ABSTRACT

Geotechnical Soil Correlation and Potential Investigation of Trial Pits at Structural Foundation Sites across the Ilaje Community School and United Grammar School, Irele in Ondo State, Nigeria, were conducted. The purpose was to correlate and assess the potential effects of sub-soil water on depth to bedrock, foundation conditions, and possible geological structures within the proposed construction area. The study evaluated the engineering properties of soil samples collected from the site using the Atterberg limit, grain size analysis, and compaction test. The geophysical results revealed five geoelectric layers: topsoil, sandy layer, sandy/sandy clay layer, sandy/sand clay layer, and sand basement layer. Analysis of the Atterberg limit indicated a dominance of inorganic clay-size particles with high plasticity and moisture content. The grain size analysis revealed the presence of well-graded gravelly clay silty sand. The classification of soil types and the compaction values obtained showed significant consistency across soil samples. Four subsurface soil layers were identified in the topsoil (mixture of sand, silt, and clay), coarse sand, clayey sand, and sand. These findings correlated well with the sub-soil investigation. The Geotechnical Trial pit data revealed that the soil condition in both communities generally required deep foundations. However, the foundation conditions of United Grammar School in Irele were more favourable than those in the Ilaje community, based on the computed values from the trial investigation.

Keywords: *Foundation Study, structural foundation, sub-soil water, and Water effects*

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INTRODUCTION

The study of soil-water interactions is essential for understanding how subsurface water influences foundation stability and longevity by affecting the geophysical properties that govern foundation behaviour, especially in areas with fluctuating groundwater levels (Yerro & Ceccato, 2023). Foundation failure in buildings is often caused by various factors, with the movement of expansive and highly plastic soil being a major contributor (Oladunjoye et al., 2020). Research on the effects of water on soil properties has demonstrated the complex and dynamic relationship between water, soil, and structural foundations. Water is an agent that influences soil mechanics by altering its strength, compaction, and bearing capacity (Drescher et al., 1988; Yerro & Ceccato, 2023).

Specifically, sub-soil water leads to varied soil's geotechnical properties, including its shear strength and compressibility. These changes may be imperceptible in dry conditions but can become pronounced when water levels fluctuate, especially during rainy seasons. Water infiltration can cause soil swelling or shrinkage, which exerts detrimental pressure on foundations. Consequently, understanding the soil-water interaction is critical for evaluating the geotechnical suitability of sites for construction and predicting long-term foundation performance (Eze et al., 2023).

Foundation failure investigations across different regions of Nigeria have been extensively explored through geophysical and geoelectrical techniques, as shown in the studies by Oladunjoye et al. (2020), Bayowa et al. (2019), and Eze et al. (2023), each highlighting site-specific subsurface conditions contributing to structural instability. Several studies have underscored the need for in-depth geotechnical investigations in evaluating how subsurface water influences foundation behaviour. Ale (2021) and Abe & Ayeni (2019) investigated soil properties linked to road deterioration in parts of Southwestern Nigeria, identifying groundwater as a key factor.

Variations in groundwater levels can lead to differential settlement, particularly in problematic soils, often resulting in structural instability. It underscores the necessity of incorporating detailed subsurface assessments and long-term groundwater dynamics into foundation design (Godlewski et al., 2019). Odundun et al. (2020) applied geoelectrical and geotechnical techniques to determine that the structural failure at Oroke High School resulted from unsuitable subsurface conditions, including clayey soils, fractures, and basement depressions. Other investigations across Nigeria have demonstrated the groundwater's significant role in foundation failures, especially in swampy and coastal areas. The swift rise in population across rural and urban areas, particularly in Ondo State, Nigeria, has posed considerable challenges for communities in Irele, Igbokoda, and the wider Ondo South region of Southwestern Nigeria. This population growth, fueled by increasing demands for domestic and agricultural purposes, has spotlighted the importance of ensuring foundation stability in building construction.

Aina and Adedipe (1996) highlighted that the sustainable and safe use of geophysical, geotechnical, and geochemical resources related to foundation development should be a shared responsibility across society rather than left to individuals alone. The geotechnical characteristics of the soil beneath influenced the stability and safety of buildings (Zhao et al., 2023). When foundation soils retain excessive moisture, they can settle unevenly, which compromises the structural integrity of buildings and may lead to partial or total collapse (Ngugi *et al*., 2021). Extended periods of rainfall elevate subsurface water levels, leading to changes in soil behaviour (Ślusarek & Łupieżowiec, 2020).

Ilaje and Irele in South Western Nigeria, and the interaction between local geology and hydrogeological conditions further complicates foundation performance. Ilaje, a coastal settlement, is subject to notable seasonal changes in groundwater levels due to rainfall and tidal effects. Meanwhile, Irele also experiences fluctuating groundwater levels of rainfall and nearby natural streams. These changing conditions contribute to variations in soil moisture content, which can cause expansive soils to swell or shrink. Such movements can apply significant stress to building foundations, gradually leading to structural weakening or damage.

This study is significant because it emphasizes the need to understand how sub-soil water affects foundation stability in flood-prone areas like Irele and Ilaje, where groundwater fluctuations pose serious risks to building safety. The scope includes analyzing geotechnical and geochemical properties of soil and groundwater, focusing on parameters such as shear strength, compaction, moisture content, and water chemistry. The study is justified by its aim to mitigate the dangers of foundation failures, offering valuable guides for construction practices in engineering and policy decisions.

The study aims to correlate the effects of water on building foundation stability in the Ilaje Community School and United Grammar School, Irele in Ondo State, Nigeria. To achieve this, it investigates the geochemical properties of running water samples, characterizes the soil engineering geological properties, and correlates geotechnical and geochemical investigations on subsurface geology.

Geology of the Study Area

Geologically, Ondo South lies in the sedimentary Basin of South Western Nigeria (pure sedimentary Basin). It forms part of the West African Precratonic Basin System, which developed during the onset of rifting and was associated with the opening of the Gulf of Guinea from the Late Jurassic to the Early Cretaceous period. The Dahomey Basin, an extensive sedimentary basin along the Gulf of Guinea, stretches from southern Ghana through Togo and the Benin Republic to the West to the Okitipupa Ridge/Benin Hinge line to the east and south of Nigeria. The Basin comprises a Cretaceous tertiary sedimentary sequence that thins out toward its east and is partially separated from the sediments of the Niger Delta Basin by the Okitipupa Ridge.

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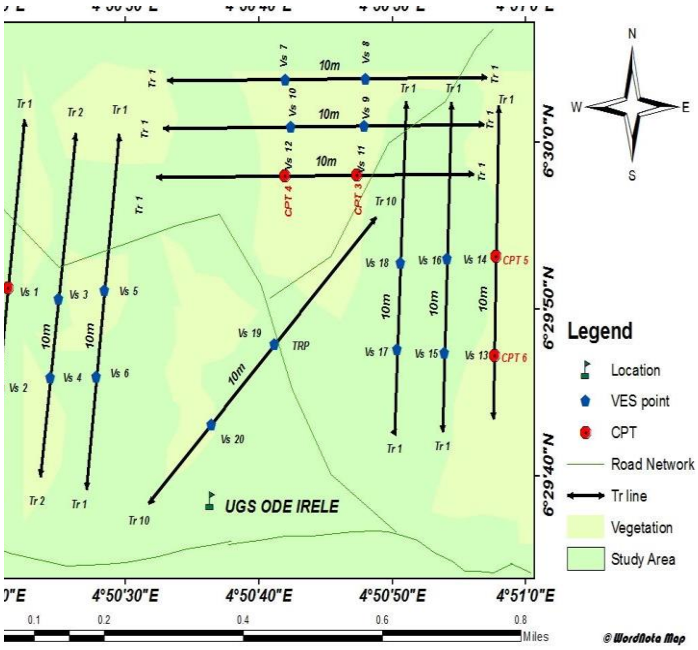

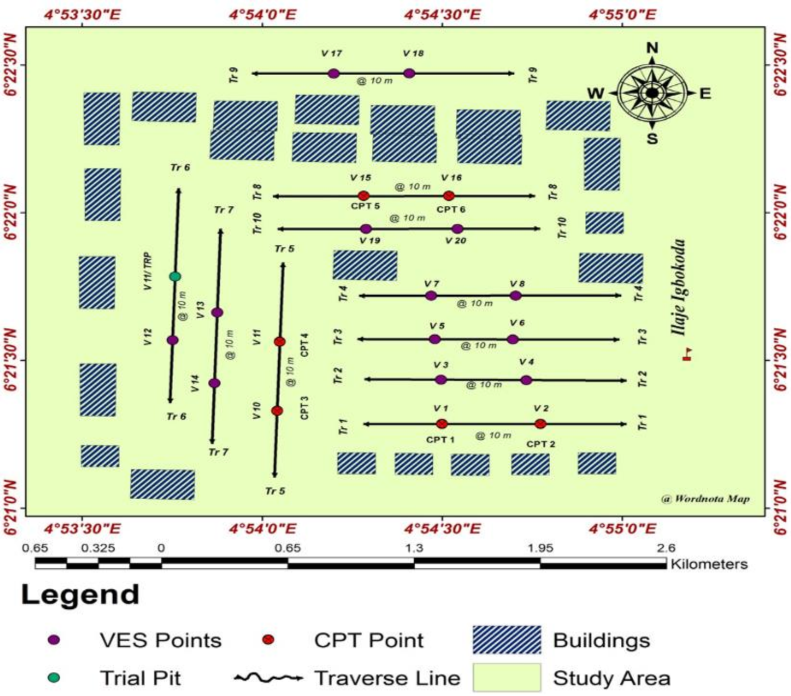

Base Map of The Study Areas: Ilaje and Irele Community

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MATERIALS AND METHOD

Samples Collection

Two trial pits were excavated (each at the centre of the study area) to obtain soil samples as possible as core materials. The samples were collected into plastic samples for disturbed samples labeled as IHSI and undisturbed samples. The samples were blown at 2.0m so we could obtain any samples for U4bag and transport them to the soil laboratory. The soil was air-dried and lightly crushed into smaller pieces for classification, strength, and specialized tests (according to the British Standard (BS 1377:1990)). Disturbed samples were labeled as UGS 0.5m, UGS 1.0, UGS 1.5, UGS 2.0, UGS 2.5m, and Undisturbed samples were labeled as UGS 1.0m U4, UGS 1.5m U4, UGS 2.0m U4, UGS 2.5m U4, and it does not occur in other locations at the Ilaje community.

Plate 1a: Photograph of trial pit showing the collection of Samples from the study areas of Irele of disturbed samples of 1.0-2.5

Plate 1b: Photograph showing the collections of undisturbed samples of 1.0m - 1.5m layer (Samples collection from the study areas of Irele)

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Samples Collection from the Ilaje and Irele Communities

Plate 2a: Photograph of trial pit showing the collection disturbed samples of 0.5m- 2.5m Ilaje

Plate 2b: Water samples from Ilaje and Irele communities

Plate 3a: Undisturbed samples from the Irele community only

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Samples Preparation

The soil and water samples were taken to the laboratory

Laboratory testing of soil samples from the Ilaje and Irele communities

Laboratory tests performed for the soil samples are Grained Size Distribution, Atterberg Limit test, Quick Undrained Triaxial Compression Tests, Oedometer Consolidation Tests, Determination of Natural and Air-Dry Moisture Content, and the Liquid and Plastic Limit of the soil were carried out.

Chemical Analysis of Water samples: the following entities were worked on.

pH, Conductivity, iron (Fe), Chlorides (Cl), and Sulfates (SO4-2).

Table 1: Summary of Laboratory Soil Test Trial Pit Results of Irele community

Zone		Depth Range (m)	Generalized Strata Description
	IRELE		
1		0.00-0.25	Connotes dark grey silty clayey sand (m-f) with occasional gravels
2		0.25-0.50	Reveals reddish-brown sandy clay with gravel in places
3		0.50-1.00	Depicts firm, reddish-brown sandy clay with gravels in places
4		1.00.-1.50	Denotes firm, reddish-brown sandy clay with gravels in places
5		1.50-2.00	Signifies firm, reddish-brown sandy clay with gravels in places

Table 2: Summary of Laboratory Soil Test Trial Pit Results

Zone	Depth Range (m)	Generalized Strata Description
IGBOKODA		
1	0.00-0.25	Reflect grey sand (m-f) with occassional gravels
2	0.25-0.50	Reveals grey sand (m-f) with occassional gravels
3	0.50-1.00	Shows grey sand (m-c) with occassional gravels
4	1.00.-1.50	Signifies grey sand (m-c) with occassional gravels
5	1.50-2.00	Depicts grey sand (m-c) with occassional gravels

Table 3: Chemical Analysis of Water Samples

Sample Nos.	PARAMETERS / LEVEL DETECTED			
	PH Value	Sulphate content (So_4^{2-PPM}	Chloride content (CL^-ppm)	Iron content (fe ppm)
IRELE OMI OLUWA	8.1	2.0	6.0	0.05
IGBOKODA	7.8	4.0	10.0	0.07

CONCLUSION

The trial pits of the study area show a water table range of 2-6 m at Igbokoda, but at Irele, there are no water tables. From the water test analyses, the pH values of water in Irele and Igbokoda are greater than 7.0, meaning they have high pH values and chloride contents. In the trial pit, the distribution of sand is more pronounced in Ilaje Igbokoda than in other locations of the study. As a result of the shallow water table of the range 2-6m, the pH and chloride contents are very high ; the water in the study area is corroded and can bleach.

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