Geotechnical Investigation of a Proposed Dam Project, Iyah Gbede, Kogi State, Nigeria

Oyanameh O.E[1], Olabode O.O[2], Korode A.I[3], Osisanya W.O[4], Fatoye O.V[5]

[1,5]*Department of Earth Sciences, Anchor University, Ayobo, Lagos, Nigeria*

[2]*Department of Geology, University of Ibadan, Ibadan, Nigeria*

[3]*Department of Petroleum Engineering and Geosciences, Petroleum Training Institute, Effurun, Nigeria*

[4]*Department of Physics, University of Benin, Benin City, Nigeria*

Abstract: **Geotechnical study was conducted at the proposed Dam project of Iyah Gbede, Ijimu Local Government Area of Kogi State with the aim of evaluating the subsoil layers that constitute the foundation soils and their competence as foundation soils for the civil engineering structures. The study involved drilling of three (3) boreholes and eleven (11) trial pits as well as Standard Penetration Test (SPT) to obtain the in situ strength parameters of the sandy layers. The lithological formations that constitute the study area layers are lateritic top soil, grey brown sandy clay, yellowish brown coarse sand, gravel and weathered rock. All the soils have average natural moisture content because it agrees with the average range of (5 – 15%) specified by Federal Ministry of Works and Housing FMWH, (1997) for civil engineering construction which is an indication of low water absorption capacities of the soil materials. The results of the geotechnical parameters of the soils obtained indicate good characteristics as construction materials with good bearing strength, good baseline information and foundation design for the establishment of the proposed dam site. .**

Keywords: **Soil Tests, Borehole drilling, Geotechnical Study, Dam Site.**

I. INTRODUCTION

With increasing cases of collapse of engineering structures reported in Kogi state (Adama 2021) and other parts of the country (Olayinka et al., 2017), this has necessitated a detailed investigation of a proposed dam site through the adoption of geotechnical study despite the geophysical investigation survey (Olabode et al., 2021) that was earlier carried out at the same site. More so, geotechnical survey gives true subsurface information and a more reliable result of any investigated site than geophysical investigation which gives apparent subsurface results. The aim of this study is to ascertain the subsoil layer condition of the soil properties that make up the foundation soils in order to establish the dam site project on a competent layer of the subsurface.

A dam is a structure constructed across a river or flowing water body to increase the water level or impede the water from flowing thereby creating a reservoir. An established dam can be used to generate hydroelectricity, flood control, irrigation, recreational activities, fish farming, tourism, regularisation of water flow, navigation etc. Water plays a very important role in life as well as global economy. The livelihood and sustainability of humanity depend largely on availability of water supply (Tanchev 2014, Pedro and Cesar 2017).

The geotechnical test method adopted at the dam site is known as Atterberg Limits which include the liquid limit, plastic limit and plasticity index. The liquid limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dried soil, at the boundary between the liquid and plastic states of consistency. The moisture content at this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together, for a distance of ½ in. (12.7 mm) along the bottom of a groove of standard dimensions separating the two halves, when the cup of a standard liquid limit apparatus is dropped 25 times from a height of 0.3937 in. (10 mm) at the rate of two drops/second.

The plastic limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dry soil, at the boundary between the plastic and semisolid states of consistency. It is the moisture content at which a soil will just begin to crumble when rolled into a thread ⅛ in. (3 mm) in diameter using a ground glass plate or other acceptable surface.

The plasticity index of a soil is the numerical difference between its liquid limit and its plastic limit, and is a dimensionless number. Both the liquid and plastic limits are moisture contents. Plasticity Index = Liquid Limit - Plastic Limit (Geotechnical Engineering Bureau (2015))

1.2 Site Location and Description

The study area is within UTM reading 0829561N and 0894184E (See Figure 2). The site is located at Ijumu Local Government Area, Iyah Gbede of Kogi State. Physiographically, the state is composed of rocky and undulating landscape. The vegetation consists of guinea savanna in the western parts and wooded savannah and grasslands in other parts of the state. The notable trees are Baobab, Akeer-Apple, Shea-Butter and Mahogany. The principal rivers are River Niger and Benue. The two main seasons experienced in the states are the wet and dry seasons. The wet (rain) season starts by April and ends in October; while the dry season commences by November and lasts till March. November - January is also very cold due to Harmattan wind. The project site area has three stream channels; Omodo (I&II) and Apala (See Figure 2). It is accessible through an untarred road. However, the Ijumu Dam Axis is accessible through farm paths undulating with an uneven topography, with thick vegetations surrounding the Dam axis.

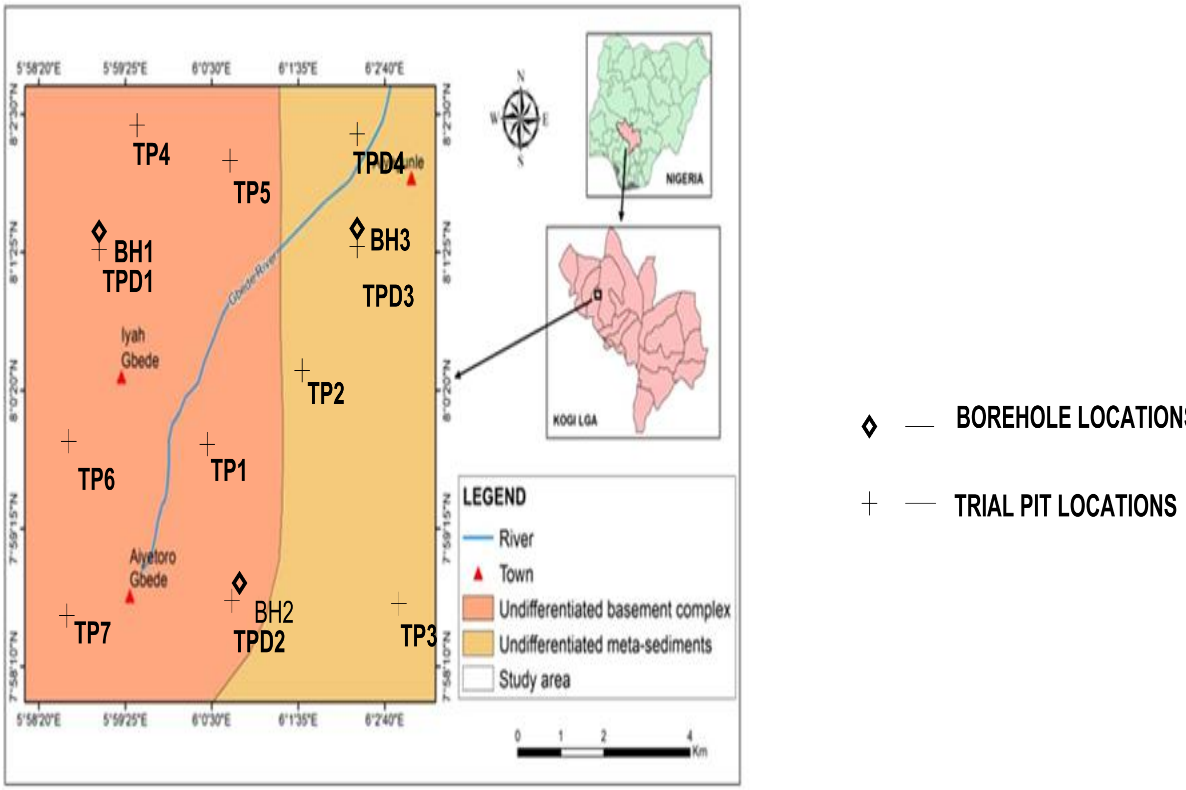


Figure 1: Location of the study area showing the boreholes and trial pits

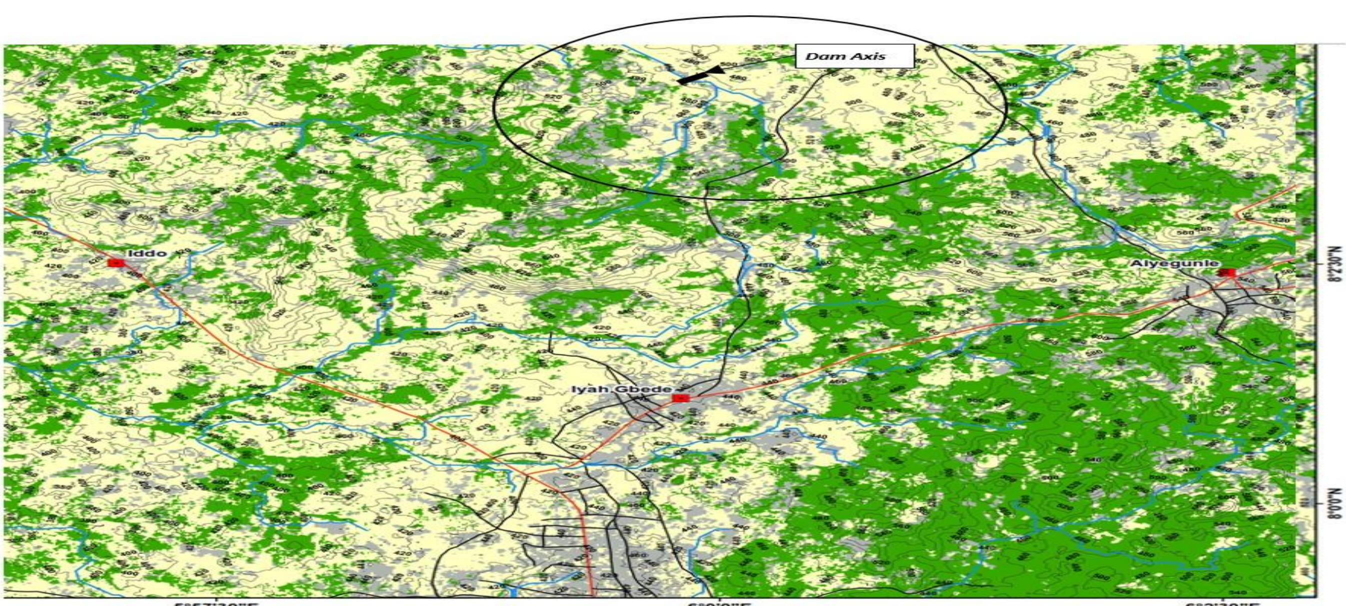


Figure 2: Location Map of the Study Area

1.3 Geology of the Study Area

The study area is mainly underlain by Biotite-Granite as well as Migmatite, amphibolites, coarse grained porphyritic biotite and biotite hornblende granites, Quartz Schists, biotite hornblende granidorites (Figure 3). Field observations indicate that the Basement Rocks have been subjected to many periods of deformation. Nigeria meteorological agency (NIMET 2008) revealed through their climatic data that the study area falls within tropical climate zone which comprises of two unique seasons which are rainy season (April to October) and dry season (November to March). The Migmatite Gneiss in the study area had undergone extensive migmatisation which may have nearly obscured and obliterated many of the earlier structures hence preventing comprehensive measurement and further interpretation of the structural evolution of the area. However, the extent or degree of tectonism is expressed in the occurrence and the magnitude of metamorphism and metamorphic structures of the area such as foliation, minor faults, joints and fractures. Consequently, it is suggested that a deformational episode occurred along with the metamorphism of the various rocks of the mapped area and its environs resulting in varied metamorphic derivatives ranging from the amphibolite facies to higher metamorphic facies condition. These migmatites may have been formed from the metamorphism and metasomatism of fractionated igneous bodies during tectonism. The segregation and migration of the melting minerals such as quartz and feldspar during regional metamorphism resulted in the banding of the leucosome and melanosome minerals. The outcrops and their associated foliation generally trend in NNE–SSW directions.

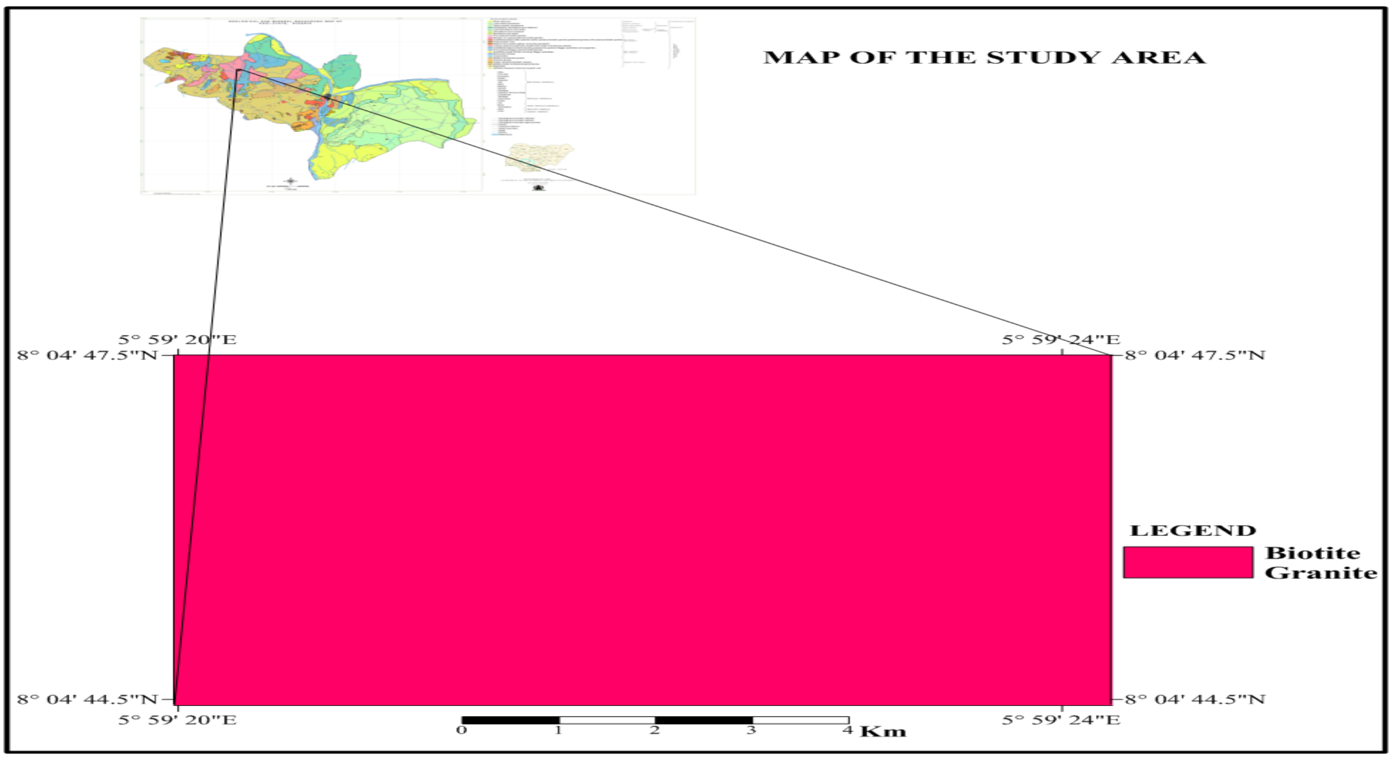


Figure 3: Geological map of the study area

II. METHODOLOGY OF FIELD INVESTIGATION AND LABORATORY TESTS

Geotechnical investigation was carried out on the proposed dam site by exploration boring and soil sampling collected from borrow pit in the study area.

2.1 Trial Pit Test

This involved excavation of eleven (11) trial pits of 1.50 m by 1.50 m deep at the proposed dam site as well as the borrow pit portion. Soil samples consisting of bulk and undisturbed soil samples were taken at depth of 1.50 m below the existing ground level (Plate 1). The undisturbed core samples were used to evaluate the quick undrained tests to determine the angle of internal friction and cohesion.

Plate 1: Pictorial Views of Trial Pits Dug at Proposed Dam Sites

2.2 Exploratory Boring and Soil Sampling

This involves drilling of a vertical borehole in the ground to obtain necessary geotechnical parameters about the sub-soil strata. In this study, five (5) exploratory borings were drilled from ground surface to virtual refusal depth using the percussion / cable-tool drilling that involved shell and auger boring technique. During this operation, soil samples were collected at intervals of 0.75 m for identification purposes and laboratory testing (Figure 1).

Standard Penetration Tests (SPT) was also carried out during the boring operation to obtain the in-situ strength parameters of sandy layers. The SPT involves driving of standard soil sampler by hammering under standardized test conditions into the soil at the bottom of the borehole while taking note of the number of blows, N, required to push the split spoon sampler from a penetrated depth of 150 mm to a depth of 450 mm. After relevant corrections to the N values obtained, the value is considered as reflecting only the influence of compressibility and shear parameter of soil and can then be used for foundation design purposes.

2.3 Laboratory Work

Laboratory tests were carried out (at Fasohog Global Service, Ondo State, Nigeria) on collected soil samples obtained from the boring activity. The tests were carried out in accordance and compliance with the specifications contained in BS 1377; and consist of the following:

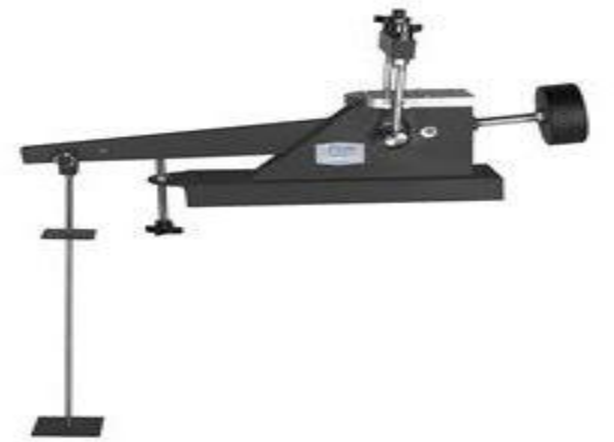
Soil Classification Tests

This was carried out on disturbed soil samples and includes the determination of the natural moisture content, Atterberg indices (liquid and plastic limits) and particle size distribution.

Soil Strength / Compressibility Tests

This involves tri-axial compression test to determine the compressive strength of the undisturbed soil samples, Compaction tests to determine Dry Density and Optimum Moisture Content and consolidation tests to determine the soil compressibility, permeability tests to determine water absorption capacity (Plate 2).

Plate 2: (a) Triaxial shear strength (b) Proctor Compaction and density



(c) Consolidation

(d) Atterberg limits

III. ANALYSIS OF DATA AND TEST RESULTS

It should be noted that for all depths and elevations recorded in this report, the existing ground surface at site was taken as datum.

3.1 Groundwater

Groundwater level around the site was obtained from within the exploratory borings. The level was determined by means of a calibrated rope with weight attached to its tip. Average groundwater level was ascertained at about 3.0 m. Groundwater was encountered during the excavation of trial pit at the proposed borrow pit site (TP1 and TP2) at depth of 1.5m as well as during the boring on the dam site at 4m and 2m at BH1 and BH2 respectively.

However, seasonal variations in groundwater level may occur during or following periods of prolonged wet weather with the possible development of perched water table above the more clayey or indurated layers.

3.2 Description of subsurface lithological layers

Description of the subsurface lithology was derived from results of the exploratory borings and laboratory analyses.

(a) Trial Pit Tests: Four trial pits (TPD1, TPD2, TPD3; TPD4) were obtained in bulk and soil samples to 1.5 m depth at the dam site. The soil profile from ground level beneath to 1.5m is made up of laterites, coarse soils and sandy clays. The soils obtained are in correlations with the samples obtained from the boring within the dam site. This is also equivalent and resultant for the low SPT (N) recorded during boring drilling at shallow depths of 0-3.0 m at BH1, BH2, with an exception at BH3. The soil properties and classifications summary are enlisted below.

Seven trial pits (TP1, TP2, TP3, TP4, TP5, TP6, and TP7) were excavated, sampled and evaluated at proposed borrow pit site. They are made up of beach sands and weathered gravelly materials (Figure 4).

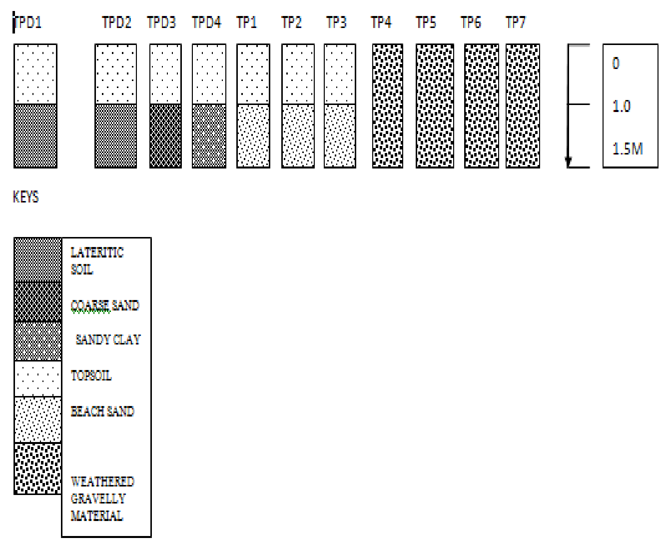


Figure 4: Soil profiles of trial pits within and without dam site

(b) Exploratory Boring Results: A relatively simple and uniform sequence was recorded beneath the study area from ground surface to a depth of about 8.25 m, 5.25 m, and 4.5 m at BH1, BH2 and BH3 respectively, and comprises of:

- Topsoil, Lateritic soil, Grey brown sandy clay, Yellowish brown coarse sand, gravel, Brownish grey fine sand, yellowish brown coarse sand and gravel, Gravel and rock and Weathered rock

A comparison of lithological logs of the boreholes is shown in Figure 5. It was observed that subsurface stratification within the boreholes are similar.

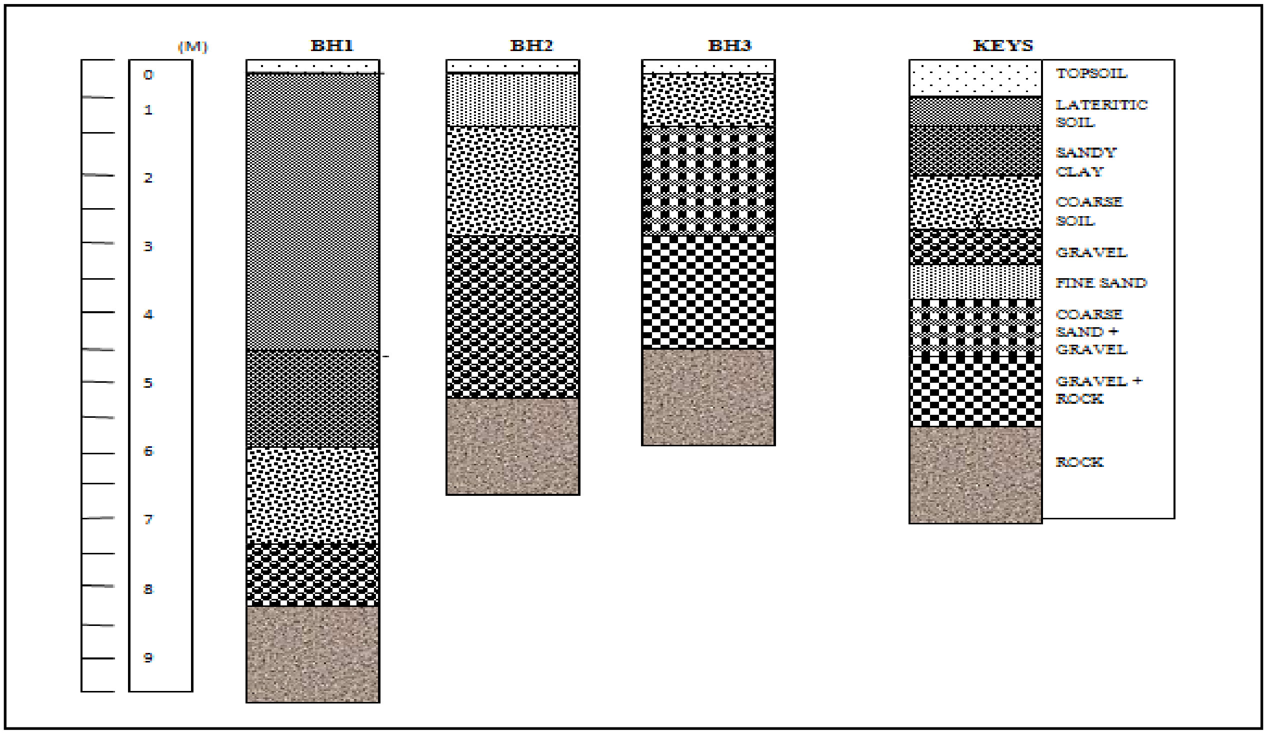


Figure 5: Comparison of Lithological Logs from Boreholes at BH1, BH2 and BH3

3.3 Presentation of Results

The summary of the test result is presented in tables 1 to 5.

Table 1: Dam axis Soil Properties and Borrow Pits for Material Search

Sample Code	Coordinates (Longitude Latitude)	Liquid Limit LL	Plastic Limit Pl	Plasticity Index PI	Linear Shrinkage Ls	Shrinkage Limit	Fine (%)	Coarse (%)	Specific Gravity	Natural Moisture Content (%)
TPD1	08° 32' 458 005 43897	30.8	22.2	8.6	4.3	12.5	24.5	68.2	2.65	10.2
TPD2	08° 33'017 005 45756	33.1	21.2	11.9	4.3	12.5	27.0	72.0	2.67	1.6
TPD3	08° 25' 361 005 35480	20.9	Non-Plastic	-	0.7	14.9	12.7	87.3	2.65	1.6
TPD4	08° 32' 898 005 43584	22.1	19.7	2.4	2.1	13.9	14.1	85.9	2.66	1.6
TP1	08°3 59.288 6°0' 15.426"	20.9	N0n-Plastic	-	1.4	14.4	13.9	86.1	2.66	11.4
TP2	08°3' 59.922 6°0' 15.055	21.2	Non-Plastic	-	1.4	14.4	17.7	82.3	2.67	11.4
TP3	08°3' 59.706 6°0' 13.702	19.3	Non-Plastic		0.7	14.9	13.8	86.2	2.66	6.4
TP4	08°3' 59.119 6°0' 14.954	23.3	21.4	1.9	2.9	13.4	20.3	79.7	2.65	1.6
TP5	08°3'59.073 6°0'13.785	18.9	Non-Plastic	-	0.7	14.9	11.1	84.6	2.66	4.3
TP6	08°3' 59.156 6°0' 13.868	23.9	22.4	1.5	2.9	13.4	19.9	80.1	2.67	10.9
TP7	08°3'59.239 6°0'13.952	27.3	21.5	5.8	3.6	13.0	22.5	72.5	2.65	12.1

Table 2: Soil Classification Summary

Sample code	GPS-Coordinates (Longitude) (Latitude)	Linear shrinkage value (%)	Liquid limit, W_L (%)	Plastic limit, W_P (%)	Plasticity index, PI (%)	% of Soil Passing 2.36mm sieve	% of Soil Passing 425µm sieve	% of Soil Passing 75µm sieve	AASHTO classification
TPD1	08˚ 32' 458 005 43897	4.3	30.8	22.2	8.6	92.7	52.4	24.5	A-2-4
TPD2	08˚ 33'017 005 45756	4.3	33.1	21.2	11.9	99.0	58.8	27.0	A-2-6
TPD3	08˚ 25' 361 005 35480	0.7	20.9	NON-PLASTIC	-	100	54.3	12.7	A-2-4
TPD4	08˚ 32' 898 005 43584	2.1	22.1	19.7	2.4	100	55.7	14.1	A-2-4
TP1	08˚3 59.288 6˚0' 15.426”	1.4	20.9	N0N-PLASTIC	-	100	49.6	13.9	A-1-B
TP2	08˚3' 59.922 6˚0' 15.055	1.4	21.2	NON-PLASTIC	-	100	50.5	17.7	A-2-4
TP3	08˚3' 59.706 6˚0' 13.702	0.7	19.3	NON-PLASTIC		100	52.1	13.8	A-2-4
TP4	08˚3' 59.119 6˚0' 14.954	2.9	23.3	21.4	1.9	100	58.4	20.3	A-2-4
TP5	08˚3'59.073 6˚0'13.785	0.7	18.9	NON-PLASTIC	-	95.7	47.4	11.1	A-1-B
TP6	08˚3' 59.156 6˚0' 13.868	2.9	23.9	22.4	1.5	100	56.7	19.9	A-2-4
TP7	08˚3'59.239 6˚0'13.952	3.6	27.3	21.5	5.8	95	51.6	22.5	A-2-4

Table 3: Soil Properties of Samples Obtained From Borehole within Dam Axis

Code	GPS-Coordinate (Longitude / Latitude)	Depth	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Linear Shrinkage (L.S)	Shrinkage Limit	% of Soil Passing 2.36mm sieve	% of Soil Passing 425µm sieve	% of Soil Passing 75µm sieve	Natural Moisture Content %
BH1	08˚ 25' 852 005 35818	0.05	27.2	22.2	5.02	2.9	13.4	100	62.1		12.4
		0.5	32	22.4	9.6	3.6	13	100	71.2	12.9	12.1
		1.5	33.1	22.6	10.5	3.6	13	100	90.6	12.8	13.3
		2.25	33.9	22.9	11	4.3	12.5	100	58.9	15.0	13.4
		3.00	32.2	21.1	11	4.3	12.5	100	52.3	14.3	14.1
		3.75	32.2	21.3	11.9	4.3	12.5	95.9	32.7	16.7	14.1
		4.50	33.1	21.3	11.8	4.3	12.5	95.8	32.3	17.2	14.2
		5.25	28.2	21.3	6.8	2.9	13.4	95.8	51	16.0	12.3
		6.00	27.2	20.1	7.1	2.9	13.4	100	38.7	14.7	12.2
BH2	08˚ 32' 672 005 44481	0.05	22.9	19.1	3.79	2.1	13.9	100	27.7	7.3	9.1
BH3	08˚ 25' 361 005 35480	0.05	22.1	-	-	10.7	8.2	98.4	47.8	7.5	1.6

Table 4: Coefficient of Consolidation and Compressibility

Sample code	Coefficient of Consolidation(C_v) M^2/ Year	Coefficient of Compressibility (Mv) MPa^{-1}
TPD1	0.01583	0.23340
TPD2	0.01526	0.27083
TPD3	0.01865	0.06133
TPD4	0.01830	0.08148
TP1	0.01574	0.07847
TP2	0.01742	0.09658
TP3	0.01838	0.07686
TP4	0.01680	0.17116
TP5	0.01905	0.03951
TP6	0.01690	0.16469
TP7	0.01629	0.20307

Table 5: Summary of OMC; MDD; Permeability and Quick Undrained Strength

S/N	SAMPLE CODE	OMC (%)	MDD (Kg/m3)	Permeability (K_{20}) cm/s	Degree of permeability	Triaxial	
						Angle of friction (Φ)	Cohesion (c)
1	TPD1	14.4	1902	0.0007295995	Low	37.6	21.2
2	TPD2	14.6	1894	0.0006404790	Low	34.1	44.1
3	TPD3	11.8	2000	0.0023548150	Medium	38.3	14.7
4	TPD4	12.6	1989	0.0021489296	Medium	37.8	22.3
5	TP1	12.4	1976	0.0027890362	Medium	39.8	18.7
6	TP2	13.2	1949	0.0014564967	Medium	37.0	16.2
7	TP3	12.2	1984	0.0029567978	Medium	38.6	13.9
8	TP4	13.8	1926	0.0011953012	Medium	37.0	15.4
9	TP5	11.3	2019	0.0044687967	Medium	40.4	10.7
10	TP6	13.6	1933	0.0013421642	medium	37.3	13.7
11	TP7	14.0	1918	0.0008661985	medium	38.0	15.7

Tables 6: Federal Ministry of Work and Housing Specification Limit for Roads and Bridges revised 1997

Material layer		Test	Specified limits	Desired limits
fill	1.	Plasticity Tests.		
	a.	Liquid limit	(<or=) 80%	(<or=) 50%
	b.	Plasticity index	(<or=) 50%	(<or=) 30
		Maximum 15% pass 0.75		
	2.	Grading Tests		
	a.	Sieve analysis	(<or=) 35% passing 200	
	3.	Density/Moisture content		
	a.	Compaction test	B.S Compaction	
	4.	C.B.R Test		>3% after 48 hours soaking
	5	In-situ dry density test		
		Top 600mm	(<or=) 100% of the MDD in B.S compaction	
		After 600mm	(<or=) 100% of the MDD in B.S compaction	
		Next to structures	(<or=) 100% of the MDD in B.S compaction	
	6.	Thickness: Each layer	(<or=) 150mm compacted thickness	

3.4 Discussion of Result

3.4.1 Laboratory Test (Along Dam Axis)

Particle size analysis carried out on the soil samples of the overburden sand gave the range of gravel fraction to be 0.0 to 14.1%, coarse 50.5% to 91.4%, and fine 7.1% to 49.5% by weight. The index properties of the clayey deposits were investigated by means of Atterberg's Limit test on the samples. The natural moisture content (W) ranged from 14.3% to 16.1%; liquid limit (ll) ranged from 33% to 41%; plastic limit (PL) ranged from 26.5% to 32.5%; while Plasticity Index (PI) ranged from 6.5% to 8.5%. The Linear Shrinkage (L.S) ranged from 4.3% to 10% and the Shrinkage Limit ranges from 8.7% to 12.5%.

3.4.2 Laboratory Test (Off Dam Axis) Borrow Pits

The result of material search from borrow pits gave the range of gravel fractions to be between 3.2- 10%; coarse fraction 44.4 - 68.6%; fine fraction 18.2 – 52.4% by weight. The natural moisture content (W) ranged from 9.1 – 14.3%; Liquid Limit (LL) ranged from 22.9-33.9%; plastic limit (PL) ranges from 19.1 – 22.9%; while Plasticity Index (PI) ranged from 3.8 -11.9%. The Linear Shrinkage (L.S) ranges from 2.1 - 4.3% and the Shrinkage Limit (S.L) ranges from 12.5 – 13.9%.

3.4.3 Discussions / interference dam and borrow pits

From tables 1 to 5 shown above, the Specific Gravity values depicts that the sub-soils are Lateritic soils. The Natural Moisture Content (W) of the analyzed soil samples varied from 1.6 – 12.1% (Table 1). All the soils have average natural moisture content, because it agrees with the average range of (5 – 15%) specified by Federal Ministry of Works and Housing FMWH, (1997) for civil engineering construction. This is an indication of low water absorption capability of the soil materials. The amount of fines (Silt + Clay %) in the soils are found to be lower than the coarse fractions which indicates good material for construction. It also consequently means they have high crushing strength. The plasticity index values (measure of affinity for water) are generally lower than 25, the maximum value recommended for sub-grade tropical Africa Soils. According to Federal Ministry of Works and Housing FMWH, (1997), sub-grade/fill materials should have Liquid Limit ≤50% and Plasticity Index ≤30% while for sub-base, Liquid Limit should be ≤30% and Plasticity Index ≤12% (Table 6). Therefore due to the low values of the plasticity indexes and liquid limits on the table above, the soils can be used as sub-grade materials but not as sub-base materials.

Madedor, (1983) recommended Linear Shrinkage of ≤8% for sub-base and values of ≤10% for sub-grade materials. However, most of the above linear shrinkage values are less than 8%. Therefore, the residual lateritic soils are good sub-grade materials for construction purposes. For any soil to be suitable for general filling and construction of sub-grade and sub-base courses of roads and other structures, the Maximum Dry Density (MDD) must exceed 1700kg/m^3 (Nigerian General Standard Acceptable Limits FMWH, 1997). The best soil for foundation is the soil with the highest (MDD) at lowest Optimum Moisture Content (OMC), (Jegede, 1999). The compaction suggests that the foundation of pavement structures must always be compacted above the MDD and OMC values to yield the maximum strength, to prevent ingress of water and distribute wheel loads uniformly into the pavement structures. 100% of the analyzed field samples conform with the 1700kg/m^3 standard of FMWH and the recommended value of 1810kg/m^3 specified by Nigeria Building and Road Research Institute (NBRRI) for bungalow bricks (Agbede and Manasseh, 2008) and therefore the residual soil has high bearing capacity and can ultimately serve as construction bearers. This trend agrees with the Quick Undrained Strength Tests (Triaxial).

According to the unified soil classification system (USCS), the results obtained from the Shear Box Tests can be used to classify the soils based on angle of friction. A soil having angle of internal friction less than 20˚ are classified as soft, between 20˚ -35˚ are classified as hard and above or greater than 35˚ are classified as stiff. The Shear box tests shows that the soils are of high strength, these values indicate that the soils in the study area have relatively high bearing capacity as a result of their respective high cohesion and relatively high angle of internal friction values.

The borrow pit samples collected for material showed low to medium Plasticity and Compressibility from the soil classification table as well as the Plasticity Index values. This trend also shows in the excellent values of cohesion and angle of internal friction (Table 5). We therefore recommend them as suitable and well drained for the purpose of construction. The permeability results ranged from 6.4×10^{-6} m/s to 4.5×10^{5} m/s. Generally, the degree of Coefficient of Permeability values ranges from low to medium. The suggested maximum coefficient of permeability by various authors is 1×10^{-9} m/s (Oltzschner, 1992; Daniel, 1993 and Rowe 2005).

However, the soil will have high bearing capacity and will be good foundation material for heavy structures. In the compacted state, the soils are expected to possess lower permeability values and can be considered for use in landfill barriers. It is considered that such soils will be useful as fills in embankments and homogenous Dams, as well as in cores of sectioned Dams.

IV. CONCLUSION

A geotechnical investigation for determination of presence of discontinuity beneath a proposed Dam site in Iyah Gbede, Kogi State has been conducted to the maximum depth of 9m.

Particle size distribution analysis of the materials show low fines content for all samples retrieved from the boreholes and trial pits with fines content (clay/silt) varying from 27% in the north to less than 10% in the south of the dam axis. Atterberg limits tests conducted indicate very low plasticity for the materials with a range of about 12 in the north to being non-plastic in sections around the south. Thus, permeability of soils is expected to be considerably high as indicated by permeability values of between 6.4×10^{-6} m/s and 4.5×10^{-5} m/s which are higher than the suggested maximum coefficient of permeability. Other than the high coefficient of permeability, other geotechnical parameters of the soils indicate good characteristics as construction materials with good bearing strength. The soils are shown to have linear shrinkage, plasticity indices, Atterberg limits, maximum dry densities and natural and optimum moisture contents within recommended ranges for suitable materials for road sub-grade and to a lesser degree for road sub-base. Thus, determination of the integrity and competence of the material needs to be further tested by rock coring method.

V. RECOMMENDATION

We recommend that reinforced-raft foundations be placed at depths not less than 1.00m below the existing ground level. The analysis has considered the need not to overstress the sub-soil beneath the foundation and reduce settlement(s) to acceptable limits. The use of reinforce-raft foundations was considered. The results of the analysis and computations indicated that allowable bearing pressure of 120KN/m^2 could be adopted for the design of conventional shallow foundation.

Factor of safety of 3 has been adopted in arriving at the above values. Anticipated total consolidation settlement would be of the order of 40mm; differential settlement of the order of 10mm is anticipated.

REFERENCES

[1] Adama John (2021); Multi-Million Naira Bridge Collapses A Week After Construction In Kogi. Dailytrust https://dailytrust.com/ Multi-Million Naira Bridge Collapses A Week After Construction In Kogi.

[2] Agbede Olufemi and Manasseh Joel (2008); Use of Cement-Sand Admixture in Laterite Brick Production for Low Cost Housing. Leonardo Electronic Journal of Practices and Technologies 7(12)

[3] BS 1377 (1975). Methods of Tests for Soils for Civil Engineering Purpose, British Standard Institution HMSO London.

[4] Daniel, D. E., 1993. Clay Liners. In: Geotechnical Practice for Waste Disposal (Daniel D.E ed). Chapman Hall, London, U.K, 137-163.

[5] Federal Ministry of Works and Housing (1997). General Specification for Roads and Bridges, Volume II, Federal Highway Department, FMWH: Lagos, Nigeria, 317 p.

[6] Geotechnical Engineering Bureau (2015), Geotechnical Test Method, Department of Transportation, State of New York, GTM 7, Revision 2 Pg 1-6

[7] Jegede G (1999). Engineering Geological Significance of the Superficial Deposits in Carrington Hill Area, Country Conc, Ireland. Nig. J. Sci. 28:153-158.

[8] Madedor AC (1983). Pavement Design Guidelines and Practice for Different Geological Area in Nigeria. In: Ola SA (Ed) Tropical Soil of Nigeria in Engineering Practice. AA Balkema Rotterdam, pp. 291-297.

[9] NIMET (2008). Nigeria Climate Review Bulletin 2007. Nigerian Meteorological Agency. NIMET-No. 001.

[10] Oltzschner, H., 1992. Anforderin an die Geologic, Hydrogeologie Und Geotechnik beim Bau von Deponie. In: THORME-KOZMIENSKY KJ (eds), Additictung Von Deponien and Altlastlen. E. F. Verlag fiir Gnergie und Umwelttechnik combit, Borlin. 53-82.

[11] Olabode O.O, Oyanameh O.E, Dorcas Idowu, Korode A.I, and Osisanya O.W (2021): Application of One Dimensional

Geophysical Investigation on Proposed Dam Project, iyah Gbede, kogi state, Nigeria. Journal of Applied Geology and Geophysics (IOSR-JAGG) Volume 9, Issue 1 Ser. 1(Jan-Feb. 2021) pg 12-20.
[12] Olayinka C. O , Abiodun S. O , Ayodeji Ogunde , Opeyemi Josuha and Daniel O. B (2017): Incessant Building Collapse in Nigeria: A Framework for Post Development Management Control
[13] Pedro L.C. and Cesar A. M (2017); Geophysical Investigation of earth dam using the electrical tomography resistivity technique. Geosciences Geociências. https://www.researchgate.net/publication/312569653
[14] Rowe, R. k., 2005. Long-term performance of contaminant barrier systems. Geotechnique. 55, (9): 631-678.
[15] TANCHEV, L. Dams and appurtenant hydraulic structures. (2° ed.). London: Taylor & Francis Group, 1073. p., 2014.