Geo-Technical and Geophysical Investigation for The Completion of Farin Ruwa Multipurpose Dam, Nasarawa State, Nigeria.

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Abstract- This soil investigation was carried out for the completion of Farin Ruwa multipurpose Dam to ascertain the engineering properties of the soil on which the Dam and the spillway were to be built and recommendation of the foundation type. The sub-surface investigation was carried using standard penetration test (SPT), a total of Sixteen boreholes were bored to refusal at between 1.5m to 10.5m with 7Nos from spillway, and 9Nos from dam axis, Deep coring was done on the main dam embankment. Water levels were recorded and samples recovered were carefully identified and taken to laboratory for tests and analysis, test result on soil samples showed permeability ranging from. 0.0490m/s to 0.0630/s (spill way zone) and 0.0430m/s to 0.0630m/s (also from dam axis) with an average of 0.0540m/s at depth 3.0-3.6m describing the drainage condition as poorly drainage situation, earth bearing pressure ranged from 166.27kn/m^2 to 340.06kn/m^2 at depth 3.0 – 3.6m (spill way zone) and 156.99kn/m^2 to 363.06kn/m^2 at depth 3.0m – 3.6m (Dam axis), percentage of fine (75km) ranged from 1.30% to 54.50% at depth < 4.6 – 5. 1m (Spill way zone) and generally low percentage of fines were encountered within the dam axis. The result of the soil investigation showed that sub-surface soil conditions are of generally fairly poor drainage condition (low seepage) an added advantage to earth dam. Allowable bearing pressure lies between 85.60kN/m^2 at depth 1.5-2.1m and 191.17kN/m^2 at depth 4.6-50m and recommended use of compacted clay material to be used as core material which should be embedded with embankment fill material, lateritic soil of enhanced property at depth not loss than 5.1m on the dam axis and coring to ascertain the presence of fractures, rock type and other strength properties.

I. INTRODUCTION

1.0 GENERAL STATEMENT

Dams are hydraulic structure that retains water by virtue of their weights, they range from small to large dams, concrete to earth dams. The serviceability life of dam/reservoir depends on the provision of efficient and effective control structure (spillway). These are important mechanism based on the fact that damming an entire water shed is not feasible, thus, damming specific quantity of water for specific purpose and any excess be safely, released and discharged through control structure (spillway).

Soil investigation is vital to hydraulics structures for stability and seepage control in both gravity and earth dam. The soil investigation was carried out by boring of Sixteen number (16no) standard penetration test SPT holes to refusal which ranged from 1.5m to 10.66m. Samples recovered from various boreholes and at respective depths were physically identified and taken to laboratory for further tests and design data vital in the design of hydraulics structures was generated based on each test administered.

1.1 SCOPE OF WORK

Geo-technical investigation was carried out with a view to assessing soil characteristics at varying depths from shallow over burden deep down to the underlying sedimentary rock formation. The process therefore involved the following field and laboratory operations as outlined below. The laboratory analyses was done in conjunction with Jasa Anis Geo-technical Consultants in Kaduna.

Boring of Sixteen (16) numbers of boreholes with Standard Penetration Test (SPT) and recovery of samples at every 1.5m and to a depth ≤ 20m or refusal.

i. Field identification of soil samples based on visual inspection and in line with basic technical approach concerning soil classification prior to a more comprehensive identification and classification using such parameters as related to index properties.
ii. Odour and organic matter inspection also to be carried out for further assessment of possible presence of deleterious substances that adversely affect concrete strength or earth monotholicity which may results in strength deterioration even with application of highest earth bearing pressure factor.

Laboratory tests conducted are as follows:

a. Grain Size Distribution
b. Atterberg Limit
c. Natural Moisture Content
d. Shear Box
e. Specific Gravity
f. Consolidation
g. Permeability
h. Chemical test (pH, sulphate content)

The tests were carried out with all precautionary measures and in conformity with the standard method of soil testing for Civil Engineering BS 1377 part 2 and 3 of 1990.

1.2 OBJECTIVES OF THE INVESTIGATION

Geo-technical soil investigations in addition to hydrological and geological information are key to dams and reservoir studies and design, therefore the objectives of this investigation are as follows:

- Determination of physical and geological soil characteristics vital for detailed and concise soil classification at varying depths.
- Determination of shear strength parameters vital for soil shear strength determination at varying soil depths.
- Determination of drainage and seepage condition of soil vital for reservoir and dams design.
- Determination of settlement and stability potential of soil under hydro static pressure.
- Determination of potential deleterious substances that might endanger sub-structures.

1.3 LOCATION AND ACCESS

The site is located at Kwarra/Mangar of Wamba Local Government area on 411276f and 003666n 48.γm as last border community to Bokos, Plateau State. The site is accessible through Sisinbaki/Chessu/Fadan Karshi road from Wamba in Nasarawa State. By road i.e accessibility to site is only by road at the present.

II. GENERAL PHYSIOGRAPHY, PRESENT STATE OF THE SITE AND SOIL EXPLORATION

The site is located at Kwarra/Mangar – Farin Ruwa Kwara area of Wamba Local Government in Nasarawa State and last community border with Jos, Plateau State. The out crust in the site exhibit characteristic material dominant of rocky and hilly undulations granite typical of Jos, Plateau in geologic formation.

Generally, the area lithologies are characterized by coarse grained lateritic soil, silty clayey sand and granite shale. Vegetation, typical of partly plateau and partly thick forest, palm tree and sparse cassava plantations and coco yam are some of active preoccupation and occasional hunting by hunters in the community.

2.0 GEOLOGY AND TOPOGRAPHY

Manger in Wamba Local Government is border community to Jos, Plateau shared common geologic formation of typical Jos, plateau. Characterized by rocky and hilly formation with vegetative cover ranging from tress to shrubs and grass land. The area lies between 41124 6E, 003666N, and 48.γm is also characterized with marked raining and dry season typical of northern Nigeria. Detail geology of the dam site will be explained under the geophysics.

Generally, soil investigations are carried out preparatory to a major construction work of such a magnitude as dams and reservoirs to reduce the excessive wastage of construction materials (economy) and by far safety to structure, serviceability, and life of people, animals and farm lands which are the recipient of ultimate dam structural failure and dam collapses (Rao 2002).

An efficient and effective design of dams, reservoirs relies on efficient and effective soil investigation to adequately provide necessary design parameters by either, trial pit or boring method, and Standard penetration test. The later was adopted in this investigation.

2.1 STANDARD PENETRATION TEST BORING METHOD

Probably, a more advanced and advantageous method over trial pit, boring involved hammer load to a rod connected to a spoon sampler through a defined height operating by precaution to a depth beneath the ground level with sampler enabling soil collection with varying depth at recorded number of blows. This method is fully described in the relevant pages and figures in the report.

III. GEOTECHNICAL INVESTIGATION AND METHODOLOGY

3.0 GENERAL

The sub-surface soil investigation was based on geotechnical studies by conducting Standard Penetration Test (SPT) to ascertain the sub-soil characteristics at varying depths along dam axis and spillway channel which will be useful in dam design and dam break studies. Soil samples were collected, identified and taken to laboratory for further tests and analysis. Water levels were usually considered and noted during boring.

3.3 STANDARD BORING TEST

A total of sixteen (16 Nos.) Standard Penetration Tests were carried out at Kwarra/Mangar – Farin Ruwa Dam, with seven (7 nos.) along the spillway centre line and nine (9 nos.) along the dam axis with three each from secondary dam 1 and 2,and main dam to refusal which ranged between 1.5m to 10.5m. Water tables were encountered at varying depths.

This was carried out in accordance with the project specification and compliance to standard method of soil investigation. Disturbed soil samples were carefully identified and taken to laboratory for further tests and analyses. This boring was achieved using a cat head drilling rig equipped with 4" casing 65.5kg hammer and from a drop of 750mm height (page 6-24Figure 2 section of the report). The geology and lithology of each bored hole are also presented further in the relevant section of this report (Figure 1a, 1b and 2a to 2d[l]).

3.3 LABORATORY TESTS

The soil samples recovered from the field during standard penetration tests were subjected to relevant laboratory tests and analyses as outlined by the scope and specifications as contained also in the project and contract terms and are itemized below:

a. Natural Moisture Content
b. Specific Gravity
c. Atterberg Limit
d. Consolidation
e. Shear Box
f. Sieve Analyses
g. Permeability
h. Compaction
i. Chemical Test (PH and Sulphate)

The tests were with a view to identifying and determining soil characteristics as it affects dams and reservoir especially drainage / seepage condition and dam stability and were carried out in accordance with the standard methods of soil testing for Civil Engineering BS 1377 part 2 and 3 of 1990 and ASTM. Detailed results of all laboratory tests and parameters as it affects dams and reservoirs are presented in Table 4.10 – 4.16, others are 4.17 – 4.19.

IV. DETAILED SUMMARY OF TEST RESULTS CONDUCTED ON SOIL SAMPLES AND RELEVANT DESGIN PARAMETERS

4.0 GENERAL

The sub-soil investigation was carried out with a view to establishing physical property of soil strata at varying depth in order that a suitable foundation type and right material are used based on acceptable soil property in achieving slope stability and maximum seepage control as it applies to dams and reservoirs.

4.1 DESIGN PARAMETERS

In view of the project variability and area spread, an average of area zones was used in assessing respective earth bearing pressure for stability and seepage potential for optimum utilization of dam capacity. These are the spillway, secondary dam 1 and 2 and main dam with the main dam providing possible hydro – use while secondary dam 1 and 2 possible water supply and irrigation practice.

4.2 DESIGN PARAMETERS AND EMPIRICAL FORMULAE

The major objectives of carrying out soil investigation prior to any construction work is to conduct detailed study both on the field and in the laboratory to obtain relevant design parameters and data, for subsequent computation of soil bearing pressure, soil classification and soil drainage condition for optimum utilization of dam / reservoir capacity. This is also based on other hydrological investigation from the area of study in the catchment area. Most widely used analytical equations are based on Terzeghi equation.

4.3 TERZEGHI DESIGN EQUATION AND DESIGN DATA

In this presentation, Terzeghi analytical Net equation for square footing was used with an appropriate safety factor of 2.5 as follows:

q net = 1.3 C NC + ƔƻNq - 1 + 0.4 BƔ NƔ

Where:
q net = Net ultimate bearing capacity
C = Cohesion of soil
Ɣ = Bulk density or unit weight of soil
ƻ = Depth of soil strata under consideration B = Breadth of the footing
NC, Nq NƔ = bearing capacity coefficients based on ø
Ø= Angle of internal friction

The useful design parameters are presented in the subsequent section of this report.

q safe / allowable = q net / FOS + Ɣƻ
where:
q net = net bearing capacity
Fos = function of safety
Ɣƻ = as defined above in equation

Table 4.1 Detailed Summary Test Results on Soil Samples, classification test

S/NO	REHOLE NO.	MPLE NO.	EPTH (M)	% PASS 7	% SAND	MOISTURE NTENT (%)	SPECIFIC GRAVITY (g/Cm^3)	REMARKS
1	BH – 01	01	0.0 – 1.5	12.30	87.70	45.27	2.60	Over burden of law present fines and medium moisture content
2	BH – 01	02	1.5 – 2.1	37.90	85.60	20.20	2.77	
3	BH – 02	01	0.0 – 1.5	56.90	43.10	24.08	2.62	
4	BH – 02	02	1.5 – 2.1	44.00	66.00	28.04	2.81	
5	BH – 03	01	0.0 – 1.5	12.50	87.50	20.60	2.53	
6	BH – 03	02	1.5 – 2.1	65.50	35.50	23.88	2.59	
7	BH – 04	01	0.0 – 1.5	1.40	98.60	24.54	2.60	
8	BH – 04	02	1.5 – 2.1	35.70	64.30	26.23	2.92	
9	BH – 04	03	3.0 – 3.6	2.80	97.20	23.60	2.71	
10	BH – 05	02	1.5 – 2.1	3.40	96.60	22.54	2.72	
11	BH – 05	03	3.0 – 3.6	45.50	54.5	18.71	2.47	
12	BH – 05	04	4.6 – 5.1	60.80	39.20	22.99	2.54	
13	BH – 06	01	0.0 – 1.5	10.40	89.60	35.11	2.65	
14	BH – 06	02	1.5 – 2.1	2.70	97.30	22.67	2.65	
15	BH – 07	02	1.5 – 2.1	64.80	35.20	33.03	2.40	
16	BH – 07	03	3.0 – 3.6	30.60	69.40	21.34	2.72	
17	BH – 07	04	4.6 – 5.1	30.60	69.40	21.34	2.72	
18	BH – 08	02	1.5 – 2.1	27.20	72.80	20.46	2.71	
19	BH – 08	03	3.0 – 3.6	73.30	26.70	27.76	2.56	
20	BH – 08	04	4.6 – 5.1	1.30	98.70	28.08	2.80	
21	BH – 09	01	0.0 – 1.5	15.30	84.70	12.68	2.85	

22	BH – 09	02	1.5 – 2.1	25.30	74.70	15.54	2.50	
23	BH – 10	02	1.5 – 2.1	9.40	90.60	20.25	2.50	
24	BH – 10	03	3.0 – 3.6	39.80	60.20	16.46	2.78	
25	BH – 10	04	4.6 – 5.1	16.60	83.40	21.45	2.76	
26	BH – 11	02	1.5 – 2.1	34.10	65.90	25.37	2.68	
27	BH – 11	03	3.0 – 3.6	0.90	99.10	36.51	2.53	
28	BH – 11	04	4.6 – 5.1	42.00	58.00	27.25	2.69	
29	BH – 12	02	1.5 – 2.1	35.30	64.70	20.92	2.69	
30	BH – 12	03	3.0 – 3.6	1.60	98.40	25.71	2.50	
31	BH – 12	04	4.6 – 5.1	1.30	98.70	31.21	2.69	
32	BH – 13	02	1.5 – 2.1	57.40	42.60	36.14	2.18	
33	BH – 13	03	3.0 – 3.6	65.10	34.90	25.36	2.73	
34	BH – 13	04	4.6 – 5.1	58.50	41.50	27.95	2.75	
35	BH – 14	02	1.5 – 2.1	56.20	43.80	16.57	2.43	
36	BH – 14	03	3.0 – 3.6	34.90	65.10	35.03	2.50	
37	BH – 14	04	4.6 – 5.1	21.50	78.50	13.19	2.55	
38	BH – 15	02	1.5 – 2.1	19.10	80.90	14.25	2.62	
39	BH – 15	03	3.0 – 3.6	32.40	67.60	15.04	2.83	
40	BH – 15	04	4.6 – 5.1	12.60	87.40	22.09	2.60	
41	BH – 16	02	1.5 – 2.1	15.60	84.40	16.48	2.68	
42	BH – 16	03	3.0 – 3.6	3.00	97.00	16.09	2.42	
43	BH – 16	04	4.6 – 51	24.90	75.10	16.09	2.94	

Table 4.2 Detailed Summary Tests Results Index Property.

S/No	rehole No.	mple No.	Depth (m)	Liquid Limit LL (%)	Plastic Limit PL (%)	Plasticity Index PI	REMARKS
1	BH – 01	01	0.0 – 1.5	12	9	3	Low Plasticity Low Plasticity
2	BH – 01	02	1.5 – 2.1	13	9	4	
3	BH – 02	01	0.0 – 1.5	14	8	6	
4	BH – 02	02	1.5 – 2.1	13	8	5	
5	BH – 03	01	0.0 – 1.5	19	10	9	
6	BH – 03	02	1.5 – 2.1	20	10	10	
7	BH – 04	01	0.0 – 1.5	14	10	4	
8	BH – 04	02	1.5 – 2.1	12	9	3	
9	BH – 04	03	3.0 – 3.6	12	10	2	
10	BH – 05	02	1.5 – 2.1	13	8	5	
11	BH – 05	03	3.0 - 3.6	15	10	5	
12	BH – 05	04	4.6 – 5.1	13	8	5	
13	BH – 06	01	0.0 – 1.5	14	9	5	
14	BH – 06	02	1.5 – 2.1	13	7	6	
15	BH – 07	02	1.5 – 2.1	14	6	8	

16	BH – 08	02	1.5 – 2.1	14	10	4	
17	BH – 08	03	3.0 – 3.6	14	9	5	
18	BH – 08	04	4.6 – 5.1	17	10	7	
19	BH – 09	01	0.0 – 1.5	13	9	4	
20	BH – 09	02	1.5 – 2.1	15	9	6	
21	BH – 10	02	1.5 – 2.1	14	9	5	
22	BH – 10	03	3.0 – 3.6	13	9	4	
23	BH – 10	04	4.6 – 5.1	12	8	4	
24	BH – 11	02	1.5 – 2.1	14	9	5	
25	BH – 11	03	3.0 – 3.6	15	8	7	
26	BH – 11	04	4.6 – 5.1	13	9	4	
27	BH – 12	02	1.5 – 2.1	14	9	5	
28	BH – 12	03	3.0 – 3.6	18	9	9	
29	BH – 12	04	4.6 – 5.1	14	7	5	
30	BH – 13	02	1.5 – 2.1	14	7	7	
31	BH – 13	03	3.0 – 3.6	13	7	6	
32	BH – 13	04	4.6 – 5.1	14	9	5	
33	BH – 14	02	1.5 – 2.1	13	9	4	
34	BH – 14	03	3.0 – 3.6	11	8	3	
35	BH – 14	04	4.6 – 5.1	12	9	3	
36	BH – 15	02	1.5 – 2.1	14	7	7	
37	BH – 15	03	3.0 – 3.6	14	8	6	
38	BH – 15	04	4.6 – 5.1	15	9	6	
39	BH – 16	02	1.5 – 2.1	10	8	2	
40	BH – 16	03	3.0 – 3.6	13	6	7	
41	BH – 16	04	4.6 – 5.1	14	8	6	

Table 4.3 Detailed Summary Tests Results on soil samples drainage conditions.

S/No	rehole No.	mple No.	epth (m)	(Permeability)	Av. Drainage at 3.0 .6 drainage condition
1	BH – 01	01	0.0 – 1.5	0.0630	
2	BH – 01	02	1.5 – 2.1	0.0630	$6.3x10^{-2}$
3	BH – 01	03	3.0 – 3.6	0.0630	
4	BH – 02	01	0.0 – 1.5	0.0490	
5	BH – 02	02	1.5 – 2.1	0.0630	$5.8x10^{-2}$
6	BH – 02	03	3.0 – 3.6	0.0630	
7	BH – 03	01	0.0 – 1.5	0.0630	
8	BH – 03	02	1.5 – 2.1	0.0490	

9	BH – 03	03	3.0 – 3.6	0.0630	$6.3x10^{-2}$
10	BH – 04	01	0.0 – 1.5	0.0490	
11	BH – 04	02	1.5 – 2.1	0.0490	$5.8x10^{-2}$
12	BH – 04	03	3.0 – 3.6	0.0630	
13	BH – 05	01	0.0 – 1.5	0.0630	
14	BH – 05	02	1.5 – 2.1	0.0490	$5.8x10^{-2}$
15	BH – 05	03	3.0 – 3.6	0.0630	
16	BH – 06	01	0.0 – 1.5	0.0630	
17	BH – 06	02	1.5 – 2.1	0.0630	$5.8x10^{-2}$
18	BH – 06	03	3.0 – 3.6	0.0630	
19	BH – 07	01	0.0 – 1.5	0.0490	
20	BH – 07	02	1.5 – 2.1	0.0630	$6.3x10^{-2}$
21	BH – 07	03	3.0 – 3.6	0.0630	
22	BH – 08	01	0.0 – 1.5	0.0490	
23	BH – 08	02	1.5 – 2.1	0.0630	$5.8x10^{-2}$
24	BH – 08	03	3.0 – 3.6	0.0630	

Table: 4.4 Summary of Test Result on Samples Earth Bearing Pressure

S/No	rehole No.	ampl e No.	epth (m)	Cohesion C (KN/m^2)	Angle ^{O}(DEGREE)	BULK DENSITY (KN/m^3)	NC	Nq	NƔ	qnet (KN/m^2)	qsafe (KN/m^2)
1	BH – 01	03	3.0-3.6	42	2.0	2.04	6.10	1.14	0.02	334.09	174.39
2	BH – 02	03	3.0-3.6	30	3.0	1.88	6.30	1.22	0.04	246.97	129.13
3	BH – 03	03	3.0-3.6	40	3.0	1.91	6.30	1.22	0.04	340.06	176.91
4	BH – 04	03	3.0-3.6	17	4.0	1.90	6.51	1.30	0.055	145.96	79.49
5	BH – 05	03	3.0-3.6	22	4.0	1.98	6.51	1.30	0.055	188.37	101.32
6	BH – 06	03	3.0-3.6	24	3	1.91	6.30	1.22	0.04	198.10	105.93
7	BH – 07	03	3.0-3.6	25	4	2.01	6.51	1.30	0.055	166.27	90.37
8	BH – 08	03	3.0-3.6	24	5	1.92	6.74	1.39	0.074	216.71	115.27
9	BH – 09	03	3.0-3.6	28	4	1.83	6.51	1.30	0.055	238.98	126.18
10	BH – 10	03	3.0-3.6	20	4	1.74	6.51	1.30	0.055	171.18	91.85
11	BH – 11	03	3.0-3.6	34	4	1.74	6.51	1.30	0.055	289.66	151.09
12	BH – 12	03	3.0-3.6	27	4	1.73	6.51	1.30	0.055	230.41	121.43
13	BH – 13	03	3.0-3.6	33	4	1.88	6.51	1.30	0.055	280.70	147.12
14	BH – 14	03	3.0-3.6	28	4	1.83	6.51	1.30	0.055	236.96	126.08
15	BH – 15	03	3.0-3.6	15	9	2.00	7.74	1.82	0.20	156.99	85.60
16	BH – 16	03	3.0-3.6	36	3	1.69	6.30	1.22	0.04	296.21	154.19
17	BH – 01	04	4.5-5.10	29	4	2.07	6.51	1.30	0.055	248.64	134.88

18	BH – 02	04	4.5-5.10	22	5	1.72	6.74	1.39	0.074	195.24	105.79
19	BH – 03	04	4.5-5.10	22	5	1.54	6.74	1.39	0.074	195.87	105.79
20	BH – 04	04	4.5-5.10	27	5	2.01	6.74	1.39	0.074	240.63	130.57
21	BH – 05	04	4.5-5.10	31	5	2.01	6.74	1.49	0.074	275.69	148.09
22	BH – 06	04	4.5-5.10	31	6	1.68	6.97	1.30	0.10	285.20	150.77
23	BH – 07	04	4.5-5.10	32	4	1.71	6.51	1.30	0.055	273.46	145.45
24	BH – 08	04	4.5-5.10	24	4	1.81	6.51	1.30	0.055	205.92	112.19
25	BH – 09	04	4.5-5.10	30	5	1.74	6.74	1.39	0.074	266.37	142.06
26	BH – 10	04	4.5-5.10	23	5	1.80	6.74	1.39	0.074	205.16	111.76
27	BH – 11	04	4.5-5.10	31	6	1.71	6.94	1.49	0.01	285.23	151.34
28	BH – 12	04	4.5-5.10	41	5	1.89	6.74	1.39	0.074	363.06	191.10
29	BH – 13	04	4.5-5.10	32	5	2.02	6.74	1.39	0.074	284.46	152.53
30	BH – 14	04	4.5-5.10	35	5	2.07	6.74	1.39	0.074	310.85	155.98
31	BH – 15	04	4.5-5.10	34	3	2.01	6.30	1.22	0.04	280.75	150.62
32	BH – 16	04	4.5-5.10	32	4	2.10	6.51	1.30	0.055	274.07	147.75

Table 4.5 Detailed Summary Test Results Conducted on Consolidation

Boring No.	Sample No. / Depth		Consolidation Test Data																				
			ΔP 0 – 25			ΔP 25 – 50			ΔP 50 – 100			ΔP 100 – 200			ΔP 200 – 400			ΔP 400 – 800			ΔP 800 – 1600		
			Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv
BH – 05	04	4.50 – 5.10	0.0558	1.6575	1.5482	0.0840	0.7513	1.0277	0.1113	0.3050	0.7761	0.1291	0.1038	0.6688	0.1363	0.0201	0.6337	0.1361	-0.0079	0.6345	0.1320	-0.0154	0.6543
BH – 10	04	4.50 – 5.10	0.0548	1.4838	1.4483	0.0819	0.6456	0.9682	0.1058	0.2588	0.7497	0.1224	0.0591	0.6481	0.1266	0.0005	0.6265	0.1255	-0.0150	0.6323	0.1220	-0.0162	0.6500
BH – 11	04	4.50 – 5.10	0.0599	1.6138	1.4373	0.0913	0.6981	0.9428	0.1186	0.2934	0.7253	0.1374	0.0963	0.6261	0.1448	0.0177	0.5944	0.1445	-0.0115	0.5955	0.1395	-0.0196	0.6169
BH – 12	04	4.50 – 5.10	0.0580	1.7413	1.3853	0.0897	0.7544	0.8950	0.1184	0.3159	0.6781	0.1387	0.1028	0.5788	0.1470	0.0159	0.5462	0.1469	-0.0115	0.5955	0.1395	-0.0196	0.6169
BH – 13	04	4.50 – 5.10	0.0564	1.7888	1.4379	0.0898	0.7256	0.9023	0.1172	0.3113	0.6916	0.1362	0.1111	0.5950	0.1446	0.0220	0.5602	0.1419	-0.0115	0.5709	0.1380	-0.0191	0.5871

BH – 14	04	4.50 – 5.10	0.0656	1.2975	1.5954	0.0765	0.5638	1.0962	0.0963	0.2281	0.8714	0.1074	0.0875	0.7811	0.1110	0.0250	0.7491	0.1118	-0.0026	0.7501	0.1083	-0.0117	0.7744

NOTE: P = Applied Pressure (KN/m^2)
Cv = Coefficient of Consolidation (m^2/yr)
Cc = Compressibility – Index
Mv = Coefficient of Volume Compressibility (m^2/KN)

Table 4.5.1 Detailed Summary Test Results Conducted on Consolidation

oring No.	Sample No. / Depth		Consolidation Test Data																				
			ΔP 0 – 25			ΔP 25 – 50			ΔP 50 – 100			ΔP 100 – 200			ΔP 200 – 400			ΔP 400 – 800			ΔP 800 – 1600		
			Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv	Cv	Cc	Mv
BH – 15	04	4.50 – 5.10	0.0574	1.4050	1.4259	0.0853	0.6031	0.9595	0.1088	0.2428	0.7523	0.1153	0.0781	0.6637	0.1203	0.0114	0.6330	0.1196	-0.0071	0.6380	0.1251	-0.0160	0.6594
BH – 16	04	4.50 – 5.10	0.0501	1.4263	1.5287	0.0748	0.6075	1.0238	0.0948	0.2550	0.8073	0.1078	0.0844	0.7101	0.1126	0.0139	0.6801	0.1119	-0.0104	0.6842	0.1161	-0.0173	0.7098

4.0 ANALYSIS ON PARTICLE SIZE DISTRIBUTION AND OTHER RELATED CLASSIFICATION PARAMETER

4.0.1 Spillway Zone

The total number of seven boring carried out on this zone for possible of wave which will regulate flow at this channel section, refusals were encountered at depth ≤ 1.5m and soil proportion of fines range from 1.30% to 64.50% around BH 7 at depth ≤ 4.6m to 5.1m and BH 3 at ≤ 1.5m to 2.1m. the formation showed intermittent values from low to over burden as granulated and firmly stable in view of its cohesiveness. Natural moisture content ranged from 18.71% to 45.27% at BH 5 depth ≤ 3.0m – 3.6m and BH4, depth 0-1.5m and corresponding to center line with the dam axis. Specific gravity were uniform at between 2.40 to 2.81.

4.0.2 Dam Axis

The dam axis zone consisting of nine boring made up of two secondary dams proposed for domestic and agricultural purposes. Fine proportions were usually seen as low. Highly compacted granulated granite shall predominate in the main dams axis proposed for hydro – generation zone. This is seen as advantage in creating monolothicity in borrowed filled material in relation to the existing soil formation, specific gravity also ranged from 2.42 to 2.85, Natural Moisture condition stood at between 12.68% to 36.14%. they are generally classified as low to medium Moisture content.

4.1 Analyzing of Drainage Condition and Seepage Potential

Dams and reservoir studies and investigation are usually concerned with the ability of the structure to retain and conserve water to its optimum designed capacity, this is only achieved if the seepage and drainage conditions are checked and kept within allowable levels.

4.3.1 Spillway Zone

Tests results on falling head permeability showed permeability ranging from 0.0490m/s to 0.0630/s with the average at between 0.058m/s and 0.068m/s for BH

5, BH6 and BH7 at depth ≤ 1.5m analyzing on the result showed that it has poor drainage condition which is good in water conservation.

4.3.2 Dam Axis

Permeability values ranged from 0.0430m/s to 0.0630m/s with the averages standing at between 0.0540m/s at depth 3.0 – 3.6m and 0.0630m/s also seen as fairly poor drainage condition but that the right material be used especially at the center of the embankment filled borrowed material to be embedded at depth ≤ 4.6 – 5.1m for maximum utilization of dam design capacity.

4.4 Analysis of Earth Bearing Pressure

The stability performance of load carrying structure relies on its ability to accommodate loading without share failure. stability of dams and reservoirs are based on their ability to withstand hydro-static/ water thrust as primary function among other things. Terzeghi analyses among square footing was used in estimating the over burden respective bearing pressures as follows:

- Net ultimate bearing capacity

1.3C NC + Ɣƻ Nq - 1 + 0.4 BƔ NƔ

- Allowable beaing capacity

q net / FOS + Ɣƻ

Where:

C = cohesion (kn/m^2)

Ɣ = bulk density of soil in Kn/m^3

ƻ = over burden depth in (m)

B = bread of foundation footing (m)

F.O.S = function of safety (assumed)

Nc, N q and N Ɣ bearing capacity coefficient cared are based on Ø

4.4.1 Spillway Zone

Earth bearing pressures as completed based on Terzeghi net ultimate bearing pressures showed over burden bearing pressures ranging from 166.27KN/m^2 to 340.06KN/m^2 at BH7 depth 3.0 – 3.6m and BH3 depth

3.0 – 3.6m. The allowable earth bearing pressure from 90.37KN/m^2 to 176.91KN/m^2 for the bore stated above under same conditions. Results showed soil condition at depth ≤ 3.0m.

4.4.2 Dam Axis

Earth bearing pressure ranged from 156.99KN/m^2 (BH16 at 3.0 – 3.6m) to 363.06 KN/m^2 (BH12 at 4.6 – 5.1m) the minimum values was recorded at around main dam axis proposed for hydro – generation and maximum around the secondary dam 1 proposed for domestics and irrigation purposes. Around the main dam axis there is fluctuating bearing pressure and occasional sample from depth (no recovery conditions in view of porous nature of materials believed to be already long aged borrowed materials). The earth bearing pressure generally increases with depth in the dam axis zone.

Analysis on index property completive effort, earth bearing pressure and drainage condition i.e seepage control depends on soil index property. A good engineering soil should be well graded and not gab-graded to meet the need of any constructional objectives test conducted on soil samples from both spillway and dam axis showed over burden as low in plasticity as liquid limit ranged from 11 – 20, plastic limit from 7 – 10 and plasticity index from 3 – 10%.

V. MAJOR FINDINGS AND CONCLUSIONS

The results of geotechnical soil investigation conducted for the completion of Farin Ruwa dam, Nasarawa state, Nigeria has the followings as major findings and conclusions.

1. The sub-surface soil drainage condition were generally fairly poor drainage condition i.e low to medium permeability which ranged from 0.0430m/s to 0.0630m/s in both explored zones comprising of spillway and dam axis.
2. Earth bearing pressures ranging from 156.99kn/m^2 at depth 3.0 – 3.6m and 4.6m to 5.1m all within the dam axis (BH16 at 3.0 – 3.6m and BH12 at 4.6 – 5.1m)
3. Allowable/safe earth bearing pressure generally for the explored sites stood at between 85.60KN/m^2 and 191.17KN/m^2.
4. The explored site exhibits material characteristics of generally rocky sand as evident even from the undulating rocky/hilly out crust dominated by fractured granite shale. This ranged from 1.30% to 64.50%
5. Natural moisture condition of the explored site also stood at between 18.71% and 45.27%, specific

gravity as between 2.40 to 2.81

6. Index property, general sub-soil characteristics could be described as low in both spillway and dam axis as values ranged from LL 11 – 20, PL 7 – 10, and PI 3 – 10.

VI. RECOMMENDATIONS

1. In view of poor drainage condition exhibited by the over burden in the explored boreholes a core material of good drainage i.e highly compacted clayey material of low permeability to be embedded by lateritic soil of adequate strength property at depth not less 3.6m is to be used to control mild seepage tendency.
2. At the spillway zone where regulatory flow control structure are expected to be put in place, high grade concrete 40 at depth ≤ not less than 1.5m is recommended. (this is subject to the type of hard rock encountered at refusal during boring).
3. Mat/Raft foundation is recommended around the spillway
4. For maximum utilization, borrow materials of enhanced property are to be used.
5. Coring in addition to all four-going suggestion is hereby recommended in order to have a clear view of the underlying rock type, presence of possible fracture within rock (which will promote high permeability i.e seepage) and other properties associated with strength and stability

REFERENCES

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