iJST EXPLORE International Journal of Science and Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-7318

Journal of Science and Technology Volume 1 No. 6, June, 2012

Preliminary Investigation of a Proposed Dam Site along River Ome, Ago Iwoye South Western Nigeria

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ABSTRACT

Soil investigation was carried out at a proposed dam site across River Ome in Ago Iwoye, southwestern Nigeria to investigate the depth to bedrock, possible geologic structures, foundation conditions of the dam axis, abutments and choice of best location for construction of dam.

Six Vertical Electrical Soundings (VES) were carried along the river course and this was done using Schlumberger configuration. Evaluation of the engineering properties of the soil was carried out for twelve samples collected across the river using atterberg limit, grain size analysis, California Bearing Ratio (CBR) and compaction characteristics of the soils.

The geophysical result showed three geo-electric layers; top sandy layer, clay and weathered/fresh basement. Analysis of the atterberg limit shows a dominance of inorganic clay size particles with high plasticity and moisture content while the grain sizes analysis reveals well graded gravelly clayey silty sand. The soil type classification, CBR and compaction values obtained showed some significant agreement.

The values of river discharge were computed during dry and wet seasons and this showed that the magnitude of flood to be averted will pose no challenge on the selection of spillway type. The integration of these methods helped in the choice of location for the dam axis.

Keywords: *Vertical Electrical Soundings (VES), Dam Axis, River Discharge, Grain Size Analysis, Compaction.*

1. INTRODUCTION

Increasing water consumption is causing a lot of problem to the dwellers of Ago Iwoye, southwestern Nigeria and this is due to rapid increase in population and their various domestic and agriculture purposes; hence, saving water of rainfall and groundwater has therefore become one of the prime objectives of the area.

Although different measures are being put in place by individual to alleviate this water scarcity, it however cannot still meet up to the demand of the population. Such measures include collection of rain water, digging of shallow well and borehole but this has not been able to guarantee a perennial availability of water for the majority of the population. The effective and risk free use of water resources for present and future generations should be a common objective for all societies (Du Preeze, 1964 and Aina and Adedipe, 1996) and should not be left for individual alone.

This problem however can be overcome by construction of a dam site which has been proposed across the River Ome in this area, so as to harness the potential of the river for domestic and agricultural purposes. River Ome is perennial river that traverse Ago-Iwoye area, flowing from northeast to southwest of the area. The evaluation of dam sites among many other parameters includes stability studies, simulation of the probable maximum flood (PMF) and uplift pressures under the dam (Guy and Lund, 2006), depth to bedrock, stratigraphic continuity, structural mapping, stability studies (Hunter et al. 2011). Studies have shown that the engineering properties of soils improved through compaction and/or addition of other soils with better properties (Ogunsanwo, 1989; Adedeji, 2002; Adeyemi and Salami, 2004). Movement of water through soils depends on two factors: the forces acting upon the water molecules and the ease with which they can flow through the soil. These factors vary from one soil to another, depending on the amount of organic matter of the site and arrangement of mineral particles which is by size and number of pores where water can be held (Bouma, 1977). In soils with large, irregularly shaped sand particles, for example, large pores remain between the sand grains. Clay particles, by contrast, fit together more compactly so that the pores are smaller but numerous.

The purpose of the study is to carry out preliminary appraisal of the location for the proposed dam and its ancillaries. It is also to determine the foundation conditions of the abutments, possible location of the dam axis and the feasibility of using the site for dam works.

Much attention will be paid on the nature of the foundation conditions of the dam axis and abutments. Considerable attention will also be paid on the rate of stream flow during the wet and dry season so as to determine the type of spillway needed that will consequently affect the magnitude of the dam to be constructed on the site. The design of an appropriate foundation type and depth will be based on certain geophysical and geotechnical parameters obtained from sample collection in the field and laboratory analysis relevant to the design.

2. THE LOCATION AND THE GEOLOGY OF THE STUDY AREA

The study area is located in Ago Iwoye Southwestern Nigeria between latitudes $6^0 55^1$ N and $6^0 58^1$N and longitudes $3^0 53^1$E and $3^0 55^1$E. It is bounded to the West by Moborode Community and to the North by Ita-Ereke village (Figure 1). The main access to the proposed domestic dam site is via un-tarred roads constructed by villages in the bid to access the stream for water supply. The topography of the area is highly influenced by the basement rocks because the terrain is generally undulating, characterized by low lying massive outcrops.

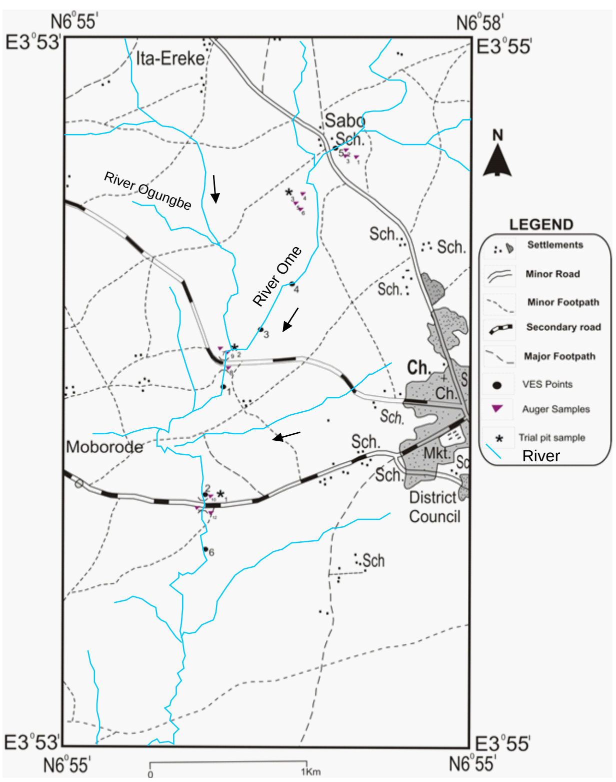

Figure 1: The Location of the Study Area showing the sampling locations and VES Points.

Drainage pattern is predominantly dendritic and the vegetation of the area falls under the tropical rain forest belt of Nigeria (Adeyemi and Salami, 2004).

Ago-Iwoye is underlain by crystalline rocks of the Precambrian Basement Complex of Nigeria, consisting mainly of gneisses, pegmatite and granites (Bouma, 1977, Onakomaiya et al., 1992, Oyawoye, 1972). The area investigated composed mainly of banded gneiss and biotite gneiss (Figure 2), and are covered by shallow overburden of between 2 to 20m. The orientations of the joints and foliations measured in the field showed that they are predominantly NE-SW direction.

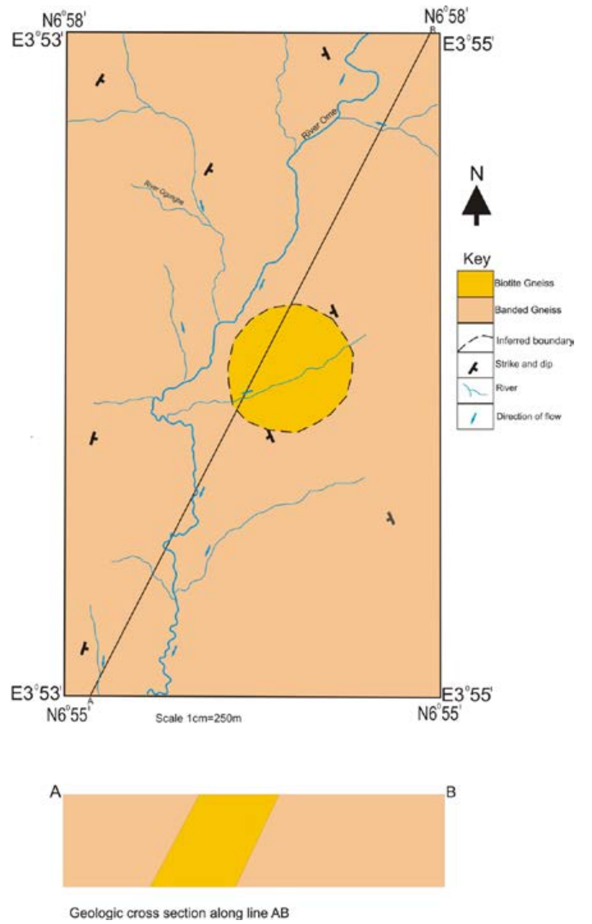

Figure 2: The Geological Map of the Study Area

3. METHODOLOGY

The method of investigation employed in this work is divided into three phases; geological, geophysical and geotechnical investigations of the proposed dam site. This involves reconnaissance survey, which helped in familiarization of the area and also in the location and observation of outcrops, sample collection and labeling.

The Geophysical investigation involves the use of Vertical Electrical Sounding (VES) method. The Schlumberger array was carried out at six different points along the river as shown in figure 3.

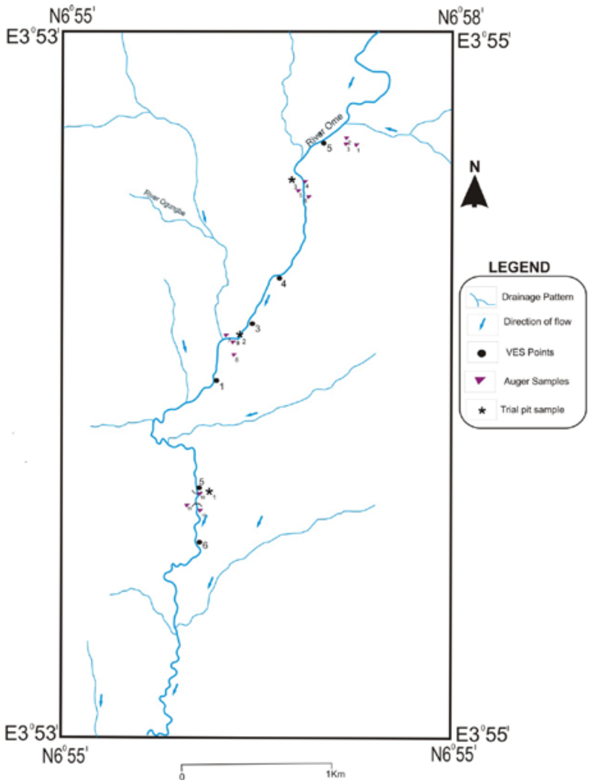

Figure 3: Drainage pattern of the Study Area showing sampling location and VES points

ABEM SAS 300 terrameter was used with a maximum current electrodes spacing (AB) of 100m due to the nearness of the underlying basement to the surface. The field data obtained was the resistance (R) and the apparent resistivity (ρ_a) was obtained by multiplying the resistance by its various geometric factor (G) i.e. $\rho a = GXR$. The values obtained were then plotted on a log-log paper as points with the resistivity values being on the vertical axis and the electrode spacing (AB/2) on the horizontal axis. The points were joined and curve matched manually using pre-calculated master curves and their auxiliaries. The results obtained from the exercise were used as the input-model for the eventual computer aided iteration. The iteration was done using WINRESIST program. The result obtained will aid in the characterization of the lithology and the overburden thickness.

The geotechnical method involves collection of representative soil samples from all the test locations as well as collection of disturbed sample for engineering test. The soil is subjected to some analysis to obtain relevant engineering parameters for foundation design.

The geotechnical properties of soil tested for include Grain size distribution, Hydrometer analysis, Consistency limit (Atterberg limit), and Shear strength characteristic (California Bearing Ratio (CBR)). For the compaction characteristics, three trial pits at a depth of about 1.6m was dug (Figure 4).

Figure 4: Trial pits for compaction analysis taken at depth of about 1.6m.

River discharge calculation was done and the first step in making a convectional measurement of river discharge is to select a measurement cross section of desirable qualities. If the stream can be waded, the hydrographer looks for a cross section of channel meeting as many of the following criteria as possible as proposed in Chow, (1964), and Sagadah et al., (1997):

a. Cross section lies within a straight reach and streamlines are parallel to each other.
b. Velocities are greater than 0.5ft/s (0.15m/s) and depths are greater than 0.5ft (0.15m).

c. Streambed is relatively uniform and free of numerous boulders and heavy aquatic growth.

d. Flow is relatively uniform and free of eddies, slack water and excessive turbulence.

e. Measurement section is relatively close to the gauging station control to avoid the effect of storage between the measurement sections during periods of rapidly changing stage.

After the cross section has been selected, the width of the string is determined. A tag-line or measuring tape is strung at right angles across the measurement section. A proportionate uniform length is also determined. The flow rate is determined using the time taken and the distance covered.

$$Stream\ flow\ rate = \frac{\text{Length of River Traverse}}{\text{Time Taken}}$$

$$Discharge = Cross\ sectional\ Area\ X\ Stream\ Flow\ Rate$$

4. RESULTS AND INTERPRETATION

4.1 Geophysical Investigation

The plots of the results of the apparent resistivities of the geophysical studies carried out in the study area shows that the VES curves in this area are predominantly H-type curve ($\rho_1 > \rho_2 < \rho_3$) and A-type curves ($\rho_1 < \rho_2 < \rho_3$), there is also occurrence of KH-type curve ($\rho_1 < \rho_2 > \rho_3 < \rho_4$). A typical example of this curve is shown in Figure 5. For the 3 geoelectric layer curves (i.e. H and A-type curve) in this area, the computed resistivity values of the first geoelectric layer, range from 40 to 465 Ωm and the thickness ranges from 0.5m to 2.1m. The second layer has resistivity range of 58 to 339 Ωm and the thickness range of 3.4 to 14.7m while the third layer has resistivity range of 920 to 1761 Ωm. The geoelectric layers observed in this area with their computed resistivity values, layer thickness and their inferred lithology are presented in Table 1.

The reflection co-efficient of the area was calculated as done by Chow, (1964), Sagadah et al., (1997), Olorunfemi and Okhue, (1992), Bayewu, (2009) and Olayinka, (1996). This is expressed by $r = \frac{(\rho n - \rho n-1)}{(\rho n - \rho n+1)}$), where ρ_n is the resistivityof the last layer (i.e. the basement) and ρ_{n-1} is the resistivity of the layer overlying the last layer. This revealed that the reflection coefficient of the last geoelectric layers in the study area ranges between 0.64 and 0.93. This is indicative of fractured basement to fresh basement.

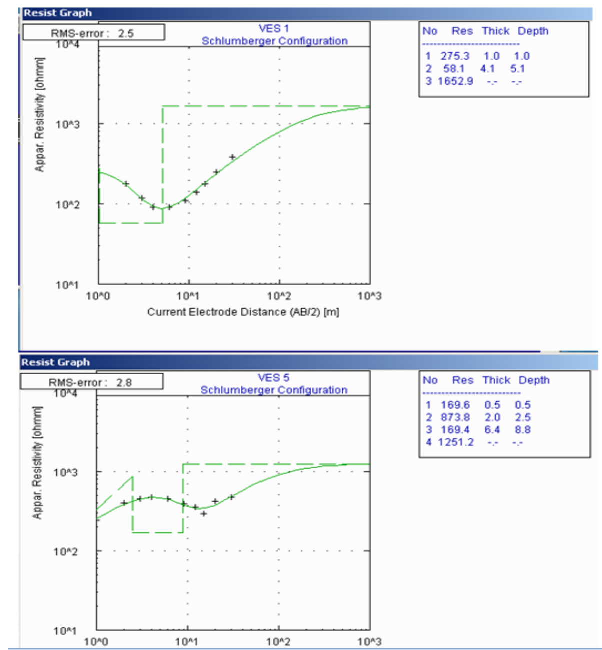

Figure 5: A typical VES Curve in the study area for VES 1 and 5

Table 1: Interpretation of VES Curves along River Ome in the study area.

Location	Layer No.	Curve Type	Resistivity (Ohm-m)	Depth to interface(m)	Layer thickness(m)	Inferred Lithology
L_1	1	H-type	275.3	1	1	Top sand layers
	2		58.1	5.1	4.1	Clays
	3		1652.9	-	-	Fresh Bedrock
L_2	1	H-type	131.3	1.8	1.8	Top sand layers
	2		205.8	13.8	12	Sands
	3		970	-	-	Weathered bedrock
L_3	1	H-type	340.3	1.7	1.7	Top sandy layer

	2		60.5	5.1	3.4	Clays
	3		1672.3	-	-	Fresh Bedrock
L_4	1	H-type	464.8	2.1	2.1	Top sandy layer
	2		213.4	8.5	6.4	Sands
	3		920.1	-	-	Weathered Bedrock
L_5	1	KH-type	169.6	0.5	0.5	Top sandy layer
	2		873.8	2.5	2	Rock fragments
	3		169.4	8.9	6.4	Sands
	4		1251.2	-	-	Fresh Bedrock
L_6	1	A-type	40.3	0.5	0.5	Top sandy layer
	2		338.9	15.2	14.7	Sands
	3		1761	-	-	Weathered Bedrock

The geo-electric section across the area is shown in Figure 6. This shows that the area has three distinct geoelectric sections; the thin sandy topsoil which spreads across the section, with a thickness range of 0.5 to 2.1m. This layer is underlain by weathered materials that are sandy in nature except for the central part which is clayey (i.e. at VES 1 and 3), in this layer, the thickness increases at the northeastern and southwestern part and decreases towards the center. The range of resistivity of this layer varies from 58 ohm-m to 873 ohm-m, with a thickness range of 3.4m to 12m. Underlying this layer is the fractured/fresh basement with resistivity range of 970.8 to 1761.0 ohm-m.

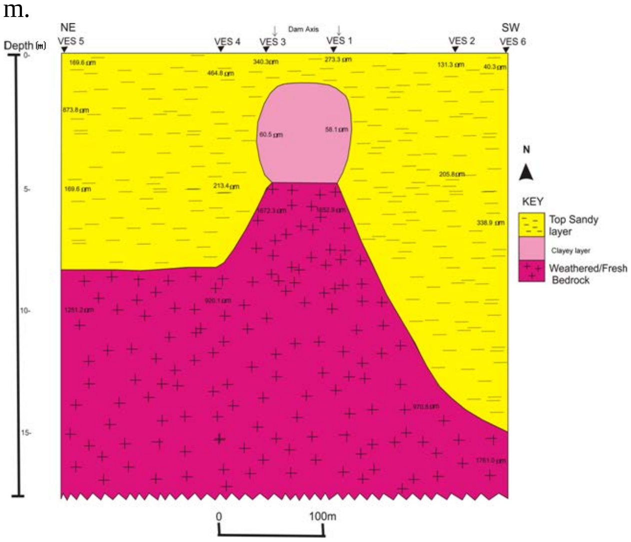

Figure 6: The Geo-electric Section of the study area showing the possible location of the dam axis

4.2 Geotechnical Investigation

The plot of Grain size distribution is shown in fig 7 and this shows that the soil samples are well graded. The permeability is calculated using the formula of Rahaman, (1976) i.e. $K=Cd_{10}^2$ where K = permeability in mm/day C = Hazen's constant which is approximately 0.0116 d_{10} = Effective size.

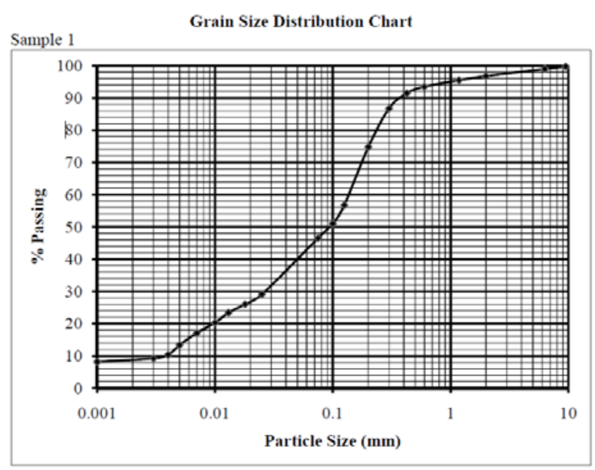

Figure 7: A typical plot of Grain size Distribution in the study area

The results obtained in this work is presented in Table 2, the permeability ranges from 0.00003 to 0.25cm/sec (i.e. 2.9 x 10^{-9} to 2.9 x 10^{-5} mm/day). The values obtained in this area are lower than the results of Rahaman, (1998) which has permeability range of 0.09 to 24.88 cm/sec. This might be due to the different geology of the two areas.

The results of the Atterberg limit tests carried out on the disturbed auger bored soil samples obtained from the field at depth of about 30cm were plotted on the Casagrande chart with the plasticity index on the ordinate axis and the liquid limit on the abscissa (Figure 8). The plastic limit varies from 19% to 46.3 % with an average value of 30% and the liquid limit ranges from 38 % to 75.1% with an average value of 56.3%. The plasticity index ranges from 4% to 46.8% with an average value of 26.1%.

Table 2: Grading Characteristics of the Soil Samples showing the Permeability Results

Sample	C_u	C_k	D_{10}^2(mm)	K(mm/day)	K(cm/sec)	Grading type
1	73.3	0.95	0.000009	1.04×10^{-7}	0.0009	Well-graded
2	-	-	-	-	-	-
3	83.3	4.03	0.000009	1.04×10^{-7}	0.0009	Well-graded
4	66.7	0.375	0.000012	1.42×10^{-7}	0.0012	Well-graded
5	35	1.35	0.000064	7.42×10^{-7}	0.0064	Well-graded
6	6.2	2.85	0.0025	2.9×10^{-5}	0.251	Well-graded
7	488.9	23.3	0.00000025	2.9×10^{-9}	0.00003	Well-graded
8	-	-	-	-	-	-
9	125	3.2	0.000004	4.7×10^{-8}	0.00041	Well-graded
10	-	-	-	-	-	-
11	58.3	1.19	0.000016	2.67×10^{-7}	0.0023	Well-graded
12	14.28	0.38	0.000018	2.05×10^{-7}	0.0017	Well-graded

The outcome of the test using the Unified Soil Classification System (USCS) shows a relatively high concentration of clay an inorganic soil type which ranges from intermediate to very high plasticity. The inorganic soil or clay falls above the A-line in the plot below while the ones that fall below the A-line are classified as the organic type or silt.

The results of the compaction test from the samples from the trial pits showed that the materials are silty or clayey gravel and sand which also corresponds to the result obtained from other test performed (i.e. consistency limit test and grain size analysis). The maximum dry density ranges from 1780-1960 kg/m^3 with an average value of 1871 kg/m^3. The optimum moisture content ranges from 10.5-15.3% with an average value of 12.6%. This result quite agrees with that obtained through geophysical prospecting of the study area.

The CBR. values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the CBR value at 2.5 mm will be greater than that at 5 mm and in such a case the former shall be taken as CBR for design purpose. If CBR for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the CBR corresponding to 5 mm penetration should be taken for design (BS 1377, 1990).

According to the classification table below, it can be deduced, taking the higher values (at both soaked and unsoaked conditions) that the soil of the study area as previously shown by other laboratory test performed is sandy clay to well graded sand.

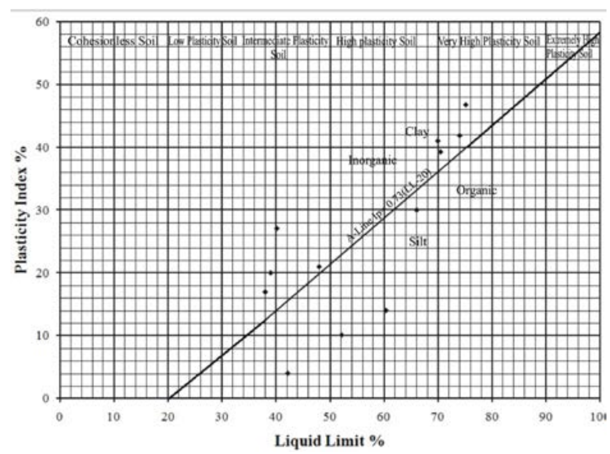

Figure 8: The Casagrande Chart for the Plasticity Interpretation in the study area

4.3 River Discharge Calculation

After carefully taking into consideration the procedure for discharge determination, the results of the river discharge were recorded during the dry and wet season (Table 3 and 4). The result presented for each location is the average discharge value for each sampling point. The flow direction of the river is North-south.

Table 3: River discharge during dry season in the study area

Location No.	Sampling depth below stream surface(m)	Cross-sectional Area (m^2)	Time measured (s)	Velocity of flow (m/s)	Discharge (m^3/day)
1	3.5	117	227	0.057	16.0
2	3.0	104	234	0.056	15.2
3	2.0	150	250	0.06	18.7

Table 4: River discharge during wet season

Location No.	Sampling depth below stream surface(m)	Cross-sectional Area (m^2)	Time measured (s)	Velocity of flow (m/s)	Discharge (m^3/day)
1	5.7	194	50	0.30	2332.8
2	5.0	180	65	0.23	1051.2
3	3.5	256	80	0.19	592.6

It can be observed that the discharge rate during the wet season is very high compared to the dry season. Hence, this allows for the determination of the spillway type. (Spillway types are dictated primarily by the run-off and stream flow characteristics, independent of site conditions or size of dam) and this showed that the magnitude of flood to be averted will pose no challenge on the selection of spillway

It should be noted that the selection of specific spillway types are influenced by the magnitude of the floods to be by-passed (ICOLD, 1986).

5. DISCUSSION

Choosing the best site for dam construction was based on findings of the three methods employed. The intensity of fracturing plays an optimum role in speculating the best location for the dam site. Geophysical and geological investigation of the area provided such information, as bedrock characteristics (nature) was computed through the availability of reflection co-efficient data of the bedrock. Field conditions of rock fracturing were observed such as joints, fractures (Geological Society of London 1977) and hence revealing the intensity of weathering and fracturing of the subsurface rocks. The intensity of fracturing and joints aperture should be as low as possible (Sagadah and Sen, 1992). This was the condition observed within the study area.

The nature of the material found between VES point 1 and 3 is sand and sandy clay. The permeability values (0.00003cm/sec and 0.251cm/sec), compaction values (MMD-1780kg/m^3 and OMC-15.3%) and the CBR values taking penetration at 2.5mm (Soaked: top- 5, bottom-5 and Unsoaked: top-20, bottom-20). Comparing this with the geophysical investigation result which revealed the geo-electric section of the different layers (Top sandy soil, clay lens and weathered/fresh bedrock), it can therefore be inferred that the best position suitable for the location of the dam axis within the study area is between VES point 1 and 3. It should also be noted here that part of the criteria for choosing this point for the location of the dam axis is the nearness of the area subsurface to fresh basement.

6. CONCLUSION

The result of the site investigation carried out at the study area using geological, geotechnical, geophysical and structural condition of the soil and rock masses in the upstream portion of the site reveals that the site stratigraphy is capable of supporting the dam and its ancillaries. The grain size analysis and compaction test carried out on the soil of the area show that the materials of the area has low water intake, hence, good for dam construction and will also be capable of supporting the structure superimposed on it. The discharge values obtained in the study area both during the dry and wet season will not pose any challenge as to making decision on the magnitude of dam to be constructed or spillway type.

This preliminary study however will give a major insight in the consideration of this River Ome for dam site and this will help in the alleviation of the water shortage in the area, thereby making the area more conducive for settlement and other purposes.

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