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Geotechnical Investigation for The Proposed Booster Station at Wuntin Dada Bauchi State, Nigeria

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Abstract-* Geotechnical as well as geophysical investigation methods were used to provide information for the assessment of the subsurface soil at BOOSTER STATION proposed site at Wuntin Dada near Abubakar Tatari Ali polytechnic gate. Percussion drilling was used to drilled the boreholes to the depths of 4 m and disturbed soil samples were obtained from the boreholes for different laboratory tests at the site. Natural moisture content, specific gravity, Atterberg Limits, Triaxial tests and Permeability Test were conducted. Borehole numbers 1, 2 and 3 have percentages of fines less than 10 %, this indicates that the influence of fine content is negligible on their engineering properties. The grain size analysis of the samples indicates that the total fine content ranges from 1.5 - 20 %, Sand 52.5 – 86.8 %, and Gravel 2.9 – 46.0 %. These values account for the moderate permeability values (1.76 ×10^{-6} – 3.50×10^{-6}). The OMC was 5.90 - 13.00 % while MDD range was 1.77 - 2.01 Mg/m^{3}. The soils' cohesion ranges from 8.0 kN/m^{2} to 75.0 kN/m^{2} and the angle of internal friction range between 25^{o} to 35^{o}. with these values, the range of computed bearing capacity was 222 – 1132 kN/m^{2}. The results of particle size distribution analysis indicate that very negligible consolidation settlement should be expected. It finally concluded that the material is of high quality with regard to strength and the integrity of the foundation.

***Indexed Terms-* Compaction, Consistency, Triaxial tests, Permeability**

I. INTRODUCTION

Geotechnical investigation is of prime importance prior to constructing any structure on ground as the load of structure is eventually transfer to soil beneath and it is necessary for soil to withstand this load during the life of structure (Neville, 2012). In field of construction geotechnical engineering is one of main pillars. Geotechnical engineering covers soil investigation, geotechnical designs and study of soil behavior under different conditions (Vasavi *et al.*, 2016). In geotechnical investigation different properties of soil are determined with the help of different tests and techniques (Phani - Kumar and Sharma, 2004). Determining soil behavior and its properties is quiet difficult as there is not any method that can give exact behavior of soil, all method which are used to predict the behavior up to certain accuracy on the basis of practices and experiences. Soil characteristics like bearing capacity, maximum dry density, Moisture content, specific gravity, particle size distribution, settlement, consolidation and Atterberg's limits gives almost every necessary information of soil which is required for safe designs and other usages (Das, 2009). By proper geotechnical investigation and designing, there is a big opportunity of capital saving as the design will be based on real time data and will be economical as some time the client use heavy foundations, walls and other elements of the structure for safety purpose (Ranjan & Rao, 2000). It also has much importance in highways and motorways as the most important thing to be consider in design of highways are the moisture base on which the drainage work of highways are decided. The drainage of an area is dependent upon the soil type. Types of Foundation of structures are selected keeping in view the soil type and conditions. Inappropriate and Poor design of foundation may lead to structural failures, so a good design of foundation basing on site investigation and laboratory test results is the first step in building construction.

II. GEOLOGY OF THE AREA

The first site is located within the Bauchi township near the gate of Abubakar Tatari Ali Polytechnic Latitude 10.3129 and Longitude 9.7720. The second site is located at Miri village, latitude 10.3121 and longitude 9.7425 along Bauchi-Jos Road. Both sites lie within the tropical climatic zone with marked wet and dry season called the Sudan Savannah vegetation belt, neighboring outcrop of igneous rocks of basaltic origin which is referred to the lithological name of charnokite and Bauchite on the geological mapping of Bauchi. As a result of many years of weathering, and decomposition in a tropical environment, the soil has transformed in some places, to a laterite soil with seems of cementitious oxide of hard pan. However, at the site, the underlying rock seems to have decomposed, leaving a relatively hard material that has a gravelly texture mixed with some fine material.

Figure 1: Showing the Map of Bauchi State

During the present geotechnical investigations, a total of 4 bore holes were sunken, at site No.1, and total of eight (8) disturbed soil samples were collected from the bored holes within the proposed site for visual inspection and laboratory investigation. The samples were collected from depths of 2.0 m to 4.0 m (one sample per 2.0 m depth from each of the bored holes). At site 2, two bole holes were drilled to depths of 3.0 m and two samples were recovered, one from each of the drilled holes. The approximate locations of bored holes at the site (site 1) is shown in Figure 2, and typical log of bore holes are presented in Figure 2.

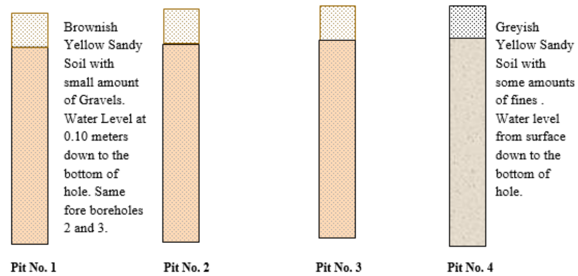

Figure 2: Showing the soil horizontal profiles for all the Five Trial pits

III. MATERIALS AND METHODS

3.1 Geotechnical Investigations

The geotechnical Investigations carried out involved samples collections, which were obtained by hand percussion drilling for laboratory analysis to investigate the parameters such as Atterberg Limits, soil classification, moisture-density relationship, shear strength parameters, permeability and ground water level.

3.1.1 Soil Sampling

Percussion drilling was used to drill the bore holes for disturbed sampling. The recovered soil samples were first subjected to visual field inspection where samples from each of the bored holes were compared to determine the possibility of merging some for the purpose of selecting representative samples per bored hole. Based on the initial field classification, 2 No. samples were selected from each bored hole for laboratory testing and further analysis amounting total a total of 10 samples, 8 soil samples and 2 rock samples.

The samples were used for the determination of Compaction, Specific gravity, Atterberg's Limits and Triaxial Shear tests. Table 1 below shows the location of the drilled boreholes from which the samples were recovered.

3.1.2 Groundwater Level Observation

Ground water levels were measured in the bore holes by observing the level of water within the drilled holes; as the samples looked saturated/ brought out of the holes together with water. The groundwater was observed at depths ranging between 0.10 m to 0.40 m respectively.

3.2 Laboratory Analyses of Samples

The samples were passed through the following laboratory tests and the results are as presented in section four below. The laboratory tests conducted on the samples included.

1. Particle Size Analysis
2. Atterberg's Limit Tests
   a. Liquid Limit (LL)
   b. Plastic Limit
   c. Linear Shrinkage
3. Compaction Test
4. Specific Gravity
5. Triaxial Compression Test
6. Direct Shear Test
7. Permeability

All tests were conducted in accordance with the British Standard, BS 1377 (1990)

3.3 Approach to Selecting Parameters

After the subsurface exploration and laboratory testing programs are complete, soil and/or rock parameters need to be selected in order to perform the necessary geotechnical design calculations/analyses. Selecting these parameters must be done using a logical, systematic approach and must be documented in the appropriate geotechnical design report. This documentation will greatly aid reviewers of the report. Every project is unique, and therefore, the geotechnical design parameters needed for design will vary from project to project. The required geotechnical design parameters were already considered during planning of the subsurface exploration and laboratory testing programs. However, these parameters must be reconsidered based on the information obtained from both programs because the parameters required for design may differ based upon the actual subsurface conditions. Consolidation settlement is not anticipated on the project; however, clay was encountered during the subsurface exploration in borehole No. 4, the area affect is relatively small.

Table1a: Holes Locations and Times of Sampling for Site 1 (Soil)

Hole Number	Sample Number	Hole Coordinate	Depth of the Sample (m)	Depth of Water Table (m)	Time Taking
1	1,1	Lat. 10.31284	2.0	0.10	10:31 – 11:15
	1,2	Long. 9.7712	4.0		
2	2,1	Lat. 10.31298	2.0	0.20	11:15 – 11:38
	2,2	Long. 9.77104	4.0		
3	3,1	Lat. 10.31273	2.0	0.40	11:38 – 12:30
	3,2	Long. 9.77114	4.0		
4	4,1	Lat. 10.31272	2.0	0.00	1:25 – 2: 15
	4,2	Long. 9.77136	4.0		

Table1b: Holes Locations and Times of Sampling for Site 2 (Rock)

Hole Number	Sample Number	Hole Coordinate	Depth of the Sample (m)	Depth of Water Table (m)	Time Taking
1	1	Lat. 10.31215	1	-	3:45 – 4:15
		Long. 9.74243	3		
2	2	Lat. 10.31212	1	-	4:15 – 4:50
		Long. 9.72462	3		

IV. RESULTS AND DISCUSSION

4.1 Particle Size Analysis

The following table shows the summary of the results for the sieve analysis and soil classification conducted on the samples.

Table 2: Summary of Particle Size Distribution Analysis and Soil Classification

Sample Ref.	Depth (m)	% Gravel	% Sand	% Fines	Coefficient of Uniformity (C_u)	Coefficient of Curvature (C_c)	Classification System	
							USCS	AASHTO
Borehole 1	2.0	10.8	87.0	2.5	8	1	Well Graded SAND (SW)	A-2-4
	4.0	11.0	87.0	2.3	7	1	Well Graded SAND (SW)	A-2-4
Borehole 2	2.0	8.2	85.8	6.0	11	1	Well Graded SAND with Clay (SW-SC)	A-2-4
	4.0	15.2	78.7	6.1	12	1	Well Graded SAND with Clay and Gravel (SW-SC)	A-2-4
Borehole 3	2.0	23.1	72.6	4.3	13	1	Well Graded SAND (SW)	A-2-4
	4.0	46.0	52.5	1.5	11	1	Well Graded SAND (SW)	A-2-4
Borehole 4	2.0	4.6	86.5	14.5	-	-	Clayey SAND (SC)	A-2-6
	4.0	2.9	77.3	19.8	-	-	Clayey SAND (SC)	A-2-6

Table 3: Summary of Atterberg's Limits Test Results

Designation	Sample Reference							
	BH 1		BH 2		BH 3		BH 4	
Depth (m)	2.0	4.0	2.0	4.0	2.0	4.0	2.0	4.0
Liquid Limit (%)	18	17	20	20	29	24	32	32
Plastic Limit (%)	-	-	16	14	19	14	21	19
Plastic Index (%)	NP	NP	4	6	10	10	11	13

4.2 Soil Classification by USCS

All the 8 soil samples were initially subjected to mechanical analysis and Atterberg's limits tests {as per BS 1377, 1990}. The grain size analysis of the tested soil samples indicates that the tested soil samples in general comprises predominantly coarse sands except for material from borehole No. 4, which is basically clay. Borehole numbers 1, 2 and 3 have percentages of fines less than 10 %, this indicates that the influence of fines (clay and silt) is negligible on the engineering properties of the soils. The engineering characteristics of these soils are almost wholly influenced by the coarse component of soils.

The grain sizes of the tested soil samples indicate that the range fine (Silts and Clay) sizes is about 1.5-20 %, Sand component 52.5 - 86.8 % and Gravel constitute about 2.9 - 46.0 %.

4.3 Soil Classification by AASHTO

The AASHTO soil classification system is used to determine the suitability of soils for earthworks, embankments, and foundation (subsurface-natural material below a constructed structure). According to AASHTO, granular soils are soils in which 35% or less are finer than the No. 200 sieve (0.075 mm). Silt-clay soils are soils in which more than 35% are finer than the No. 200 sieve.

The American Association of Highway and Transportation Officials soil classification system was also used to classify the soils tested. All the soils tested fall within the group of granular materials (precisely Sandy; A-2-4 and A-2-6) groups, except for material from bore hole No. 4, depth 1.0 - 4.0 m which fall under the Silty to Clayey (A-2- 4) group. These soils with little or no fines (groups GW, GP, SW, and SP) are generally stable and pervious.

V. SWELLING POTENTIAL

Clay minerals swell due to increase in the thickness of the diffuse ion layer as water is supplied. Because of the potential hazards to foundation construction on soils that undergo high volume change, there is need to identify such soils. An empirical index used for the identification of these soils is the percentage of swell under a $6.9KN/m^2$ (1Psi) surcharge of a laterally confined specimen compacted at optimum moisture content (OMC) to maximum dry density (MDD) in a standard AASHTO compaction test.

The relationship that exists between the swell potential (S) and the plasticity Index (PI) is given by:

$$S = (2.16 \times 10^{-3})(PI)^{2.44}$$

The plasticity of the soils tested range between 0 to 22, with only about 5% of them having 24 to 27; which from the criteria given by Ralp Peck, et al (Table 4 below) can be considered to be of low to medium swelling potential. Therefore swelling is not a potential problem.

Table 4: Relationship between Swelling Potential of soils and Plasticity Index

Swelling Potential	Plasticity Index
Low	0-15
Medium	10-35
High	20-35
Very High	35 and Above

VI. COMPACTION CHARACTERISTICS

Table 5 summarizes the results of the compaction test carried out on the samples. For these tests, as indicated in the table, the Optimum Moisture Content range was 5.90 - 13.00 % while Maximum Dry Density range was 1.77 - 2.01 Mg/m^3. The ranges conform to the values expected of coarse - grained soils with high Natural Moisture Content (saturated) and very little clay content. The intermediate MDD values are typical of coarse-grained soils of this nature. The relatively high values of natural moisture contents is as a result of the high water level in the borehole during the period of sampling.

Table 5: Summary of Specific Gravity, NMC & Compaction Test Result

Sample Designation	Depth (m)	Specific Gravity	Natural Moisture Content, NMC (%)	Compaction Characteristics	
				Max Dry Density, MDD (Mg/m^3)	Optimum Moisture Content, OMC (%)
Borehole 1	2.0	2.67	Sample was Saturated	2.01	8.20
	4.0	2.66	Sample was Saturated	1.78	5.90
Borehole 2	2.0	2.64	Sample was Saturated	2.01	8.50

	4.0	2.74	Sample was Saturated	1.92	6.00
Borehole 3	2.0	2.78	Sample was Saturated	1.77	11.50
	4.0	2.77	Sample was Saturated	1.92	6.00
Borehole 4	2.0	2.82	Sample was Saturated	1.86	13.00
	4.0	2.80	Sample was Saturated	1.85	13.00

VII. STRENGTH AND STABILITY

The shear strength parameters for the samples at the sites are obtained from the Triaxial shear and Shear Direct tests. Summary of the result of these tests are as presented on Tables 6a and 6b below. From this Tables, the soils' cohesion of the Booster and Reservoir stations ranges from 8.0 kN/m^2 to 75.0 kN/m^2 and the angle of internal friction range between 25^o to 35^o. These values are quite significant and indicate that the foundation materials are of high quality with regard to strength.

Table 6a: Shear Strength Parameters Booster Station Site Wuntin Dada

Sample Designation	Depth (m)	Triaxial Shear Test Parameters		Net Bearing Capacity (kPa)
		Cohesion, C (kN/m^2)	Internal Friction Φ^o	
Borehole 1	2.0	55	30	884.0
	4.0	60	32	1132.0
Borehole 2	2.0	55	30	868.0
	4.0	50	33	1108.0
	2.0	75	28	915.0

Sample Designation	Depth (m)	Shear Box Test Parameters		Net Bearing Capacity (kPa)
		Cohesion, C (kN/m^2)	Internal Friction Φ^o	
Borehole 1	3.0	54	35	1565
Borehole 2	3.0	52	35	1535
Borehole 3	4.0	60	27	728.0
Borehole 4	2.0	8	25	377.0
	4.0	23	26	222.0

Table 6b: Shear Strength Parameters of Reservoir Site Miri

VIII. PERMEABILITY AND DRAINAGE

The soils contain significant amount of coarse material (sand) and smaller amounts of fines (silt and clay particles sizes). These account for the moderate permeability values. Table 7 shows the values of permeabilities of the samples.

Table 7: Coefficient of Permeability for the soil samples

Sample Designation	Borehole 1		Borehole 2		Borehole 3		Borehole 4	
Depth (m)	2.0	4.0	2.0	4.0	2.0	4.0	2.0	4.0
Coefficient of Permeability, K ($\times 10^{-6}$)	3.50	1.76	1.89	2.11	15.5	6.91	12.5	2.75

IX. SETTLEMENT ANALYSIS

From the results of particle size distribution analysis, the average amount of fine materials in the soil being 7.2% (0 to 18%) and liquid limit < 50%. It is obvious that very negligible, if any, amount of consolidation settlement should be expected, because the clay content and the plasticity of the soil reveals no evidence of possible consolidation.

X. CONCLUSION AND RECOMMENDATIONS

10.1 Conclusion

From the foregoing, it can be seen that the existing materials within boreholes 1, 2 and 3 have adequate characteristics as required for foundation of structure. it has been observed that area around borehole 4 is clayey which will require special treatment.

10.2 Recommendations

Base on the conclusion, the following are recommended:

1) For pad foundation practice, it is recommended that the footing levels should be of minimum depth of 1.5 meters below the existing ground surface (level).
2) The dimensions of the structural footings (i.e. width, length and thickness) should be determine using rigorous analysis based on the allowable bearing capacity and in computing thickness of footing. The punching shear and direct shear limiting guideline from BS 8110 should be used.
3) The sizes of strip foundation beneath 225 mm (9") block-walls should be 650 mm. Crack 9 reinforcement of at least 4 No. Y16 bars is recommended at the top and bottom with links of 8 mm diameter, spaced at 300 mm centre to centre to bridge over any soft soil material that may be encountered particularly around borehole No. 4.
4) The depth to the base of all strip footings should be a minimum depth of 1.0 meter.
5) The minimum allowable bearing capacity computed based on the direct shear tests carried out was 222 kN/m^2. A value of 200kN/m^2 may be used in the design of the foundation.
6) Some amount of consolidation settlement is expected around borehole No. 4 since the soil contain significant amount of silt with some clayey material.

REFERENCES

[1] Arulrajah, A., Disfani, M. M., Horpibulsuk, S., Suksiri, P. & Prongmanee, N. (2014). Physical Properties and Shear Strength Response of Recycled Construction Materials in Unbound Pavement Base/Subbase Application. Construction and Buildind Materials.53,245-257.

[2] Craig, R. (2004). *Soil Mechanics*. London: Spon press.

[3] Das, B. (2009). *Priciples of Geotechnical Engineering*. Madrid: Cengage Learning

[4] James, J. & Pandian, P. K. (2016). Industrial Wastes as Auxiliary Additives to Cement/Lime Stabilization of Soils. *Advances in Civil Engineering*.

[5] Joachin, A. W. R & Kandiah, S. (1941). *The Composition of Some Local Soils Concretion and Clays.* Tropical Agriculture. 67.

[6] Lekha, B.M., Ravi, A.U. & Sarang, G. (2013). Fatque and Engineering properties for chemically Stabilized Soil for pavement. Indian Geotech Journal. 43 (1), 96-104.

[7] Neville, B. (2012). Towards a Sustainable Balance of Population and Resources. *Journal of Futures Studies*. 16(4), 107-116.

[8] O'Flaherty, C. A. (2002). Soil-Stabilized Pavements in Highways: The Location, Design, Construction and Maintenance of Pavements C. A. O'Flaherty(ed). Malta, Butterworth-Heinemann.

[9] Osinubi, K. J. (1998a). Permeability of Lime Treated Lateritic Soil. *Journal of Transportation Engineering, ASCE*. 124(5): pp. 465-469

[10] Phani Kumar, B. R. & Sharma, R. S. (2004). Effect of fly ash on engineering properties of expansive soils. *Journal of Geotechnical and Geoenvironmental Engineering*. *130*(7), 764-767.

[11] Ranjan, G. & Rao, A.S. (2000). Basic and applied Soil Mechanics. 2nd edition. New Age International Publisher. New Delhi, India.

[12] Rao, A. N. N. & Chittaranjan, M. (2011). Application of Agricultural and domestic wastes in Geotechnical application: An overview.

Journal of Environmental Research and Development. 3 (5), 673-678.

[13] Sherwood, P. T. (1993). *Soil Stabilization with Cement and Lime: A State-of-The-Art Review* Department of Transport, Transport Research Laboratory, United Kingdom.

[14] Singh, M. & Mittal, A. (2014). A Review on the Soil Stabilisation with Waste Materials. International Journal of Engineering Research and Applications. 2248-9622.

[15] Surya, S. T. & Siddhartha, P. (2015). Stabilization of subgrade soil of highway pavementusing waste tyre pieces. *International journal of innovative research in science, engineering and technolog. 4* (5), 3265-3273.