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Engineering Properties of the Residual Soils Underlying the Proposed Site for Soccer Pitch at Obafemi Awolowo University, Ile-Ife, Southwestern Nigeria

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Abstract - Ten representative soil samples from the proposed site for a soccer pitch at the Obafemi Awolowo University International School were subjected to soil engineering tests. *In-situ* and laboratory analyses were carried out. The grain size distribution curves showed that the soils were well graded. The soil materials passing the No. 200 BS sieve (mm) were 4%, 6%, 5%, 9%, 7%, 6%, 12%, 4%, 8% and 8% for Samples 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10, respectively. Samples: 4, 5, 6, 7, 9 and 10 belong to SC class on the USCS classification system, are clayey sands and sand-clay mixtures. All the soil samples were highly plastic, with liquid limits ranging from 37.7% to 64.0%, plastic limit from 19.11% to 35.12%, and plasticity index from 13.18% to 34.86%. The soil samples were permeable with optimum moisture contents from 0.56% to 2.09%, specific gravity from 1.71 to 2.93, and maximum dry density from 1.33 KN/m^3 to 2.06 KN/m^3. The study concluded that the soils are competent as subgrade material and the site suitable for soccer pitch construction. However, soil modification should be done on the residual soils found in the area to improve the engineering properties to sustain turfs.

Keywords – *Engineering Properties, Soil Classification, Soccer Pitch, Sport Turf, Obafemi Awolowo University*

I. INTRODUCTION

Basic understanding of soils and how to manage them are very helpful for maintaining quality athletic fields. Soils have four major parts: mineral matter, organic matter, air porosity or space and capillary or water-filled porosity. The proportion of each varies with the soil type and condition. The mineral fraction is the largest component of a soil. Soil particles range in size from less than 0.002 mm to greater than 2 mm in diameter although larger particles are often present [1]. Depending on sizes, soil particles are grouped into four (4) major types in increasing order of soil particle sizes: clay, silt, sand and gravel [2]. Soil texture is determined by the relative proportion of these various sizes of soil particles.

The soil particle size classifications by Massachusetts Institute of Technology, United State Department of Agriculture, American Association of State Highway and Transportation Officials (AASHTO), and the United State Army Corps of Engineers, indicates that clay size particles are the smallest of the three sizes. Clay particle size are those soil particles less than 0.002 mm. Clays have a large surface area and are chemically very active in the soil. Clays are the major mineral fraction responsible for plant food or nutrient storage in a soil. This is a major advantage in the growth of sport turfs. Clay particles compacts easily, posing a great challenge in athletic field. The silt particle size group are between sand and clay. Silt particle sizes range from 0.05 mm to 0.002 mm. Silt is undesirable on athletic field soil because it compacts, and provides little in the way of plant food storage. The sand particle sizes range from 0.05 mm to 2.0 mm. Soil fragment greater than 2. 0 mm is referred to as gravel or boulder.

Athletic field soils should be springy and yielding, yet firm enough to resist compaction under hard use and heavy traffic. In athletic fields, the soil under turf areas receives a lot of abuse during use. Some areas receive more abuse than others on athletic fields. Hence a basic understanding of soils and their management are important to maintain quality athletic fields. Most sport fields are constructed on residual soils with or without treatment. These soils may have high water holding capacities and surface drainage problems. Therefore, not all soils are useful for sports fields.

Managers of sport turf often add sand to improve on the physical properties of an existing field in a process called soil modification. The methods generally used in soil modification include mixing sand into the soil or simply top-dressing the soil with a layer of sand. If done properly, both methods can improve the soil conditions. Soil should be modified so that the final top mix contain at least seventy percent sand [3].

Good drainage is important for sport fields. Movement of water onto the field from surrounding areas, type of soil and soil depth, ability to remove excess water away from the field and weather factors such as rainfall are some of the factors to consider when designing drainage systems for a sport field [4]. Under poor drainage conditions, turf growth is inhibited and nutritional and disease disorders can develop. Poorly drained soils are readily compacted. Surface drainage prevents puddles forming from precipitation or irrigation on the soil surface. Subsurface drainage is necessary if water percolates through the top soil faster than that allowed by the natural subsoil drainage. Proper drainage removes water from both the surface and subsurface.

This study assesses the suitability of residual soil present in the study area for use in constructing a soccer pitch. This will be achieved by determining the engineering properties of the soil as well as the infiltration characteristics within the study area.

II. STUDY AREA

The study area is located within the premises of the Obafemi Awolowo University (OAU) International School in Ife Central Local Government Area, Ile-Ife, Osun State (Fig. 1). The study area has a length of 230 m and width of 120 m with a total area of 27,600 m^2. The study area is highly accessible as there are both major and minor roads as well as footpaths linking the study area with the rest of OAU Campus and the Ile-Ife town. The OAU Campus, which includes the study area, lies within the tropical climatic region is marked by a well-defined dry season lasting approximately five months per year from November to March. The rainy season usually starts around April ending around October. Mean annual rainfall is about 1400 mm [5] and the average temperature is between 28 ^oC and 33 ^oC [6]. The study area has relatively flat topography with surface elevation ranging from 250 m to 255 m above mean sea level. Within the OAU Campus, the drainage forms a dendritic pattern. The study area is underlain by mica schist and quartzite, which belong to the migmatite-gneiss-quartzite complex of the Ife-Ilesha schist belt of southwestern Nigeria [7]. Mica schist is a metasedimentary rock composed predominantly of biotite and quartz with minor constituents of muscovite and garnet. The mica schist within the study area is low-lying and severely weathered but the foliation is well preserved. Quartzite is a metamorphic rock resulting from the metamorphism of sandstone and is composed mainly of quartz. The quartzite within the study area is also low-lying. Most of the rock exposures in the study area result from the excavation works done on the site.

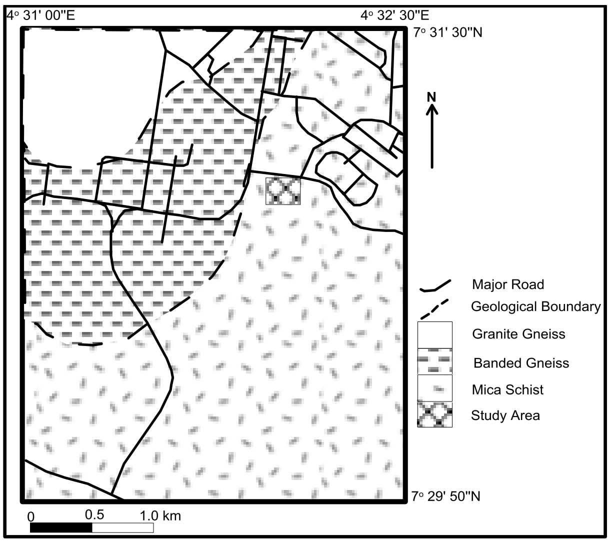

Figure 1. Geological Map of OAU Campus Showing Location of Study Area [8]

III. MATERIALS AND METHODS

Ten different soil samples were collected randomly within the study area (Fig. 2). The soil samples were collected at a depth range of 5 cm to 15 cm from the surface. Laboratory tests were conducted on the soil samples to determine their index properties, grain size distribution and permeability characteristics using standard methods of analysis. This involved drying the soil samples at room temperature for three weeks and the lumps pulverised by means of mortar with rubber plastic. 500 g of the soil was subjected to mechanical sieve analysis, involving the shaking of the soil sample through a set of sieves of known weight that have progressively smaller openings. The liquid limit test was carried out in line with standard procedure using the standard liquid limit apparatus designed by Cassagrande [9]. Some 200 g each of the dried representative soil samples passing through 0.425 mm BS sieve was used to obtain the plasticity limit of the soil according to standard procedures for plasticity limit test. Three such procedures were carried out and the water content determined after drying the soil in the oven for 24 hours. The specific gravity of the soil samples was obtained using a 100 mL density bottle. The in-situ bulk density of each of the soil samples was determined using the core cutter method. The natural moisture content of the soil samples was determined using the oven drying method. The coefficient of permeability of each of the soil samples was estimated from the particle size distribution curve using the Hazen's equation (Equation 1). This formula is most appropriate for sandy material where d_{10} is between approximately 0.1 mm and 3.0 mm [10], and coefficient of uniformity (C_u) less than 5.0 [11].

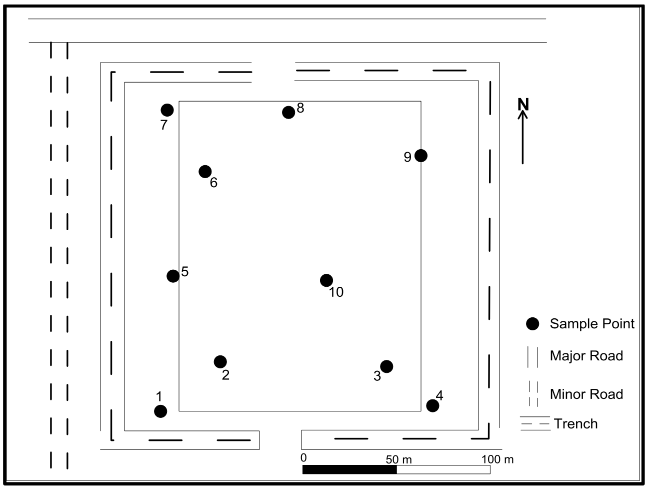

Figure 2. Sketch of the Proposed Site for Soccer Pitch at OAU International School [12]

$$k = Cd_{10}^2 \quad (1)$$

where: k = Coefficient of permeability (cm. s^{-1})
D_{10} = Effective size (cm)
C = Constant, usually taken as 100 $cm^{-1}s^{-1}$.

IV. RESULTS AND DISCUSSIONS

The D_{10}, D_{30} and D_{60} for all the soil samples deduced from the grain size distribution curve is shown in Table 1. These values correspond to the 10%, 30% and 60% finer by weight respectively, on the particle size distribution curve. The effective sizes of the soil ranged from 0.068 to 0.200mm, D_{30} ranged from 0.12 to 0.57mm, and D_{60} ranged from 0.7 to 2.1mm. The C_u and coefficient of curvature (C_c) of the soil samples were calculated from the data obtained for D_{10}, D_{30} and D_{60} using Equations 2 and 3.

$$C_u = \frac{D_{60}}{D_{10}} \quad (2)$$

$$C_c = \frac{D_{30}^2}{D_{10} \times D_{60}} \quad (3)$$

The C_u is nearly unity for a uniformly graded soil. For a uniform soil, C_u will be less than 4. For a well-graded soil, C_u will be greater than 4 for gravel and greater than 6 for sands [2]. The C_u obtained ranged from 7 to 25 (Table 1), indicating that the soils are sandy. Samples 3, 5 and 8 have approximately the same C_u of 11. Sample 7 has the highest C_u, suggesting a fairly more porous soil than the rest of the samples. C_c between 1 and 3 indicates a smooth particle distribution curve. Irregular curves have higher or lower C_c. For a gap graded soil, C_c is less than 1 or greater than 3 [2]. The C_c obtained range from 0.12 to 0.77 (Table 1), indicating gap graded soils. Sample 2 has the least C_c of 0.12, while Sample 8 has the highest C_c of 0.77.

The permeability of the soil was determined, based on the particle size analysis, using the Hazen's formula showed that the soil samples are permeable as they all fall in the sand range of 10^{-3} to 1 cm s^{-1} [13]. Samples 4, 7 and 10 have relatively low coefficient of permeability with Sample 7 having the least (Table 1). Field evidence and laboratory investigation on the soil sample show that Sample 7 is porous as it contains much clay content. Sample 8 has the highest coefficient of permeability and it corresponds with the location on the field with greatest seepage problems.

The liquid limit and plasticity index are used to classify the fine-grained soil. For inorganic clays liquid limit values are usually never greater than 100 %. The soil samples have liquid limit ranging from 37.70 % to 64.00 % (Table 2). The plasticity limits obtained ranged from 19.11 % to 35.12 % (Table 2). The plasticity index shows that the clay in soil samples: 1, 2, 3, 4, 9 and 10 are highly plastic. Samples: 5, 7 and 8 exhibit medium plasticity.

The specific gravity of different mineral constituent varies widely but that of majority of soil particles range between 2.6 and 2.8 [14]. The specific gravity of soil samples obtained from this study ranged between 1.71 and 2.93 (Table 2), indicating that Samples: 3, 4, 5, 6, 8 and 9 are clay soil types. Sample 9 is soil containing mica or iron. Samples: 1, 2 and 7 are intermediate between clay and mica or iron soil type. Sample 10 is abnormally high which might have resulted from error in the laboratory procedure.

TABLE I. PERMEABILITY OBTAINED FROM PARTICLE SIZE DISTRIBUTION CURVE

Sample No	Effective Size D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	C_u	C_c	D_{10}^2 (mm)	Constant (C)	k (cm s^{-1})
1	0.12	0.26	1.40	12	0.40	1.44 x10^{-4}	100	1.44 x10^{-2}
2	0.10	0.12	1.20	12	0.12	1.00 x10^{-4}	100	1.44 x10^{-2}
3	0.12	0.26	1.40	11	0.40	1.44 x10^{-4}	100	1.44 x10^{-2}
4	0.10	0.25	1.20	13	0.55	0.90 x10^{-4}	100	0.90 x10^{-2}
5	0.10	0.20	1.10	11	0.36	1.00 x10^{-4}	100	1.00 x10^{-2}
6	0.14	0.35	1.40	10	0.63	1.96 x10^{-4}	100	1.96 x10^{-2}
7	0.07	0.26	1.70	25	0.58	0.46 x10^{-4}	100	0.46 x10^{-2}
8	0.20	0.57	2.10	11	0.77	4.00 x10^{-4}	100	4.00 x10^{-2}
9	0.10	0.20	0.70	7	0.57	1.00 x10^{-4}	100	1.00 x10^{-2}
10	0.09	0.23	1.40	16	0.42	0.81 x10^{-4}	100	0.81 x10^{-2}

TABLE II. INDEX PROPERTIES OF SOIL SAMPLES

Sample No	Liquid Limit (%)	Plasticity Limit (%)	Plasticity Index (%)	Liquid Index (%)	Specific Gravity	Natural Moisture Content	Bulk Density (KN/m^3)	Dry Density (KN/m^3)
1	54.93	33.19	21.74	1.733	1.71	2.07	1.57	1.54
2	52.00	33.27	18.73	1.027	1.73	1.36	1.43	1.41
3	51.60	26.82	24.78	0.672	2.72	0.94	1.35	1.33
4	54.00	34.74	19.26	1.203	2.81	1.55	1.43	1.40
5	50.30	34.47	15.83	0.695	2.77	1.04	1.91	1.89
6	64.00	29.14	34.86	1.139	2.84	1.43	2.09	2.06
7	48.30	35.12	13.18	1.739	2.26	2.09	1.83	1.79
8	37.70	21.47	16.23	0.395	2.81	0.61	1.83	1.82
9	54.20	34.03	20.17	0.220	2.81	0.56	1.61	1.60
10	50.60	19.11	31.49	0.459	2.93	0.65	1.51	1.50

TABLE III. CLASSIFICATION OF SOIL SAMPLES

Sample No	Grading Analysis (mm)							Atterberg Limits			Soil Classification	
	4.75	2.00	0.859	0.425	0.212	0.150	0.075	LL (%)	PL (%)	PI	ASSHTO	USCS
1	96	71	47	37	23	13	4	54.93	33.19	21.74	A-1-b	SW
2	95	78	57	47	45	19	6	52.00	33.27	18.73	A-1-b	SW
3	94	74	49	37	19	13	5	51.60	26.82	24.78	A-1-b	SW
4	91	76	54	42	22	16	9	54.00	34.74	19.26	A-1-b	SC
5	95	77	51	39	20	14	7	50.30	34.47	15.83	A-1-b	SC
6	90	72	50	37	16	11	6	64.00	29.14	34.86	A-1-b	SC
7	86	65	47	40	27	21	12	48.30	35.12	13.18	A-1-b	SC
8	83	59	38	29	11	7	4	37.70	21.47	16.23	A-1-a	SW
9	91	81	64	50	19	13	8	54.20	34.03	20.17	A-1-b	SC
10	91	73	52	41	23	16	8	50.60	19.11	31.49	A-1-b	SC

The different soil samples were classified using the Unified Soil Classification System (USCS) and AASHTO classification system (Table 3). Based on the USCS, Samples: 1, 2, 3 and 8 are SW; well-graded sands and gravelly sands with little or no fines (Table 3), while Samples: 4, 5, 6, 7, 9 and 10 are SC; sand-clay mixtures. Based on the AASHTO classification system, all the soil samples were A-1-b except Sample 8 which was A-1-a. This indicates that the soil samples composed of stone fragments, gravel, and sand with little or no fines.

V. CONCLUSIONS

The proposed site for a soccer pitch at the Obafemi Awolowo University International School is underlain by quartz-mica schist. The residual soils above the quartz-mica schist is composed of clayey sands and sand-clay mixtures. The residual soil will make a good soccer pitch if used as subgrade materials as they all have good, permeable soils which are good for soccer pitch. The soil samples have good to excellent drainage characteristics, limited water and nutrient holding capacity. The soils would not undergo compaction since they all fall within sand to sand-silt mixtures. In terms of engineering properties based on the USCS, the soils with SW classes indicate well graded sands, gravelly sands, little or no fines with excellent shear strength and negligible compressibility. Their workability as construction material is excellent and when compacted, they will be pervious. The SC classes are clay sands, sand-silt mixtures, they have good to fair shear strength. Their compressibility is negligible or low and their workability as construction material is good. When they are compacted, they will be impervious.

The site chosen for the purpose of constructing a soccer pitch is suitable as good subgrade material based on their engineering properties. This area is on water course hence, the turfs that will be planted will fare well and develop properly.

VI. RECOMMENDATIONS

Based on the field observations and results obtained from this study, the following recommendations are hereby made:

i. Since the soils on this site are pervious to fairly pervious to impervious, it means that the soils are heterogeneous. Therefore, proper drainage of the pitch should be done to ensure the durability of the soccer pitch;

ii. Soil modification should be carried out for the top soil of the soccer pitch, most especially in areas where Samples 4, 7 and 10 were taken because of their high porosity in order to avoid compaction of the soils;

iii. Although the site has been excavated to the water table, necessary geophysical investigation should be carried out to properly understand the subsurface conditions of the site before full construction works commence;

iv. Proper test boring of a site should always be carried out to determine the water table before excavation works begin;

v. Proper attention should be given to the area where Sample 8 was taken to avoid seepage problem as this might always cause water logging on the pitch when rainfall is at its peak since the area is in the tropical rain forest; and

vi. Proper embankment should be done on the far north of the site to avoid the collapse of the road passing through the far north to avoid slumping of the soil and consequently, the destruction of the pitch.

REFERENCES

[1] N. W. Hummel, J. C. Neal and A. M. Petrovic, "Athletic Field Maintenance. Information Bulletin 213", Cornell University Cooperative Extension, Cornell University, Ithaca, New York, 1988.

[2] B. M. Das, "Principles of Geotechnical engineering," 5th Edition, CL Engineering, 2001, 593 pp.

[3] K. Tomasz and R. Wlodzlmlerz, "Physical Properties, Permeability and Retentiveness of Silt Loam and its Composites with Sand for Constructing Carrying Layer of a Football Field," Journal of Ecological Engineering, Volume 15, No. 4, 2014, pp. 37 – 45.

[4] T. Golab and K. Gondek, "The Influence of Soil Compaction on Chemical Properties of Mollic Fluvisol Soil under Lucerne (Medicago sativa L.)," Polish Journal of Environmental Studies, Volume 22 (1), 2013, pp. 107 - 113.

[5] A. Adeniji, "Reservoir Sedimentation: The Case of the Opa Reservoir Catchment, Southwestern Nigeria," South African Geographical Journal, Volume 87 (2), 2005, pp. 123 – 128.

[6] O. O. Ogunkoya, "Water Balance of a Small Catchment with Permeable Soils in Ile-Ife Area, Southwestern Nigeria", Journal of Mining and Geology, Volume 36 (1), 2000, pp. 105 – 111.

[7] M. A. Rahaman, "Review of Basement Geology of Southwestern Nigeria," In Geology of Nigeria, Kogbe, C. A., (ed.), Elizabethan Press, Lagos, 1976, pp. 41- 57.

[8] T. N. Boesse and O. O. Ocan, "Geology and Evolution of the Ife-Ilesha Schist Belt Southwestern Nigeria," Symposium on Benin-Nigeria Geo-Traverse of Proterozoic Geology and Tectonics of High-Grade Terrains, 1989, pp. 87 – 107.

[9] IS 2720 – 5, "Indian Standard. Methods of Test for Soils, Part 5: Preparation of Dry Soil Samples for Various Test," CED 43 Soil and Foundation Engineering, 1985, 16 pp.

[10] C. W. Fetter, "Applied Hydrogeology," Prentice Hall Inc., New Jersey, 4^{th} Edition, 2001, 598 pp.

[11] J. Odong, "Evaluation of Empirical Formulae for Determination of Hydraulic Conductivity based on Grain-Size Analysis," The Journal of American Science, 4(1), 2008, ISSN 1545-1003.

[12] O. S. Okewole, "Soil Engineering Properties of the Residual Soils Underlying the Proposed Site for Soccer Pitch at Obafemi Awolowo University International School, Ile-Ife, Osun State," Unpublished B. Sc. Thesis, Obafemi Awolowo University, Ile-Ife, Nigeria, 2014, 72 pp.

[13] J. Bear, "Hydraulics of Groundwater," McGraw-Hill Inc., New York, 1972, 544 pp.

[14] T. N. Ramamurthy and T. G. Sitharam, "Geotechnical Engineering," S. Chand, New Delhi, 2005, 310 pp.

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