

Proposed Nigerian Specification For Airport Pavement Foundation Design (A Case Study Of Asaba Airport Site)

¹Kayode-Ojo, N., ²Anyafulu U. O. and ³Ehiorobo, J. O.

Department of Civil Engineering,

Faculty of Engineering,

University of Benin, Benin City, Edo State, Nigeria.

Corresponding Author: Kayode-Ojo, N

Abstract

Airport projects are becoming the desire of every state of the Nigeria. The increase in the development of airports implies increase in the design and construction of airport runways which have been identified as the most important facility in any airfield. This study was aimed at producing a proposed Nigerian specification for earthworks in airport pavement foundation design and construction. The soils from the study area (Asaba Airport, Delta State, Nigeria) were characterized and classified using the Unified Soil Classification System (USCS), compared with the US Federal Aviation Authority (FAA) standard and the functional standard of the British Ministry of Defense for Airfield Pavements. The soils were found to be sandy clays of low to intermediate plasticity. The maximum dry density of soils under study ranged from 1850 kg/m^3 – 2000 kg/m^3 , their CBRs ranged between 6 and 15.15% while the approximate values of their modulus of subgrade reaction ranged from 3.84×10^6 to $5.54 \times 10^6 \text{ kg/m}^3$. With the characteristics above, the soils met the criteria of the FAA for airport pavement foundation design and construction. To arrive at a Nigerian standard for specification of earthworks in Airport pavement foundation design and construction, modifications were made to the American standard and the resultant document suggested for adoption as the Nigerian standard for evaluation and specification of earthworks (subgrades) in Airport pavement foundation design and construction.

Keywords: Airport Pavement, California Bearing Ratio, Earthwork, Foundation, Evaluation.

INTRODUCTION

Airports are unique entities that have profound economic, social and environmental effects on a local, regional and even national level. They provide the means for efficient movement of passengers and goods virtually anywhere in the world, playing a vital role in the trend toward globalization and inter-connections between international trade and local economies [1]. Airports are classified based on their operations as domestic, international or cargo [2]. Airports are shaping urban space in the twenty-first century much as highways did in the twentieth century, railroads did in the nineteenth century and seaports did in the eighteenth century [3].

Aviation will thus continue to play an important role in the future prosperity of the Nigerian and world economies[4]. Since the establishment of air transport services in Nigeria, there has been tremendous increase in air traffic in the country and this has been very well documented [5][6][7]. The democratic government of the country has shown great awareness of the positive relationship between airport infrastructural development and economic growth. Expectedly, Government embarked on a massive restructuring of the aviation industry including the resuscitation of abandoned airport projects and the modernization of others [8].

Presently, Nigeria has 22 airports and many of them have been upgraded recently to international airports that can handle modern aircrafts. Suggestions have also been made for more airports to be constructed in other parts of the country [9]. Going by this trend, most states of the federation are embarking on the development of airports in their states and this is expected to be on the increase. The increase in the development of airports implies increase in the design and construction of airport runways (pavements) which have been identified as the most important singular facility in any airfield [10]. Airport pavements are designed and constructed to provide adequate support for aircraft loads and to always be a suitable surface for aircraft operations. To meet these requirements, they must not fail under the loads imposed on them. In addition, they must be able to withstand without damage, the abrasive action of traffic, adverse weather conditions, and other deteriorating influences [11]. .

Airport runways could be rigid or flexible pavements. Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of materials. Each layer receives loads from the above layer, spreads them out, and passes on these loads to the next layer below. Thus the stresses will be reduced, which are maximum at the top layer and minimum on the top of subgrade.

In order to take maximum advantage of this property, layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material (and most expensive) on the top and the lowest load bearing capacity material (and least expensive) on the bottom. For flexible pavements, structural design is mainly concerned with determining appropriate layer thickness and composition. The main design factors are stresses due to traffic load and temperature variations [12].

Federal Aviation Administration advisory circular[13] suggests that arrival traffic be ignored when designing airport pavements, not only because aeroplanes typically arrive at an airport with less fuel and therefore less weight, but also because remaining lift on the wings helps alleviate the dynamic load effects of touchdown impact. Instead, she recommends the use of the maximum anticipated take-off weight for design, adding that this even provides a degree of conservatism in the design. One of the compulsory geomaterials encountered in the design and construction of pavements generally is the soil [14].

This generally is the subgrade on which the pavement is built. Other layers of pavement like sub-base and base are also commonly constituted of soils especially in lightly loaded pavements like those of rural roads. Soils are of different types, characteristics and engineering properties. It is the engineering properties of the soil that reveal their characteristics which in turn determine their use or relevance for different engineering structures. Soils as construction materials are available all over the country however, not all soils may be used for the construction of pavements considering the expected structural performance and durability (life span) of such costly investments as airport pavements. The foregoing factors therefore amongst others necessitated the undertaking of this study. Presently, we have the Nigerian highway design manual, but there is no Nigerian design document for airport pavements. There is the “Federal Ministry of Works (FMW) General Specifications for Roads and Bridges”[15], but there is no Nigerian specification for airport pavements which include taxiways, runways, aprons among other aerodrome facilities. The standards for design and construction so far known are those of America (Federal Aviation Administration (FAA)) and other international standards. This study is to evaluate subgrade soils for the purpose of producing a Nigerian specification for earthworks in airport pavement foundation design. The literatures reviewed showed that pavement foundations material quality is a function on which the performance of pavements, depend and that soil classification is the key to successful selection of pavement foundation materials. [14] [16] [17] [18]

[19]. However, that information is silent on the quality of materials from the proposed area for this study and did not reveal the classification of soils within the area of this study.

MATERIALS AND METHODS

Description of the Area

The study area is Asaba, the capital of Delta State in Nigeria. The city of Asaba (Figure 1) lies approximately between Latitudes $6^{\circ} 40' - 6^{\circ} 51' N$ and Longitudes $6^{\circ} 40' E - 6^{\circ} 45' E$. It is bounded on the east and north east by the River Niger and on the west by the rolling slopes of the Asaba plateau [20].



Fig. 1.0: Map of the Study Area

Collection of Samples

Suggested criteria for the location, depth and number of borings for new construction are given in Table 1 wide variations in these criteria can be expected due to local conditions[13].

Table 1 Typical Subsurface Boring Spacing and Depth for New Construction [13].

Area	Spacing	Depth
Runways and taxiing	Random Across Pavement at 60m intervals	Cut Areas – 3 m Below Finished Grade Fill areas – 3m Below Existing Ground
Other Areas of Pavement	1 Boring per 930 sq. m of Area	Cut Areas – 3m Below Finished Grade Fill areas – 3m Below Existing Ground
Borrow Areas	Sufficient Tests to Clearly Define the Borrow Material	To Depth of Borrow Excavation

The samples used for this study were disturbed samples which were collected from the borings at different depth according to the guidelines in Table 1 at the Asaba Airport site.

Specified Laboratory Tests

Laboratory tests relevant to this study include:

- Atterberg (consistency) limits.
- Particle size analysis

- iii. Compaction test to determine the moisture – density relations of soils.
- iv. CBR Test in line with ASTM: D1883-05 “Standard Test Method for CBR (California Bearing Ratio) of laboratory compacted soils”,

These tests were carried out in line with methods specified in the Standard Test Method for liquid limit plastic limit and plasticity index of soils [21][22].

The tests above were specified for flexible airport pavements. For rigid airport pavements the plate bearing test to determine the modulus of subgrade Reaction would be necessary. In this study, the moduli of subgrade reaction were obtained from an empirical relationship based on the CBR value of soils.

RESULTS AND DISCUSSIONS

Presentation of Results

Table 2 shows the summary of the laboratory tests results.

Location Chainage	Sample No	Depth Of Sample (m)	B.S Compaction Standard Proctor 2.5kg Rammer.		Atterberg Limit %			C B R (%)	Sieve Analysis Sieve Sizes(mm.) Percentage Passing (%)						
			MDD Kg/m ³	OM.C %	LL	PL	PI		236	1.18	0.6	0.425	0.3	0.15	0.075
0 + 000	1	2.5-3.00	1920	15.52	31.46	15.51	15.95	11.36	100	99	92	83	74	55	41
0 + 100	2	2.5-3.00	1920	15.73	31.88	16.50	15.38	11.03	100	99	91	83	74	55	40
0 + 200	3	2.5-3.00	1910	15.27	30.68	15.01	15.67	11.06	100	99	91	83	74	55	41
0 + 300	4	2.5-3.00	1980	9.84	39.18	13.51	25.67	12.12	100	99	89	76	64	45	36
0 + 400	5	2.5-3.00	1920	15.23	39.02	12.94	26.08	12.15	100	99	89	76	64	45	36
0 + 500	6	2.5-3.00	1980	10.53	38.56	12.92	26.64	12.13	100	99	89	76	64	46	37
0 + 600	7	2.5-3.00	1990	9.97	38.15	12.66	25.49	12.14	100	99	89	76	64	46	37
0 + 700	8	2.5-3.00	2000	9.95	34.98	15.11	19.87	12.88	100	99	90	80	66	45	35
0 + 800	9	2.5-3.00	1980	9.94	33.84	14.98	18.86	12.91	100	99	90	80	66	45	35
0 + 900	10	2.5-3.00	2000	9.96	32.79	13.92	18.87	12.90	100	99	90	80	66	45	35
1 + 000	11	2.5-3.00	1900	14.98	34.23	16.02	18.21	13.64	100	99	93	84	73	49	38
1 + 100	12	2.5-3.00	1890	14.98	34.20	16.01	18.19	13.64	100	99	93	83	72	49	38
1 + 200	13	2.5-3.00	1850	15.04	34.24	16.16	18.08	13.68	100	99	93	84	72	49	38
1 + 300	14	2.5-3.00	1950	12.04	34.75	15.28	20.47	11.36	100	99	91	81	68	44	33
1 + 400	15	2.5-3.00	1950	12.33	34.72	15.28	19.44	11.43	100	99	91	81	69	44	33
1 + 500	16	2.5-3.00	1960	12.22	34.69	15.59	19.10	11.36	100	99	91	81	68	44	33
1 + 600	17	2.5-3.00	1970	12.14	34.39	14.96	19.43	11.37	100	99	91	81	69	44	33
1 + 700	18	2.5-3.00	1950	11.59	35.95	17.29	18.68	14.39	100	99	91	81	69	44	33
1 + 800	19	2.5-3.00	1980	10.0	35.81	14.69	21.12	14.40	100	90	91	72	60	40	31
1 + 900	20	2.5-3.00	1990	10.72	35.38	12.51	22.87	14.98	100	99	90	81	69	49	40
2 + 000	21	2.5-3.00	1900	13.72	35.54	12.81	22.73	14.93	100	99	90	81	69	48	40
2 + 100	22	2.5-3.00	1990	10.61	35.54	12.81	22.73	9.84	100	99	93	82	69	47	37
2 + 200	23	2.5-3.00	1940	10.61	35.54	12.25	23.29	9.78	100	99	93	82	69	47	37
2 + 300	24	2.5-3.00	1990	10.37	35.58	12.51	23.07	9.81	100	99	93	82	69	47	37
2 + 400	25	2.5-3.00	1930	13.16	28.09	15.00	13.09	6.06	100	99	94	87	76	61	41
2 + 500	26	2.5-3.00	1880	13.84	25.70	15.00	10.70	5.99	100	94	89	81	70	55	35
2 + 600	27	2.5-3.00	1990	10.28	18.76	17.45	1.31	4.54	100	99	92	79	63	35	23
2 + 700	28	2.5-3.00	1930	12.50	18.94	16.72	2.22	6.09	100	99	91	79	63	35	23
2 + 800	29	2.5-3.00	1930	15.00	18.74	15.03	3.71	6.10	100	99	92	83	74	56	43
2 + 900	30	2.5-3.00	1900	12.55	19.79	13.14	6.65	6.11	100	99	91	83	74	56	43
3 + 000	31	2.5-3.00	1940	15.90	17.46	9.08	8.38	15.15	100	100	93	82	67	50	42
3 + 100	32	2.5-3.00	1900	15.72	17.51	9.47	8.04	13.5	100	100	93	82	67	50	42

From Table 2, the test results of Atterberg limits showed that the liquid limit of the soils ranges between 17.46 and 39.18, plastic limit between 9.08 and 17.95 and plasticity index between 1.31 and 26.64. The range of plasticity of these soils lies between low to medium plasticity. The laboratory test results of Particle size analysis (Sieve analysis) are also in Table 2; here the various fractions contained in each sample were exposed. It can be seen that the soils within the area of study have fractions ranging from fine sand to fine gravel, the cementing silt or clay fractions having been washed away before sieving. The laboratory test results on compaction of

soils studied is as presented in Table 2. The results reveal that the soils have a maximum dry density (MDD) ranging between 1850 – 2000 kg/m³ and optimum moisture content (OMC) ranging between 9.84 – 15.73%.

The results of CBR tests are as presented in Table 2. CBR values ranged between 4.54 to 15.5%. However, common paving engineering practice is to select a design CBR value that is one standard deviation below the mean [13] as a rule, a design CBR value of 3 is the lowest practical value that should be assigned. In instances where the subgrade strength is

lower than CBR value equal to 3, the subgrade should be improved through stabilization or other means to raise the CBR value [13].

The various CBR values for each of the test points needs to be harmonized into a single CBR value for design purposes and this was shown in Table 3. It shows that the CBR of the soil from the study area is approximately 8 and is adjudged suitable as it is above the acceptable minimum value of 3.

Table 3: Determination of design
CBR value from laboratory test results

Sample No.	CBR Tests Results (X)	(X-X̄)	(X-X̄) ²
1	11.36	0.15	0.0225
2	11.03	-0.18	0.0324
3	11.06	-0.15	0.0225
4	12.12	0.91	0.8281
5	12.15	0.94	0.8836
6	12.13	0.92	0.8464
7	12.14	0.93	0.8649
8	12.88	1.67	2.7889
9	12.91	1.7	2.89
10	12.90	1.69	2.8561
11	13.64	2.43	5.9049
12	13.64	2.43	5.9049
13	13.68	2.47	6.1009
14	11.36	0.15	0.0225
15	11.43	0.22	0.0484
16	11.36	0.15	0.0225
17	11.37	0.16	0.0256
18	14.39	3.18	10.1124
19	14.40	3.19	10.1761
20	14.98	3.77	14.2129
21	14.93	3.72	13.8384
22	9.84	-1.37	1.8769
23	9.78	-1.43	2.0449
24	9.81	-1.4	1.96
25	6.06	-5.15	26.5225
26	5.99	-5.22	27.2484
27	4.54	-6.67	44.4889
28	6.09	-5.12	26.2144
29	6.10	-5.11	26.1121
30	6.11	-5.1	26.01
31	15.15	3.94	15.5236
32	13.5	2.29	5.2441
Σ	358.83		281.6507

Table 4 Characteristics of Soils in the study area

Location Chainage	Sample No	B.S Compaction Standard Proctor 2.5kg Rammer.		Atterberg Limit %			C B R (%)	Approx. Modulus of Subgrade Reaction (k) (kg/m ³)	Sieve Analysis Sieve Sizes (mm). Percentage Passing (%)						
									2.36	1.18	0.6	0.425	0.3	0.15	0.075
0 + 000	1	1920	15.52	31.46	15.51	15.95	11.36	4.32 x 10 ⁶	100	99	92	83	74	55	41
0 + 100	2	1920	15.73	31.88	16.50	15.38	11.03	4.22 x 10 ⁶	100	99	91	83	74	55	40
0 + 200	3	1910	15.27	30.68	15.01	15.67	11.06	4.23 x 10 ⁶	100	99	91	83	74	55	41
0 + 300	4	1980	9.84	39.18	13.51	25.67	12.12	4.55 x 10 ⁶	100	99	89	76	64	45	36
0 + 400	5	1920	15.23	39.02	12.94	26.08	12.15	4.55 x 10 ⁶	100	99	89	76	64	45	36
0 + 500	6	1980	10.53	38.56	12.92	26.64	12.13	4.55 x 10 ⁶	100	99	89	76	64	46	37
0 + 600	7	1990	9.97	38.15	12.66	25.49	12.14	4.55 x 10 ⁶	100	99	89	76	64	46	37
0 + 700	8	2000	9.95	34.98	15.11	19.87	12.88	4.77 x 10 ⁶	100	99	90	80	66	45	35
0 + 800	9	1980	9.94	33.84	14.98	18.86	12.91	4.77 x 10 ⁶	100	99	90	80	66	45	35
0 + 900	10	2000	9.96	32.79	13.92	18.87	12.90	4.77 x 10 ⁶	100	99	90	80	66	45	35
1 + 000	11	1900	14.98	34.23	16.02	18.21	13.64	4.98 x 10 ⁶	100	99	93	84	73	49	38

Table 4 Characteristics of Soils in the study area (Continuation)

1+100	12	1890	14.98	34.20	16.01	18.19	13.64	4.98 x 10 ⁶	100	99	93	83	72	49	38
1+200	13	1850	15.04	34.24	16.16	18.08	13.68	4.98 x 10 ⁶	100	99	93	84	72	49	38
1+300	14	1950	12.04	34.75	15.28	20.47	11.36	4.32 x 10 ⁶	100	99	91	81	68	44	33
1+400	15	1950	12.33	34.72	15.28	19.44	11.43	4.32 x 10 ⁶	100	99	91	81	69	44	33
1+500	16	1960	12.22	34.69	15.59	19.10	11.36	4.32 x 10 ⁶	100	99	91	81	68	44	33
1+600	17	1970	12.14	34.39	14.96	19.43	11.37	4.32 x 10 ⁶	100	99	91	81	69	44	33
1+100	12	1890	14.98	34.20	16.01	18.19	13.64	4.98 x 10 ⁶	100	99	93	83	72	49	38
1+200	13	1850	15.04	34.24	16.16	18.08	13.68	4.98 x 10 ⁶	100	99	93	84	72	49	38
1+300	14	1950	12.04	34.75	15.28	20.47	11.36	4.32 x 10 ⁶	100	99	91	81	68	44	33
1+400	15	1950	12.33	34.72	15.28	19.44	11.43	4.32 x 10 ⁶	100	99	91	81	69	44	33
1+500	16	1960	12.22	34.69	15.59	19.10	11.36	4.32 x 10 ⁶	100	99	91	81	68	44	33
1+600	17	1970	12.14	34.39	14.96	19.43	11.37	4.32 x 10 ⁶	100	99	91	81	69	44	33
1+700	18	1950	11.59	35.95	17.29	18.68	14.39	5.20 x 10 ⁶	100	99	91	81	69	44	33
1+800	19	1980	10.0	35.81	14.69	21.12	14.40	5.20x 10 ⁶	100	90	91	72	60	40	31
1+900	20	1990	10.72	35.38	12.51	22.87	14.98	5.36 x 10 ⁶	100	99	90	81	69	49	40
2+000	21	1900	13.72	35.54	12.81	22.73	14.93	5.35 x 10 ⁶	100	99	90	81	69	48	40
2+300	24	1990	10.37	35.58	12.51	23.07	9.81	3.85x 10 ⁶	100	99	93	82	69	47	37
2+400	25	1930	13.16	28.09	15.00	13.09	6.06	2.65 x 10 ⁶	100	99	94	87	76	61	41
2+500	26	1880	13.84	25.70	15.00	10.70	5.99	2.66 x 10 ⁶	100	94	89	81	70	55	35
2+600	27	1990	10.28	18.76	17.45	1.31	4.54	2.16 x 10 ⁶	100	99	92	79	63	35	23
2+700	28	1930	12.50	18.94	16.72	2.22	6.09	2.66 x 10 ⁶	100	99	91	79	63	35	23
2+800	29	1930	15.00	18.74	15.03	3.71	6.10	2.66x 10 ⁶	100	99	92	83	74	56	43
2+900	30	1900	12.55	19.79	13.15	6.64	6.11	2.67 x 10 ⁶	100	99	91	83	74	56	43
3+000	31	1940	15.90	17.46	9.08	8.38	15.15	5.41 x 10 ⁶	100	100	93	82	67	50	42
3+100	32	1900	15.72	17.51	9.47	8.04	13.5	4.94 x 10 ⁶	100	100	93	82	67	50	42

Comparison of Characteristics of Soils from the Study Area with the American Standard

Presented in Table 5 are soil characteristics pertinent to pavement foundations. This table was adapted from the Advisory Circular [13] of the Federal Aviation Administration, US Department of Transportation. It contains proven soil characteristics for airport pavement foundations obtained from years of experience in research and practice in the aspects of airport pavements. This table is herein used as a base to evaluate the characteristics of soils studied and to adjudge their suitability or otherwise as airport pavement foundation materials.

From the soil classification, it was established that the soils from the study area fall into the class of silts of low plasticity (ML) and clays of low to medium plasticity (CL) groups. The group includes soils as silts, sandy silts, gravely silts or diatomaceous soils, lean clays, sandy clays or gravelly clays.

For these soils, Table 5 specifies the maximum dry density range between 1600 – 2000kg/m³, CBR ranges between 5-15% and modulus of subgrade reaction ranges from 2.77x10⁶ kg/m³ to 5.44x10⁶ kg/m³.

A comparison of the specified soil strength parameters (Maximum dry density MDD, CBR and subgrade modulus, with those of the soils under study as presented in Tables 4 and 5 shows that:

- (a) The maximum dry density of soils under study ranged between 1850 kg/m³ to 2000kg/m³ (Table 4). This falls within the acceptable range of 1600 – 2000 Kg/m³ (Table 65) and is adjudged to be satisfactory.

- (b) The CBR of Soils under study ranged between 5.99 - 15.15% (Tables 5 except for one point with CBR of 4.54%). This is within the range of 5-15% specified in Table 6, and is very satisfactory.

- (c) Subgrade modulus is a parameter required for design of rigid Airport pavements (AC/1505320-6E, 2009). This parameter can be derived using the relationship:

$$k = \left(\frac{1500 \times CBR}{26} \right)^{0.7788} \quad (2.0)$$

(k is in Pci) and for k in kg/ m³ the equation becomes

$$k = 27680 \left(\frac{1500 \times CBR}{26} \right)^{0.7788}$$

CBR value can be converted to approximate subgrade modulus[13]. The values in Pci were converted to g/cm³. This exercise was carried out to provide an idea of the suitability of the soils under study for the design of rigid Airport pavements.

A comparison of the approximate values of the subgrade modulus reaction of the soils under study (Table 4) with those on Table 6 which contains the acceptable standards, reveals that the subgrade modulus of soils under study ranges between 2.16x10⁶ kg/m³ to 5.41x10⁶ kg/m³. This further shows that for the 3km runway study route from which the soils under study were sampled, only six locations (Ch.2+400 – Ch.2+ 900) had values of subgrade modulus, lower than the prescribed minimum of 2.77x10⁶ kg/m³ while the other 25 locations had values ranging between 3.84 x 10⁶ to 5.54 x 10⁶ kg/m³ which are within the specified range of 2.77 x 10⁶ kg/m³ to 5.44 x 10⁶ kg/m³ specified for the class of soils corresponding to those under study. Generally,

therefore, the soils under study have acceptable the design of rigid Airport pavements.
approximate modulus of subgrade reaction value for

Table 5 Soil Characteristics Pertinent to Pavement Foundations (Adapted from Table 2-2 US DOT FAA Advisory Circular 150/5320-6E, 2009)

Major Divisions		Letter	Name	Value as Foundation When Not Subject to Frost Action	Value as Base Directly under Wearing Surface	Potential Frost Action	Compressibility and Expansion	Drainage Characteristic	Unit Dry Weight (kg/m ³)	CBR	Subgrade Modulus <i>k</i> (kg/m ³)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Coarse-gravelly soils	Gravel and gravelly soils	OW	Gravel or sandy gravel, well graded	Excellent	Good	None to very slight	Almost none	Excellent	2.2-2.24x10 ³	60-80	8.3x10 ⁶ or more
		GP	Gravel or sandy gravel, poorly graded	Good	Poor to fail-	None to very slight	Almost none	Excellent	1.92-2.08 x10 ³	35-60	8.3x10 ⁶ or more
		GU	Gravel or sandy gravel, uniformly graded	Good to excellent	Poor	None to very slight	Almost none	Excellent	1.84-2.00 x10 ³	25-50	8.3x10 ⁶ or more
		GM	Silty gravel or silty sandy gravel	Good	Fair to good	Slight to medium	Very slight	Fair to poor	2.08-2.32 x10 ³	40-80	8.3x10 ⁶ or more
		GC	Clayey gravel or clayey sandy gravel	Good to excellent	Poor	Slight to medium	Slight	Poor to practically impervious	1.92-2.24 x10 ³	20-40	(5.54 - 8.3)x10 ⁶
	Sand and sandy soils	SW	Sand or gravelly sand, well graded	Good	Poor to not suitable	None to very slight	Almost none	Excellent	1.76-2.08 x10 ³	20-40	(5.54 - 8.3)x10 ⁶
		SP	Sand or gravelly sand, poorly graded	Fair to good	Not suitable	None to very slight	Almost none	Excellent	1.68-1.92 x10 ³	15-25	(5.54 - 8.3)x10 ⁶
		SU	Sand or gravelly sand, Poor uniformly Not suitably graded	Fair to good	Poor	None to very slight	Almost none	Excellent	1.6-1.84 x10 ³	10-20	(5.54 - 8.3)x10 ⁶
		SM	Silty sand or silty gravelly sand	Good	Not suitable	Slight to high	Very slight	Fair to poor	1.92-2.16 x10 ³	20-40	(5.54 - 8.3)x10 ⁶
		SC	Clayey sand or clayey gravelly sand	Fair to good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	1.68-2.08 x10 ³	10-20	(5.54 - 8.3)x10 ⁶
Fine grained soils	Low compressibility LL<50	ML	Silts, sandy silts, gravelly silts, or diatomaceous soils	Fair to good	Not suitable	Medium to very high	Slight to medium	Fair to poor	1.6-2.00 x10 ³	5-15	(2.77-5.54)x10 ⁶
		CL	Lean clays, sandy clays, or gravelly clays	Fair to good	Not suitable	Medium to very high	Medium	Practically impervious	1.6-2.00 x10 ³	5-15	(2.77-5.54)x10 ⁶
		OL	Organic silts or lean organic clays	Poor	Not suitable	Medium to very high	Medium to high	Poor	1.44-1.68 x10 ³	4-8	(2.77-5.54)x10 ⁶
	High compressibility LL>50	MH	Micaceous clays or diatomaceous soils	Poor	Not suitable	Medium to very high	High	Fair to poor	1.28-1.6 x10 ³	4-8	(2.77-5.54)x10 ⁶
		CH	Fat clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	1.44-1.76 x10 ³	3-5	(1.38-2.77)x10 ⁶
		OH	Fat organic clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	1.28-1.68 x10 ³	3-5	(1.38-2.77)x10 ⁶
Peat and other fibrous organic – soils		Pt	Peat, humus and other	Not suitable	Not suitable	Slight	Very high	Fair to poor			

Comparison of Characteristics of Soils from the Study Area with the British Standard

The British standard like the American standard, is based on the Casagrande Soil Classification for

Airfields and is termed the Extended Soils Classification with Material characteristics. It was published in Table A2 of Defence Works Functional Standards 09 "Geotechnical Investigations for Design and Construction of Airfield Pavements" by the British Ministry of Defence. It contains the standards against which the Soil characteristics from the study area is herewith compared. From the Soil classification done, it was established that the soils from the study area fall into the class of silts of low plasticity (ML) and clays of low to medium plasticity (CL) groups. The group includes soils as silts, sandy silts, gravely silts or diatomaceous soils, lean clays, sandy clays or gravely clays. For these soils, the Table A2 of Defence Works specifies the maximum dry density range between 1520 -1920 kg/m³, CBR ranges between 5-15% and modulus of subgrade reaction ranges from 30 x 10⁶ kg/m³ to 50 x 10⁶ kg/m³.

A comparison of the specified soil strength parameters (Maximum dry density MDD, CBR and subgrade modulus, with those of the soils under study as presented in Tables 6 showed that:

- (a) The maximum dry density of soils under study ranged between 1850 kg/m³ to 2000 kg/m³ (Table 5). This is higher than the specified range of 1520 – 1920 kg/m³ and is adjudged to be very satisfactory.
- (b) The CBR of Soils under study ranged between 5.99 - 15.15% (Table 6 except for one point with CBR of 4.54%). This is within the range of 5-15% specified, and is very satisfactory.
- (c) A comparison of the approximate values of the modulus of subgrade reaction of the soils under study (Table 5) with the acceptable standards, reveals that the subgrade modulus of soils under study ranges between 2.16x10⁶ kg/m³ to 5.41x10⁶ kg/m³. Consequently, the soils under study did not meet the British standard specification for modulus of subgrade reaction. However, it is pertinent to note that the British standards of evaluation considered did not provide a rating for the Soil characteristics as pavement foundation rather it evaluated their value as temporary pavements; one with dual palliatives and the other with soil treatment. These criteria for rating is higher than that used by the FAA (i.e. The American standard) which rated the soils characteristics for use as pavement foundations. The British evaluation of subgrades therefore is perhaps done with stage construction of the airfield pavement in view. The soils under study in their evaluation as temporary pavement were rated poor. It follows then that though such soils were poor as temporary pavements, they could

still be used as pavement foundations especially as subgrades as the Casagrande's characterisation which was used already rated the soil groups under consideration as Fair to Poor in their rating as Pavement Foundation when not subject to frost. This rating is exactly the same with that of the American standard.

Comparison between American and British Standards for Soils Evaluation in Airport Pavement Design and Construction

Both standards are based on the Casagrande classification for air fields. They both evaluated soil characteristics for airfield pavements. They have similar range of values specified for maximum dry density and CBR of soils. However, the British standard specifies higher values for modulus of subgrade reaction than the American Standard. This is because the British standard evaluates compacted subgrades for use as temporary Pavements (this could be with stage construction in mind) while the American standard evaluates soil characteristics for use as Pavement foundations.

Suggested Nigerian Standards / Specification for Subgrade Material

Characteristics for Airport Pavement Foundations

From the discussion in section 3.5 above, it could be seen that the British standard considers the value of compacted subgrades as temporary pavement. This is possible in stage construction of airfield pavements. Hence their specified characteristics in terms of modulus of subgrade reaction are far higher than those specified in the American standard, which considers value of soils as Pavement foundation. Sequel to the fact that the American standard considers value of soils for use in Pavement foundations, it is herein suggested that the American standard be modified for adoption as the Nigerian standard / specification of material Characteristics for Airport Pavement Subgrades. The suggested modifications are:

- (1) Expunge the column on potential frost action in Table 5 (The American standard) since frost is not an environmental experience in Nigeria.
- (2) Change the heading on column 5 of the American standard from Value as foundation when not subject to frost to value as foundation in the light of (1) above

Table 6 below contains the suggested modifications to the American standards and is the suggested Nigerian standard / specification for subgrade materials pertinent to Airport Pavement foundations.

Table 6 Suggested Nigerian Standard / Specification For Subgrade Materials Pertinent To Airport Pavement Foundation

Major Divisions		Letter	Name	Value as Foundation	Value as Base Directly under Wearing Surface	Compressibility and Expansion	Drainage Characteristic	Unit Dry Weight (kg/m ³)	CBR	Subgrade Modulus <i>k</i> (kg/m ³)
(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)	(10)	(11)	(1.2)
Coarse-gravelly soils	Gravel and gravelly soils	OW	Grave) or sandy gravel, well graded	Excellent	Good	Almost none	Excellent	2-2.24x10 ³	60-80	8.3x10 ⁶ or more
		GP	Gravel or sandy gravel, poorly graded	Good	Poor to fail-	Almost none	Excellent	1.92-2.08 x10 ³	35-60	8.3x10 ⁶ or more
		GU	Gravel or sandy gravel, uniformly graded	Good to excel lent	Poor	Almost none	Excellent	1.84-2.00 x10 ³	25-50	8.3x10 ⁶ or more
		GM	Silty gravel or silty sandy gravel	Good	Fair to good	Very slight	Fair lo poor	2.08-2.32 x10 ³	40-80	8.3x10 ⁶ or more
		GC	Clayey gravel or clayey sandy grave!	Good to excellent	Poor	Slight	Poor to practically impervious	1.92-2.24 x10 ³	20-40	(5.54 - 8.3)x10 ⁶
	Sand and sandy soils	SW	Sand or gravelly sand, well graded	Good	Poor lo not suitable	Almost none	Excellent	1.76-2.08 x10 ³	20-40	(5.54 - 8.3)x10 ⁶
		SP	Sand or gravelly sand, poorly graded	Fair to good	Not suitable	Almost none	Excellent	1.68-1.92 x10 ³	15-25	(5.54 - 8.3)x10 ⁶
		SU	Sand or gravelly sand, Poor uniformly Not suitably graded	Fair to good	Poor	Almost none	Excellent	1.6-1.84 x10 ³	10-20	(5.54 - 8.3)x10 ⁶
		SM	Silty sand or silty gravelly sand	Good	Not suitable	Very slight	Fair to poor	1.92-2.16 x10 ³	20-40	(5.54 - 8.3)x10 ⁶
		SC	Clayey sand or clayey gravelly sand	Fair to good	Not suitable	Slight to medium	Poor to practically impervious	1.68-2.08 x10 ³	10-20	(5.54 - 8.3)x10 ⁶
Fine grained soils	Low compress - ibility LL<50	ML	Silts, sandy silts, gravelly silts, or diatomaceous soils	Fair to good	Not suitable	Slight to medium	Fair to poor	1.6-2.00 x10 ³	5-15	(2.77-5.54)x10 ⁶
		CL	Lean clays, sandy clays, or gravelly clays	Fair to good	Not suitable	Medium	Practically impervious	1.6-2.00 x10 ³	5-15	(2.77-5.54)x10 ⁶
		OL	Organic silts or lean organic clays	Poor	Not suitable	Medium to high	Poor	1.44-1.68 x10 ³	4-8	(2.77-5.54)x10 ⁶
	High compress - ibility LL<50	MH	Micaceous clays or diatomaceous soils	Poor	Not suitable	High	Fait to poor	1.28-1.6 x10 ³	4-8	(2.77-5.54)x10 ⁶
		CH	Fat clays	Poor to very poor	Not suitable	High	Practically impervious	1.44-1.76 x10 ³	3-5	(1.38-2.77)x10 ⁶
		OH	Fat organic clays	Poor to very poor	Not suitable	High	Practically impervious	1.28-1.68 x10 ³	3-5	(1.38-2.77)x10 ⁶
Peat arid other fibrous organic –soils		Pt	Peat, humus and other	Not suitable	Not suitable	Very high	Fair to poor			

CONCLUSIONS

From the results and analysis of the laboratory tests, the following conclusions were made.

- (1) An evaluation of the characteristics of soils from the study area with particular reference to existing requirements of subsisting international standards for Airport Pavement foundation was carried out and the soils from the study area were found to possess acceptable qualities
- (2) After a close study of the soil characteristics from the study area and a thorough comparison

of these characteristics with those specified in some international standards, it became clear that certain modifications could be made to adopt the American standards published by the Federal Aviation Authority (FAA) of the United States Department of Transportation, as the Nigerian Standard / Specification for Subgrade materials in Airport Pavement foundation design and construction.

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